GENERAL ORGANIZATION

Volume 1 of the Papua LNG Project Upstream Environmental Impact Statement consists of 22 chapters that describe the legal context, Project, existing environment, impact assessment and mitigation and management measures.

The main report is structured as follows:

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16.1 – Defining the Scope and Information Needs for Ecosystem Services

TOTAL
TOTAL E&P PNG LIMITED

PAPUA LNG PROJEK

SOTPELA RIPOT

TOTAL E&P PNG LIMITED

Desemba 2019
(Ripot Namba 01215B_23_v3)

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Tebol sovim het tok bilong ripot

Sapta

Tebol

Namba

Plet

Sotpela Ripot

1. Plen bilong Kirapim Wok

Total E&P PNG Limited (TEP PNG) na ol kampani husait i wok bung wantaim, itingting long kirapim wok Papua LNG Projek (displa Projek). Dispela Projek em wok bung namel long TEP PNG (40.13%), ExxonMobil PNG Antelope Limited na ExxonMobil PNG Elk Limited (37.03%) na PAC LNG Assets Limited, PAC LNG International Limited, PAC LNG Investments Limited, PAC LNG Overseas Limited na PAC LNG Holdings Limited (22.84%). Dispela projek igat tupela hap, 'Upstream' na 'Downstream'. Upstream wok bai istat long Elk na Antelope na kam mak long banis bilong PNG LNG long Caution Bay. 'Downstream' bai istap insait long banis bilong PNG LNG long Caution Bay. Projek bai igat opereta igo pas long 'Upstream' na opereta igo pas long 'Downstream'. Kampani igo pas long olgeta 'Upstream' wok em TEP PNG.

Dispela Projek bai kamapim wok long rausim na klinim gas na 'condensate' long 'Elk' na 'Antelope' insait long 'Petroleum Retention License 15' (PRL 15), long Galf Provins, Papua Niugini. Bai igat tupela 'pipeline' ilusim PRL-15 na ron antap long graun igo abrusim Muro na kamap long 'Orokolo Bay'. Na behain bai ron ananit long solwara igo kamap long 'Caution Bay' na igo insait long banis bilong PNG LNG 'Plant Site'. PNG LNG 'Plant Site' long 'Caution Bay' istap tupela ten (20) kilomita arasait long Pot Mosbi (Map ES1.1). Dispela em ol sampela bikpela wok mak bilong Projek

- Long hap we 'Well pads' na 'wells' istap long en, bai igat 'pipeline' ikarim gas imiks wantaim pipia na wara igo long 'Central Processing Facility' (CPF).
- Long CPF wok bilong klinim gas bai ikamap we masin bai rausim pipia na wara na lusim 'gas' na 'condensate' istap.
- Bai igat tupela 'pipeline'. Wanpela liklik na naraplea em bikpela. Sais bilong liklik em '10 inch' na bikpela em '40 inch'. Bikpela 'pipeline' bai karim gas na liklik bai karim 'condensate' long CPF na igo olgeta lo PNG LNG 'plant site' long Caution Bay.
- Bai igat ol operesen lo sapotim ol wok olsem niupela kemp we ol wok manmeri bai istap na wok, woksop bilong masin, hap bilong putim ol samtin bilong mekim wok projek, niupela rot long sapotim projek, na surukim ples balus igo longpela, hap lo kisim ston na hap bilong putim pipia bilong projek.

Hettok bilong ol narapla sait blo displa Projek istap lo Tebol ES1.1

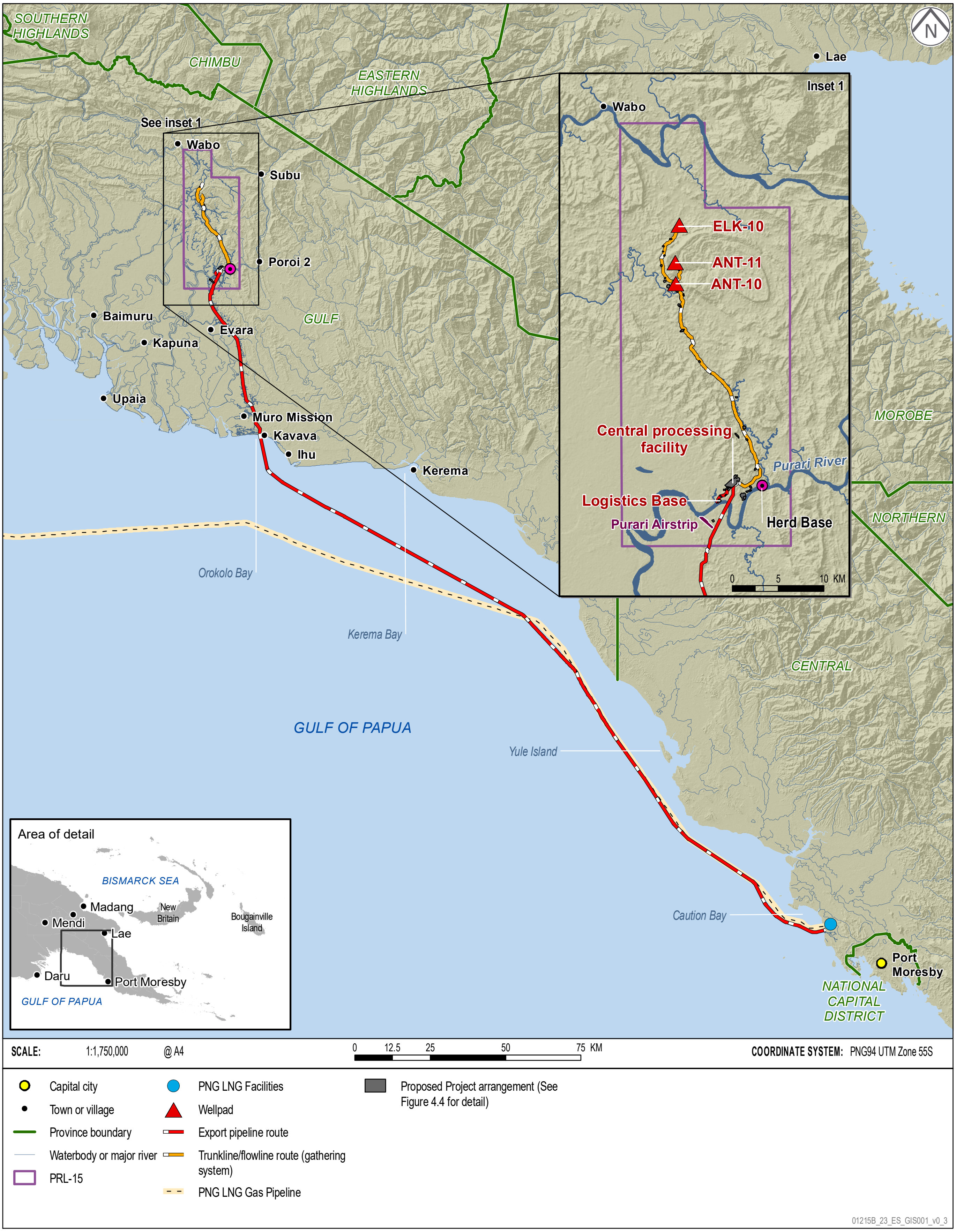
Taim projek ikamap klostu long pinis bilong em, bai kampani kamapim wanpela plen long rausim olgeta samtin bilong projek yusim long kamapim wok. Dispela plen tu bai ilukluk long stretim olgeta pipia we projek ibin kamapim.

Klostu taim bai projek kamapim 'Basic Engineering'[1] wok.

As tingting bilong Projek em long kamapim 'gas' na 'condensate' we istap long 'Elk' na 'Antelope' 'gas field' insait long PRL-15 na salim igo long narapela kantri na tu long insait yet long PNG. Projek bai tingting strong na wok hat long lukautim ol pipol, busgraun, wara, na tu luksave long wok gavman na bisinis.

1 Dispela em wanpela wok bilong ojek ol ikolim 'Front-End Engineering and Design' (FEED).

FIGURE ES1.1


SOUTHERN HIGHLANDS
CHIMBU
EASTERN HIGHLANDS
GULF
MOROBE
NORTHERN
CENTRAL
NATIONAL CAPITAL DISTRICT
See inset 1
Wabo
Subu
Poroi 2
Baimuru
Evara
Kapuna
Upaia
Muro Mission
Kavava
Ihu
Kerema
Lae
Orokolo Bay
Kerema Bay
GULF OF PAPUA
Yule Island
Caution Bay
Port Moresby
Inset 1
ELK-10
ANT-11
ANT-10
Central processing facility
Purari River
Logistics Base
Purari Airstrip
Herd Base
0 5 10 KM
Area of detail
BISMARCK SEA
Madang
Mendi
Lae
New Britain
Bougainville Island
Daru
Port Moresby
GULF OF PAPUA
SCALE: 1:1,750,000 @ A4
0 12.5 25 50 75 KM
COORDINATE SYSTEM: PNG94 UTM Zone 55S
Capital city
Town or village
Province boundary
Waterbody or major river
PRL-15
PNG LNG Facilities
Wellpad
Export pipeline route
Trunkline/flowline route (gathering system)
PNG LNG Gas Pipeline
Proposed Project arrangement (See Figure 4.4 for detail)
01215B_23_ES_GIS001_v0_3

Tebol ES1.1 – Bikpela toktok bilong kamapim Projek

US$4 billion Wok painimaut itok olsem, namel moni mak bilong kamapim wok projek long 'upstream' iolsem US$4 billion sapos ol bin mekim long yia 2018. Na antap long dispela ibai igat narapla wok ('subsequent compression phases') we moni mak bai olsem US$0.9 billion.	**'840 MMscfd'** Long wanwan krismas namel mak bilong gas we projek bai kamapim. Lukolsem Projek bai winim klostu olsem '820 MMscfd' (antap mak bilong 'gas') 'gas' na '15,000 barrels' long wanwan dei long salim igo long narapela kantri.
'6.2 to 7.5 trillion cubic feet (Tcf)' Taim 'gas' ikam long antap long graun bai ibruk igo long 'gas' na 'condensate' bai lukolsem 'condensate' bai igat '15' igo long '20' 'bbl' long wanwan 'MMscf' 'gas' mak.	**Tripela (3) 'wellpads'** Igat tupela 'production pad' bilong 'gas', wanpela long 'Elk' na narapela long 'Antelope'. Igat narapela 'wellpad' bilong wara istap long 'Antelope'. Igat nainpela 'well' olgeta.
Tupela ten (10) na faivpela (5) krismas Faivpela (5) krismas bilong wok kamapim projek na tupela ten krismas (20) bilong ronim Projek na salim 'gas'. Dispela wok bilong Projek bai ron olgeta aua na olgeta dei long olgeta wik.	**Siksti (60) kilomita 'export pipeline' ron antap long graun na tupela handrit na siksti (260) kilomita 'export pipeline' ron ananit long solwara** 'Export pipeline' ron antap long graun bai istat long tamblo sait long arere bilong PRL-15 igo kamap long nambis bilong 'Orokolo Bay'. Lo displa hap, 'export pipeline' bai katim solwara bilong Galf bilong Papua na bihainim wankain rot olsem PNG LNG 'pipeline' na kam kamap long banis bilong PNG LNG long 'Caution Bay'. Strong bilong 'pipeline' bai igo inap fopela ten (40) krismas.
936 ha Hap ples we Projek bai kamap em klostu olsem nain handrit na tripela ten na sikis (936) 'ha'. Lo displa hap graun, klostu olsem'20%' em we sampela wok bilong ol narapela lain ibin kamap bipo.	**Klostu 6,000-pela wokmanmeri taim Projek em bisi stret** Namba blo ol wokmanmeri ibai namel long 50 igo inap 6000 long taim Projek ikamap long traipela mak.

'EIS' em wanpela wok painimaut long luksave long wanem samtin iken kamap long busgraun, wara, enimol na ol diwai istap long en taim projek ikirap na wok igo. Dispela wok painimaut tu bai iluksave long hau ol manmeri isave stap, raun na kaikai na tu hau ol isave bihainim pasin tumbuna. Dispela wokpainimaut (EIS) imakim hau projek ibihanim olgeta lo bilong PNG waintaim lo bilong kampani na tu ol bikpela toklukaut we olgeta kantri save behainim Dispela projek bai kisim dinau moni long ol bikpela benk[2].. Long kisim dispela dinau, Projek bai bihainim ol lo we 'International Finance Corporation' (IFC) imakim long lukautim busgraun na wara na ol pipol (IFC 2012). Projek tu bai bihainim lo we 'World Bank Group' imakim long lukautim busgraun na wara na gutpela sinduan bilong ol pipol (IFC 2007).

2. Hap we Projek bai stap

2.1 Bus, graun na wara long hap bilong Projek

Dispela Projek bai ikaramapim sampela maunten, graun tamblo long maunten na nambis tu we istap tamblo long bikpela maunten ol ikolim 'Central Range'. Hap bilong projek em ikaramapim ol kainkain bus, graun na wara. Wara Purari wantaim olgeta hanwara bilong em isave pulim wara long dispela hap na igo bungim sol wara.

Long antap insait long PRL-15 igat sampela liklik maunten na baret. Tamblo igat ol flatpela graun na tais wara Purari na hanwara bilong em na wesan graun long 'Orokolo Bay' (Piksa ES2.1).

Long hap solwara we projek bai ikamap istat long 'Orokolo Bay' na go ananit long solwara ('Gulf of Papua') igo inap long 'Caution Bay'.

2 Dispela wokpainimaut (EIS) bilong busgraun, wara na pipol ikam arere long banis bilong PNG LNG Projek long 'Caution Bay'.

Piksa ES2.1 – Wara Purari tanimtanim olsem snek igo bungim solwara

Piksa: BMT WBM

2.2 Ol diwai na animol long wara na graun

Bus, graun na wara helpim gro bilong planti kainkain bus, gras na kain samting olsem, na tu ol enimol isave kaikai lo en. Dispela hap igat faivpela (5) kain bus istap (maunten bus (Piksa ES2.2), bus arere long wara, bus bilong tais na bush mangro,na bus arere long nambis). Ol binatang na pis ol samting istap insait long wara (‘freshwater, estuarine, wetland’) isave behainim hap we ol save kisim kaikai isi na stap long em. Sampela binatang na pis bai ilaik stap long bus arere long wara, bus tais na bus mangro. Hap we ‘export pipeline’ bai ron ananit long solwara igat kaikain hap we ol solwara gras istap na rif istap arere long ‘Caution Bay’ tasol.

Long yia 2000 ikam inap nau, igat bikpela wok katim diwai ikamap long hap we projek istap. Dispela hap igat planti mak bilong ol manmeri wokim ples, wokim gaden, na tu ol mak bilong ol kampani painim ‘oil’ na ‘gas’ bipo.

Piksa ES2.2 – Liklik Hap we Maunten Bus bilong bipo istap yet

Piksa: Iain Woxvold

2.3 Pipol, moni na pasin tumbuna

Insait long hap bilong projek igat olsem tripela ten na aet (38) ples-hauslain (Piksa ES2.3), wanpela kemp bilong ol kamman na wanpela gavman stesin. Tupela ples-hauslain, Mapaio pis Kemp na Poroi 1, istap insait long lisens hap bilong PRL-15. Sevenpela (7) tokples istap insait long hap bilong projek. Olgeta dispela tokples igat wankain tumbuna stori, kastom na tumbuna pasin. Ol dispela lain istap long PRL-15 na long wara Purari na hap bilong ‘export pipeline’. Ol pipol bilong projek area isave yusim bus, graun na wara long kisim kaikai (Piksa ES2.4). Ol ples-hauslain long hap bilong projek ibin igat save long wok bilong ol narapela projek ikamap pinis long ples bilong ol olsem katim diwai na salim.

Long hap bilong projek igat nainpela (9) klinik iwok gut na narapela tripela (3) ino orait tumas. Na tu igat tripela ten na tu (32) ol skul istap insait long hap bilong projek. Nambawan wok painimaut (‘baseline study’) isoim olsem igat olsem ples tumbuna ibin stap bipo na kastom samting long em na tu igat ol ples tumbuna stori istap long en insait long hap bilong projek.

Piksa ES2.3 – Kain haus istap long ples-hauslain

Piksa: ERIAS Group

Piksa ES2.4 – Wok Painim Pis long Wara Purari bungim solwara

Piksa: ERIAS Group

3. Wok bilong kisim tingting olgeta lain

TEP PNG iluksave olsem bung wantaim ol ‘stakeholder’ em bikpela samting. Taim wok painimaut (EIS) ikamap, ol ibin bungim ol ‘stakeholder’ bilong projek. Long yia 2015 kam inap nau kampani (TEP PNG) ibin mekim ol ‘program’ we igat kainkain wei long wok bung wantaim ol ‘stakeholder’ bilong projek.

TEP PNG bai wok yet long bungim olgeta ‘stakeholder’ long sait bilong projek. TEP PNG wantaim ‘Conservation and Environment Protection Authority’ (CEPA) bai mekim wanpela bikpela wok long toksave long olgeta ‘stakeholder’ long sait bilong wok painimaut (EIS) ol ibin mekim long behainim s.55 bilong lo bilong busgraunwara *(Environment Act 2000)*. (igat plen blo displa wok bai kamap lo bilong yia 2020).

4. Skelim ol Senis na Gutpela Samting Projek bai ikamapim

Senis na gutpela samting projek bai ikamapim em ol kain olsem:

- Kisim graun.
- Rausim bus.
- Stretim graun.
- Karim kago na pipol igo kam (long sip, balus na rot).
- Sanapim kemp na ronim kemp bilong sotpela taim na tu long stap longpela taim.
- Wok Drilim.
- Wok kamapim, ronim na lukautim ‘pipeline’.
- Skelim na stretim ol pipia.
- Sanapim bris bilong kago bilong sip, rausim wesen long sip kam soa long wara long ‘Logistics Base’.
- Masin bilong kilim ‘gas’ (CPF), lukautim wara igat rabis na pipia ‘gas’.
- Pulim wara long graun na lukautim wara ron antap lo graun.
- Digim ston.
- Kaikai bensin na disol.
- Kisim manmeri long wok na kago bilong projek.
- Stretim olgeta samtimg taim projek ipinis.

Sotpela ripot bilong luksave long ol senis bai ikamap we dispela wok painimaut (EIS) ibin skelim istap insait long Tebol ES4.1. Sampela moa toktok long mekim klia ol displa sotpela ripot i stap long Sapta 11 go inap long 17 blo dispela wokpainimaut (EIS).

Tebol ES4.1 – Ol sampelakain senis we dispela wokpainimaut (EIS) iskelim olsem ol iken kamap bikos long dispela projek EIS

Antap long Graun
Graun ken suruk na gris bilong graun ken go daun.
Swit bilong wara ananit long graun ken lus na tu wara antap long graun iken sot.
Strong bilong wara long karim ol pipia iken igo daun.
Swit bilong wara antap long graun iken lus.

Tebol ES4.1 – Ol sampelakain senis we dispela wokpainimaut (EIS) iskelim olsem ol iken kamap bikos long dispela projek EIS (go mo yet)

Antap long Graun
Ol namba bilong kainkain enimol, pis, binatang, bus na gras isave stap long wara bai iken igo daun taim ples ol istap igo sot.
Ples bilong kainkain enimol, pis, binatang, bus na gras iken igo bagarap.
Namba bilong kainkain enimol, pis, binatang, bus na grass bai iken igo daun.
Bilong Solwara
Swit bilong solwara iken lus.
Ol namba bilong kainkain enimol, pis, binatang na gras save stap long solwara bai iken igo daun taim ples ol istap isenis.
Pipol na Tumbuna Pasin
Pasin sindaun bilong ol pipol iken bagarap.
Bikhet na raskol pasin iken igo bikpela.
Ol pipol iken sot long graun long mekim gaden, painim abus, wokim haus na kisim ol samting bilong bus.
Ol senis (gutpla na nogut) long painim wok, wok bisnis na wei blo kisim moni.
Ol sevis bilong gavman olsem skul na haussik bai sot.
Ol birua bilong ol kainkian sik iken kamap bikpela.
Ol lida ikamp long tumbana kastom iken bugim hevi wantaim ol yangpela lain husait tu ilaik kamap lida.
Ples tumbuna ibin stap bipo na igat kastom samting long en na tu ples tumbuna we igat stori long en, iken lus.
Ol kaikai, ol timba na ol narapela samtimg yumi save kisim long bus iken igo sot.
Gutpela bilong ol pipol (Amenity)
Sampela senis o birua iken kamap long sindaun na helt bilong ol ples lain na ol wokmanmeri.
Lukluk bilong ples iken isenis tasol ino gutpela tumas.
Gokam bilong pipol na kago (long sip, balus na rot) iken igo kranki.

Projek iken kamapim sampela senis nogut. Projek igat wei long laukautim na stretim ol dispela kain senis. Nambawan wei em long abrusim olgeta dispela kain senis. Tasol sapos abrusim ino inap, projek mas wokim dispela senis igo liklik. Na sapos wanpela senis nogut ikamap orait, projek imas stretim dispela hap bihain, na tu wokim kompensasen, o mekim wanpela wok bekim long narapela hap. Wok painimaut (EIS) iskelim olsem planti ol senis bin ikamap bipo, olsem iliklik tru o liklik tasol (taim projek glasim wantaim ol samting bilong lukautim na stretim senis). Long taim bilong ‘FEED’, sapos sampela senis nogut istap (bikpela liklik or bikpela tru) bai projek ilukluk long sampela wei gen long lukautim na stretim dispela senis. Projek bai bung waintain ol ‘stakholder’ long wokim wei bilong mekim wok bekim long narapela hap na kompenseson tu.

Tupela provins (Galf na Sentrol) bai ikisim win moni (‘royalties’ na ‘development levies’). Ol papagraun we Minista luksave olsem ‘landowner’ bilong projek bai kisim helpim (‘statutory benefits’) ikam long gavman. Ol lain stap arere long hap bilong projek itu bai kisim sampela halevim long projek kain olsem skul bilong wok, kisim, wok na bisnis long projek.

5. Wei blo lukautim Busgraunwara na Pipol

Projek igat lo bilong em yet bilong lukautim gutpela sindaun na pasin-wok bilong ol pipol na busgraunwara. Dispela lo bilong projek bai makim rot bilong projek bai ron, glasim na ripotim.

Projek bai imekim wanpela het plen (ESMP) bilong lukautim busgraunwara na ol pipol. Bai igat ol liklik lukaut plen ananit long dispela het plen. Ol lukaut plen bai imakim rot bilong Projek bai ikamapim tingting (‘Project commitment’) igo insait long wok bilong kampani na tu putim wei bilong glasim ol senis projek ibringim, na long glasim ol rot long stretim long gutpela wei.

Olgeta kontrak TEP PNG bai imekim wantaim ol kontrakta iwok long Projek imakim olsem ol imas behainim tingting bilong het plen (ESMP). Long luksave long sampela samting ino kamap long mak, bai igat wanwan wok panimaut long het plen. Dispela het plen bai ilukluk long kaikai bilong tingting bilong Projek (‘Project Commitment’), na tu em bai lukluk long Tokorait Pepa long busgraunwara (‘Environment permit conditions’) taim iredi. Het plen tu bai ilukluk long senis (‘design refinement’) ikamap long Projek na ol senis ikamap long lo bilong gavmen.

Wok bihanim ol lo na plen bilong projek na tu ol tingting bilong Projek we kampani itok bai wokim em mas wokim stret bikos gavman bai luksave long ol dispela wok. Ol plen na wok imas bihainim stret na noken tru abrusim mak. Bai igat wok painimuaut oltaim na ripot bihanaim ol dispela ol wokmak.

Sampela moa ol toktok na luksave Dispela ripot (EIS) em mas igo aut long pablik long bihainim lo bilong busgraunwara bilong kantri (‘*Environment Act 2000’)*.

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

EXECUTIVE SUMMARY

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

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Chapter

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Plate

Executive Summary

1. Proposed Development

Total E&P PNG Limited (TEP PNG) and its joint venture partners propose to develop the Papua LNG Project. The Project is a joint venture between TEP PNG (40.13 %), ExxonMobil PNG Antelope Limited and ExxonMobil PNG Elk Limited (37.03%), and PAC LNG Assets Limited, PAC LNG International Limited, PAC LNG Investments Limited, PAC LNG Overseas Holding Limited and PAC LNG Holdings Limited (22.84%). The Project separates operatorship of what are referred to as the 'upstream' and 'downstream' facilities, delimited in Caution Bay by the PNG LNG facility lease boundary. TEP PNG is the proponent, and will be the operator, of the upstream facilities for the Project.

The Project will involve producing and processing the gas and condensate from the Elk-Antelope gas reserves in Petroleum Retention License 15 (PRL-15), located in Gulf Province, Papua New Guinea and then piping them overland, and then offshore in the Gulf of Papua, to the existing PNG LNG producing and exporting facility (PNG LNG Facilities) in Caution Bay, Central Province, 20 km northwest of Port Moresby (Figure ES1.1). Key Project components include:

- Wellpads and wells where the reservoir fluids will be produced and the buried flowlines and trunklines that will transport the reservoir fluids to a central processing facility (CPF).
- The CPF where the reservoir fluids will be separated into gas and condensate, and processed.
- Export pipelines, which will comprise a 40-inch diameter gas pipeline and a 10-inch diameter condensate pipeline to transport the gas and condensate products from the CPF to the PNG LNG Facilities at Caution Bay.
- Infrastructure, which includes the new Logistics Base, the construction and operations accommodation camps, the access road network, the Purari Airstrip extension, landfills and quarries.

An overview of key project development facts is provided in Table ES1.1

A decommissioning plan will be developed at the end of operations that identifies decommissioning options for all equipment and materials, including products used and wastes generated on site.

The Project intends to move into the Basic Engineering[1] phase.

The Project objective is to develop the gas and condensate resources in the Elk-Antelope gas field in PRL-15 and export petroleum primarily internationally but also domestically, while considering the environmental, social, political and commercial constraints.

1 This is equivalent to the front-end engineering and design (FEED) phase of a project.

PROJECT LOCATION

Papua LNG Project | Environmental Impact Statement

FIGURE ES1.1

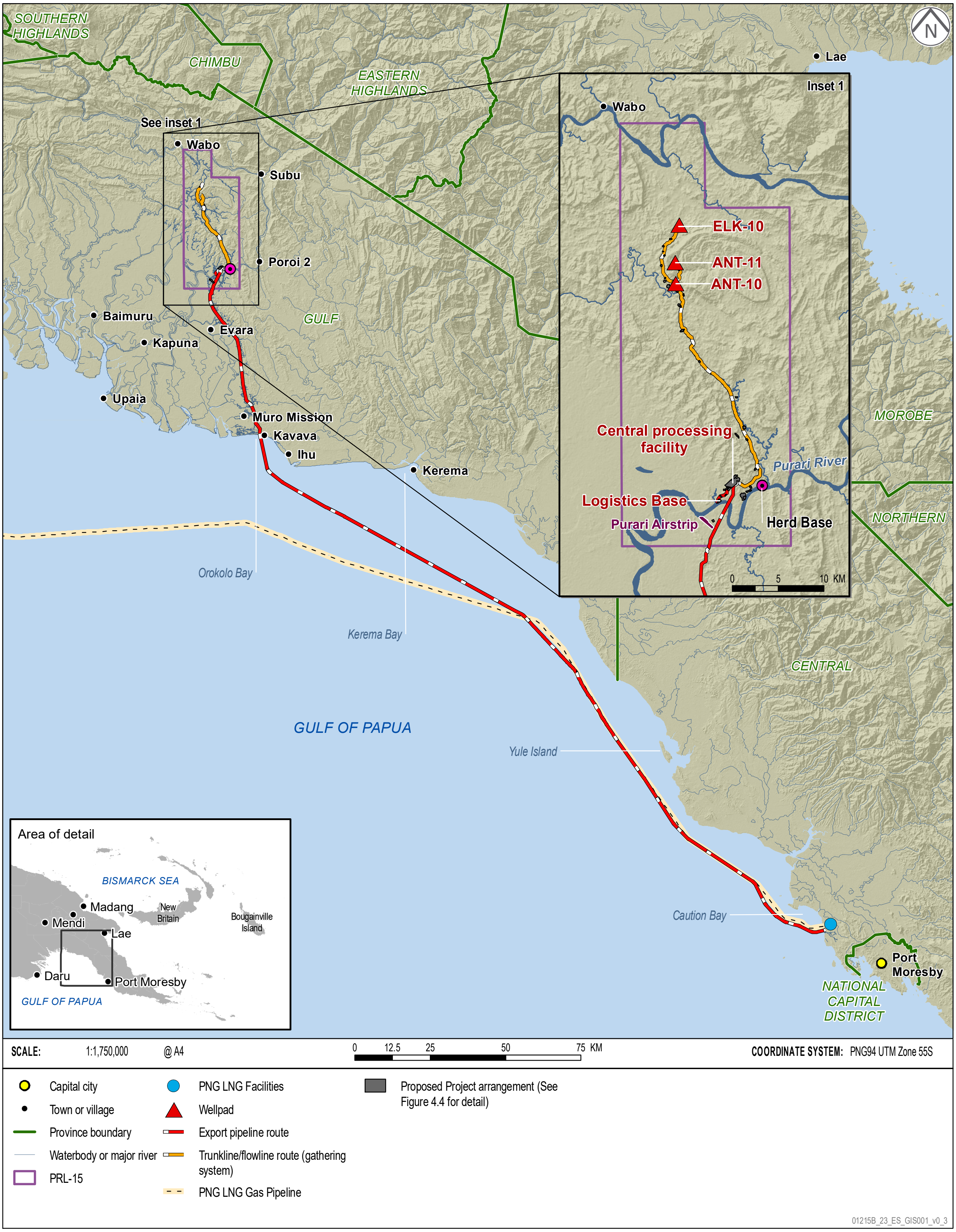

Table ES1.1 – Key Project Development Facts

US$4 billion Preliminary median capital cost estimate for the upstream portion of the Papua LNG Project development costs (2018 real terms) for the initial development, plus US$0.9 billion for the subsequent compression phases	**840 MMscfd** Average production of raw gas on an annual basis About 820 MMscfd (peak value) of treated gas and 15,000 barrels per day of condensate exported.
6.2 to 7.5 trillion cubic feet (Tcf) of initial gas in place and a condensate to gas ratio estimated between 15 to 20 bbl/MMscf.	**3 wellpads** One Elk production pad, one Antelope production pad, and an additional pad at Antelope for produced water. Nine wells in total.
25 years 5 years of construction and 20 years of operations. The Project operations will take place 24 hours per day, 7 days per week.	**60-km onshore export pipeline and a 260-km offshore export pipeline** The onshore export pipeline route will extend from the Purari River at the south end of PRL-15 to the coast at Orokolo Bay. From there, the export pipelines will traverse the Gulf of Papua and will generally follow the same route as the marine PNG LNG gas pipeline, before connecting with downstream LNG facilities in Caution Bay. Design life is 40 years.
936 ha Estimated total area of direct disturbance is 936 ha. Of this, approximately 20% uses existing disturbed areas.	**Approximately 6,000 workforce, at peak** The number of workers ranges from 50 to approximately 6,000 during construction.

The EIS assesses the potential impacts on the environment, amenity, and social, cultural and ecosystem services due to the Project[2]. The EIS has been prepared to satisfy relevant PNG laws, regulations and permits; company internal requirements, and International applicable standards and guidelines. As the Project is likely to seek financing by international finance institutions, applicable International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability (IFC, 2012) and World Bank Group Environmental, Health and Safety Guidelines (IFC, 2007) have also been considered in this EIS.

2. Project Setting

2.1 Physical Environment

The Project area of influence is situated on the foothills, alluvial plains and beach areas south of Central Range, and encompasses various topographic features and landforms.

The terrestrial setting is with the lower Purari River catchment. Topography comprises ridge and ravine landforms of low-altitude hills to the north in PRL-15, descending to the broad, flat floodplains of the Purari River delta (Plate ES2.1) and sand dunes along the Orokolo Bay coast.

The marine setting comprises Orokolo Bay and the continental shelf along the eastern side of the Gulf of Papua to Caution Bay.

2 This EIS excludes Papua LNG project facilities inside the PNG LNG lease boundary in Caution Bay, which are subject to a separate assessment and permitting process.

Plate ES2.1 – Meandering River of the Purari River Delta

Phot: BMT WBM

2.2 Biological Environment

The physical environment supports the growth of dense and varied natural vegetation that sustains high regional biodiversity. Five broad terrestrial vegetation groups are identified (i.e., hill forest (Plate ES2.2), alluvial forest, freshwater swamp vegetation, mangroves and littoral forest). Freshwater, estuarine and wetland habitats are characterized by riparian areas of lowland or alluvial forests, swamp vegetation and mangroves. Various marine benthic habitats occur along the export pipeline corridor with seagrass meadows and subtidal reefs confined to Caution Bay.

Commercial logging operations since the early 2000s have degraded large areas of primary forest, and signs of human settlement, subsistence farming, and oil and gas exploration activities are also visible across the landscape.

Plate ES2.2 – Remnant Hill Forest

Photo: Iain Woxvold

2.3 Socio-economics and Cultural Heritage

There are 38 villages (Plate ES2.3), 1 settlement and one government station in the Project area of influence. Of these, Mapaio Fish Camp and Poroi 1 village are located in PRL-15. Seven distinct groups, defined by the language they speak, are recorded, with each having similar history, cultural beliefs and traditional practices. These communities occur in PRL-15, and along the Purari River corridor and export pipeline route. Reliance on natural resources further defines these communities, and fishing (Plate ES2.4), hunting and collecting are the primary resource uses. Communities have experienced previous exposure to industrial projects and activities beyond oil and gas (e.g., logging).

Local people access healthcare at nine operating and three partially operating health facilities, and there are 32 functioning schools in the Project area of influence.

The environmental and social baseline formally recorded tangible and intangible cultural heritage sites in the Project area of influence.

Plate ES2.3 – Typical Village House

Photo: ERIAS Group

Plate ES2.4 – Fishing in the Purari River Delta Estuary

Photo: ERIAS Group

3. Stakeholder Engagement

TEP PNG recognizes the importance of developing and maintaining relationships with Project stakeholders. Since early 2015, TEP PNG has implemented a program of consistent, planned and targeted engagement with Project stakeholders, using a range of approaches designed to address the specific needs of each stakeholder group.

Information disclosure and consultations have been undertaken as part of the EIS process and specific consultation and disclosure of the EIS will take place with the Conservation and Environment Protection Authority to satisfy requirements under s. 55 of the *Environment Act 2000* (aiming for Q1 2020).

4. Assessment of the Project's Impacts and Benefits

Impacts and benefits are predicted to arise from Project activities such as:

- Land acquisition.
- Vegetation clearing.
- Earthworks.
- Logistics and transport (e.g., water, air and roads).
- Construction and operation of temporary and permanent accommodation camps.
- Drilling.
- Pipeline construction, operations and maintenance.
- Waste management.
- Jetty construction and dredging at the Logistics Base.
- CPF operations (e.g., gas processing), produced water and acid gas management.
- Water extraction and discharge of surface runoff.
- Quarrying.
- Fuel and energy consumption.
- Project employment and procurement.
- Decommissioning.

Summary of the potential key impacts assessed in the EIS are listed in Table ES4.1. Additional detail is provided in Chapters 11 to 17 of the EIS.

Table ES4.1 – Potential Key Impacts Assessed in the EIS

Terrestrial
Landform destabilization and deterioration in soil properties.
Deterioration of groundwater quality and reduction in groundwater resource.
Altered hydraulic and sediment transport processes and reduced stream flow.
Deterioration in surface water quality.
Loss of freshwater and estuarine aquatic habitat or biodiversity.
Loss and degradation of habitats and key resources/sites.
Loss of flora and fauna individuals and populations.

Table ES4.1 – Potential Impacts Assessed in the EIS (cont'd)

Marine
Deterioration in marine water quality.
Loss of marine aquatic habitat or biodiversity.
Social and Cultural Heritage
Decline in customary social systems.
Increase in antisocial behaviors and crime.
Reductions in livelihoods and land access.
Changes (positive and negative) to employment, business opportunities and income.
Increased pressure on education, health facilities and services.
Increased risk, frequency, and severity of disease.
Challenges to traditional leadership and governance.
Loss or disturbance to tangible cultural heritage sites and intangible cultural heritage.
Decrease in provisioning ecosystem services (e.g., wild plant foods, timber)
Amenity
Disturbance, human health, and nuisance effects.
Decline, loss of or change to existing visual amenity or landscape character.
Disturbance to commercial traffic and transport.

Mitigation measures have been applied to potential impacts by implementing the mitigation hierarchy, e.g., avoid impacts, where possible, minimize impacts when avoidance is impossible and when they remain, consider rehabilitation or restoration, and ultimately compensate/offset. Most residual impacts were assessed as negligible to minor (considering embedded design controls, and mitigation and management measures). Where significant impacts remain (i.e., impacts were assessed as moderate or higher), additional opportunities for mitigation will be explored during the FEED Project phase. Additional requirements related to offsetting or compensation will be designed where appropriate, and in consultation with relevant communities, stakeholders and government agencies, as required.

The Gulf and Central provinces will experience direct and indirect financial benefits, e.g., royalties and development levies. Legally recognized landowners will receive statutory benefits from the State. The wider Project-affected communities in the Project area are likely to benefit through Project training, employment or other business opportunities.

5. Environmental and Social Management System

The Project's Health, Safety, Environment and Social Management System forms the framework for environmental and social management, monitoring and reporting under which the Project will operate.

The Project Environmental and Social Management Plan (ESMP) will be developed and implemented within this framework, from which detailed management plans will be developed. The management plans will support implementation of Project commitments and will define the monitoring requirements to assess mitigation performance and efficiency.

Specialist contractors will undertake activities on behalf of TEP PNG and will be contractually obligated to implement and comply with the Project's ESMP. The ESMP and monitoring procedures will be subject to periodic review and evaluation to identify any deficiencies. The ESMP will address the outcomes of commitments made in this EIS, the environment permit conditions when they become available, design refinements as Project development progresses and any changes in regulatory requirements.

Compliance with applicable standards, and the effectiveness of the Project's design controls and commitments, will be monitored and assessed against measurable performance indicators. Performance will be reported according to applicable requirements.

Further Information and Submissions
The EIS will be made available to the public according to the *Environment Act 2000*.

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 1: Introduction

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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1. Introduction

1.1 Overview

Total E&P PNG Limited (TEP PNG) and its joint venture partners (Section 1.2) propose to commercialize the Elk-Antelope gas and condensate reserves in Petroleum Retention License 15 (PRL-15), located in Gulf Province, Papua New Guinea. This Project, referred to as the Papua LNG Project, will involve producing and processing the gas and condensate, and then transporting it via pipeline overland and then offshore in the Gulf of Papua to the existing PNG LNG producing and exporting facility in Caution Bay, Central Province (Figure 1.1).

This environmental impact statement (EIS) is the statutory basis for the environmental and social impact assessment of the Project under s. 53 of the *Environment Act 2000,* which is administered by the Conservation and Environment Protection Authority (CEPA). This impact assessment, prepared according to *the Environment Act 2000*, will enable a decision from the Environment Council and the Minister for Environment, Conservation and Climate Change on whether the Project should proceed and, if so, under what conditions. This EIS excludes Papua LNG Project facilities inside the PNG LNG project lease boundary in Caution Bay, which are subject to a separate assessment and permitting process.

The EIS sets out a development proposal to enable an assessment of the Project’s environmental and social impacts by:

- The relevant PNG Government agencies in evaluating the Project’s potential environmental and social impacts and in formulating conditions under which it might proceed.
- The public in formulating their responses to the EIS.
- The joint venture partners in their decision to sanction the Project to proceed.

The EIS has been prepared to satisfy relevant PNG laws, regulations and permits; TOTAL internal requirements, and International applicable standards and guidelines. As the Project is likely to seek financing by international finance institutions (‘Lenders’), applicable International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability (IFC, 2012) and World Bank Group Environmental, Health and Safety Guidelines (IFC, 2007) have also been considered in this EIS.

This chapter provides background information on the proposed Project, including the proponent and the joint venture partners in the Project (Section 1.2); the nature and locations of the main facilities and infrastructure, the Project’s development timetable and its current status (Section 1.3); the history of activities that led to this proposal and the proposal’s viability, an outline of the Project’s objectives, impacts and benefits, and its alignment with the State of Papua New Guinea economic and social development policies and strategies (Section 1.4); and information about the EIS statutory context and document structure, and how to obtain a copy of the report (Section 1.5).

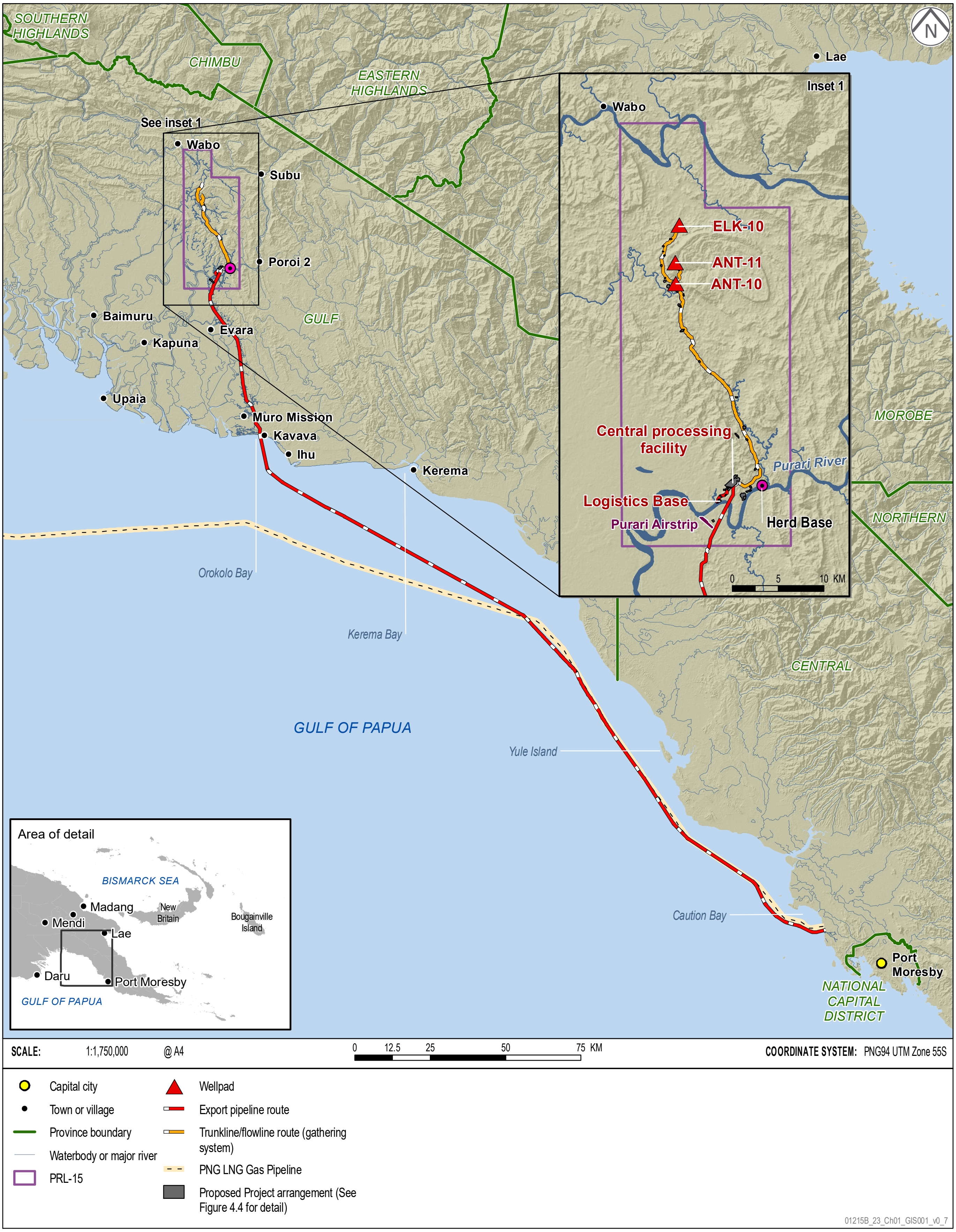
1.2 Project Proponent

The Project is a joint venture between TEP PNG (40.13%), ExxonMobil PNG Antelope Limited and ExxonMobil PNG Elk Limited (collectively 37.03%, referred to as ‘ExxonMobil PNG’), and PAC LNG Assets Limited, PAC LNG International Limited, PAC LNG Investments Limited, PAC LNG Overseas Holding Limited and PAC LNG Holdings Limited (collectively 22.84%, referred to as ‘Oil Search PNG’). The Project involves constructing upstream and downstream facilities including a processing plant, gas and condensate pipelines, and liquefaction trains. The Project makes efficient

PROJECT LOCATION

Papua LNG Project | Environmental Impact Statement

FIGURE 1.1



use of multiple operators to capture synergies through collaboration to stimulate work-sharing campaigns and to adopt improved execution and contracting models, taking advantage of the expertise of each of the selected operators while respecting the terms of existing legal agreements.

The Project separates operatorship of what are referred to as the ‘upstream’ and ‘downstream’ facilities between two operators. TEP PNG will design, construct and operate the upstream aspects of the Project including the wells and associated infrastructure at the gas production field in PRL-15, an upstream central processing facility (CPF) and onshore and offshore gas and condensate export pipelines up to the PNG LNG project lease boundary. TEP PNG is the proponent of, and will operate, the upstream facilities on behalf of the other joint venture partners. This EIS, i.e., the upstream EIS, addresses the upstream facilities.

The downstream LNG facilities of the Papua LNG Project will be added to the existing PNG LNG facilities at Caution Bay, 20 km northwest of Port Moresby. To enhance synergies with the existing PNG LNG project, Niugini LNG Operating Company Limited, an affiliate of Exxon Mobil will design, construct and operate, and seek approval for, the Project’s downstream facilities.

The State of Papua New Guinea, through the government and the legally recognized landowners, have rights under the *Oil and Gas Act 1998* to acquire up to a 22.5% participating interest in the development license. Should this right be exercised, the current participating interests would be reduced accordingly.

1.2.1 Total E&P PNG Limited

TEP PNG is the proponent and will be the operator of the Project’s upstream facilities. The company is a wholly-owned subsidiary of TOTAL S.A. (TOTAL), the second-largest global LNG company with operations in more than 130 countries. TOTAL is a French multinational integrated oil and gas company. Its businesses cover the oil and gas chain from exploration and production to power generation, transportation, refining, petroleum product marketing, and international crude oil and product trading. It is also a large-scale chemicals manufacturer and a major player in the natural gas and solar energy industries.

TEP PNG is committed to developing the Project in a manner that minimizes adverse environmental and social effects of the development activities, enhances positive impacts, and safeguards assets and third-party interests. The Project will be developed in accordance with TOTAL company, Total E&P[1] and TEP PNG standards and specifications as described in Chapter 2, Regulatory Framework, Policies, Standards and Guidelines.

1.2.2 Project Partners

ExxonMobil is a world-leading petroleum and petrochemical company based in the United States. Its wholly-owned affiliates, ExxonMobil PNG Antelope Limited and ExxonMobil PNG Elk Limited are partners in the Project.

ExxonMobil PNG Limited, a subsidiary of ExxonMobil, is operator of the PNG LNG joint venture, which includes affiliates of Oil Search, Santos, Kumul Petroleum, JX Nippon and Mineral Resources Development Company. The PNG LNG project is an integrated LNG development with gas production and processing facilities in Hela and the Southern Highlands. The project, which includes natural gas liquefaction and storage facilities located northwest of Port Moresby at Caution Bay, produces approximately 8.0 million tonnes of LNG per year. Over 700 km of pipelines connect the facilities.

1 Total E&P is a division of TOTAL S.A.

Oil Search is an oil and gas exploration and development company that has been operating in Papua New Guinea since 1929. The company is the country's largest oil and gas producer and has interests in all the nation's producing oil and gas fields. Oil Search's main asset is a 29% interest in the PNG LNG project operated by ExxonMobil PNG Limited. Its wholly-owned affiliates PAC LNG Assets Limited, PAC LNG International Limited, PAC LNG Investments Limited, PAC LNG Overseas Holding Limited and PAC LNG Holdings Limited are partners in the Project.

1.3 Project Overview

1.3.1 Development Outline

The Elk-Antelope gas fields are in PRL-15 in Baimuru Rural local-level government area, in Kikori District, Gulf Province. It is situated in a remote area approximately 120 km northwest of the provincial capital of Kerema, which is on the coast of the Gulf of Papua, and 340 km northwest of Port Moresby and the National Capital District (see Figure 1.1).

The Project will comprise the upstream development of the gas resources from the Elk and Antelope reservoirs in PRL-15, construction and operation of facilities to extract gas, and an upstream central processing facility (CPF). The CPF will also be in PRL-15, approximately 30 km south of the gas field, close to the Purari River and the existing Herd Base (see Figure 1.1).

Onshore and offshore export pipelines will convey gas and condensate from the CPF to the new LNG facilities to be co-located with the existing PNG LNG Facilities at Caution Bay, 20 km northwest of Port Moresby (Figure 1.2). The new LNG facilities at Caution Bay are subject to a separate EIS and approvals process.

The design life for the Project will be 25 years (40 years for the export pipelines).

Further Project details are provided in Chapter 4, Project Description.

1.3.2 Producing the Gas and Condensate

Both the Elk and Antelope reservoirs will be developed to produce gas and condensate, with one and seven gas producing wells, respectively. Two wellpads will be developed, one for each reservoir, i.e., an Elk production pad and an Antelope production pad.

Raw gas from the Antelope production wells will be conveyed to the CPF by two buried, 22-inch diameter pipelines (trunklines) of about 28 km each. Raw gas from the Elk production well will be conveyed to the CPF via a buried 14-inch diameter pipeline (flowline) of about 38 km. The Elk flowline will follow the same route as the Antelope trunklines to the CPF, for most of its route.

The CPF will separate reservoir fluids into gas and condensate, and process the gas and condensate to meet export specifications. During approximately the first 10 years of production, the Antelope reservoir has sufficient pressure for the CPF to operate without gas compression. The wellhead pressure is expected to decrease progressively during the production life due to reservoir depletion, and additional compression facilities; therefore, will be required to maintain the CPF operating conditions. Dedicated compression is required for the ELK trunkline so the pressure matches that of the Antelope reservoir and to lower the Elk production system pressure to rapidly deplete the Elk reservoir.

Several acid gas management concepts were, and still are, being assessed that variously consider acid gas removal; these are described in more detail in Chapter 5, Project Options and Alternatives. The concept presented in the EIS entails removing and processing small quantities of hydrogen

SIMPLIFIED BLOCK FLOW DIAGRAM OF THE OVERALL PAPUA LNG PROJECT

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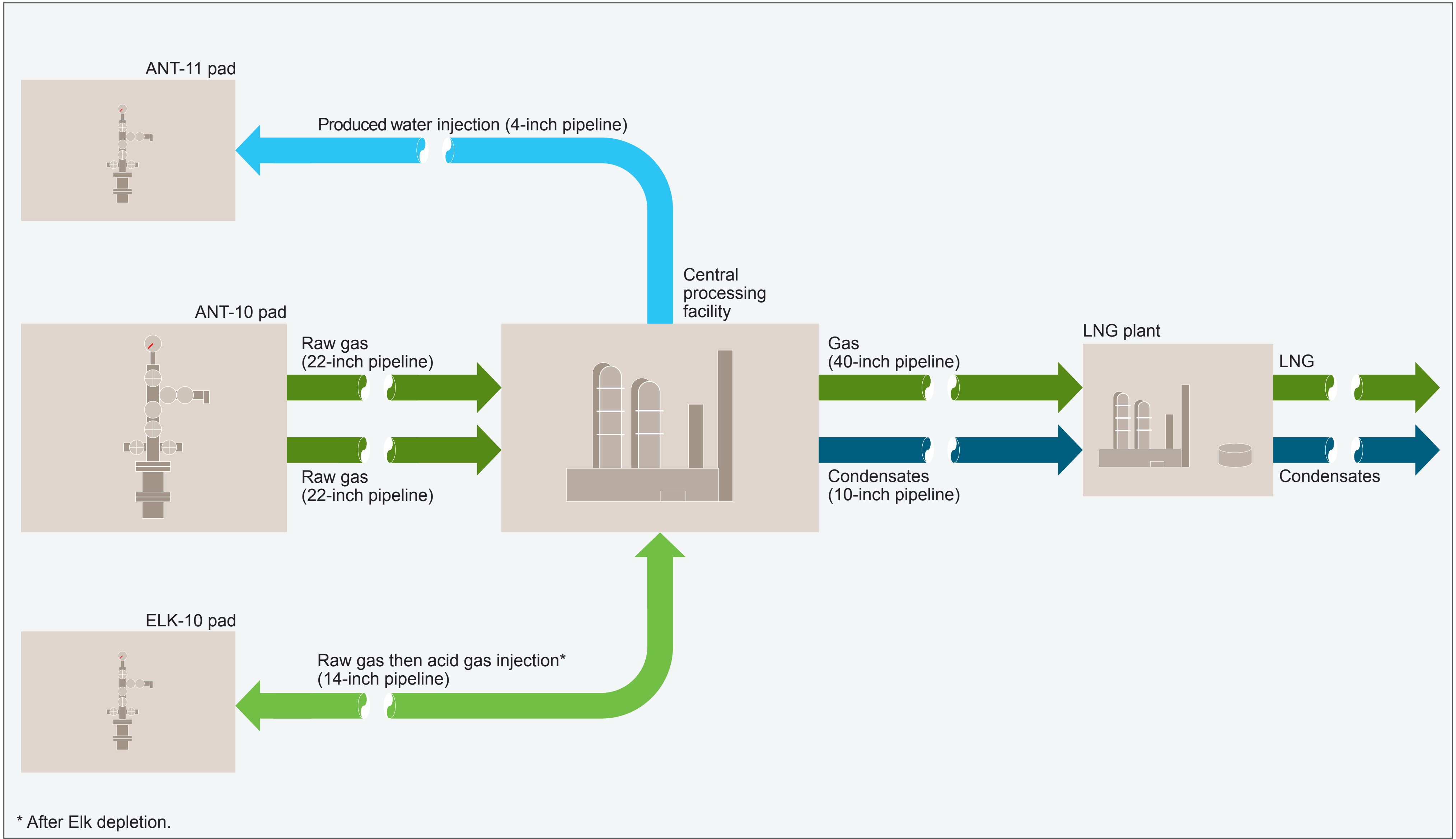
FIGURE 1.2



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sulfide (H_2S) and carbon dioxide (CO_2) in the raw gas, which are initially released to the atmosphere, before injection into the Elk reservoir is possible (after its depletion). A 4-inch-diameter pipeline will transport treated produced water from the CPF to the Antelope injection pad for injection into the Antelope reservoir.

1.3.3 Transporting the Gas and Condensate

Gas and condensate will be transported separately from the CPF to the Project's liquefaction facilities in the LNG Plant at Caution Bay, Central Province, using a 40-inch diameter pipeline for the gas and a 10-inch diameter pipeline for the condensate. The onshore export pipeline route will extend from the Purari River at the south end of PRL-15 for approximately 60 km to the coast at Orokolo Bay. From there, the export pipelines will traverse approximately 260 km of the Gulf of Papua and will generally follow the same route as the marine PNG LNG gas pipeline, before connecting with new LNG facilities in Caution Bay.

In 2017, TEP PNG and ExxonMobil began discussing the addition of gas processing facilities at the existing PNG LNG plant to treat the Project's gas. Finally, integration of the Project's downstream LNG facilities with the existing PNG LNG plant has been retained as the base case (Section 1.3.1). Two additional liquefaction trains will be constructed for the Papua LNG Project at the LNG Plant. These trains will use the spare capacity of the existing utility, storage and loading facilities; and existing common facilities will be expanded, as needed, to meet additional requirements of the expanded facility. The gas commercialization alternatives investigated by TEP PNG are summarized in Chapter 5, Project Options and Alternatives.

1.3.4 Infrastructure

Facilities and infrastructure that will be constructed to support the construction and operation include a new logistics base on the Purari River; extension of the existing Purari Airstrip (see Figure 1.1); temporary construction and permanent operation accommodation camps; a road network between the main facilities (e.g., wellpads, CPF and camps and new logistics base) on the northern side of the Purari River in PRL-15; and waste facilities, e.g., landfills. A minor access road (the former construction running track) will follow the export pipeline route in the export pipeline right of way from the Purari River south to Orokolo Bay for monitoring and maintenance during operations.

1.3.5 Logistics

The Project's logistics solution is complex due to the remote location, and the complete absence of roads and infrastructure. Equipment and materials will be transported from Port Moresby by sea offshore of Central and Gulf provinces and then principally along the Purari River to Herd Base initially and later to the new logistics base. Land transport will then access the remainder of the Project area from these bases.

The workforce will be transported to the CPF site by air to and from the upgraded Purari Airstrip.

1.3.6 Current Project Status and Development Timeline

TEP PNG completed feasibility and alternatives studies from 2014 to 2019 through its preliminary, screening, conceptual and pre-Project[2] phases. The pre-Project phase refined the Project development concept with inputs from environmental and social investigations undertaken as part

2 This is equivalent to the pre-front-end engineering and design (FEED) phase of a project.

of the EIS (see Chapters 3 and 5), and set the base case design for the impact assessment in this EIS.

The Project intends to move into the Basic Engineering[3] phase and will further refine the pre-Project design. An indicative Project schedule is provided in Chapter 4

1.4 Project History and Viability

1.4.1 History of the Resource

InterOil Corporation (InterOil) made the first gas discovery in the Elk-Antelope gas field in the Elk structure in 2006, with subsequent wells drilled through 2006 and 2007, followed by the discovery of gas in the Antelope structure in 2008 (Figure 1.3).

Specifically:

- 2006: The Elk reservoir was discovered by drilling the Elk-1[4] exploration well.
- 2007: Elk-2 was drilled about 4.5 km north of Elk-1.
- 2008: The Elk-4 exploration well discovered the Antelope reservoir.

InterOil was an independent oil and gas business that was formed in 1997 and incorporated in Canada. InterOil's main interests were in Papua New Guinea where the company held exploration licences.

Drilling the ANT-1, ANT-2 and ANT-3 wells between 2008 and 2012 at Antelope further confirmed the petrochemical properties.

InterOil initially proposed to develop the Elk-Antelope gas field in a different joint venture development known as the Elk-Antelope Gasfield Project or the Gulf LNG Project, and had plans to construct and operate pipelines, condensate stripping plants, liquefaction plants and associated infrastructure.

This development did not proceed, and TEP PNG and Oil Search PNG subsequently acquired interests in PRL-15 in March 2014. TEP PNG, holding the largest interest in the joint venture, was appointed operator of PRL-15 and of the Papua LNG Project in August 2015. Appraisal well drilling has been ongoing on the Elk-Antelope gas field since 2014 (see Figure 1.3), and the results from these activities informed the pre-Project engineering studies. The drilling involved the following wells:

- 2014 to 2016: ANT-4, ANT-5 and ANT-6 wells were drilled.
- 2016 to 2017: ANT-7 was drilled as the last appraisal well of the Antelope structure.

On 21 July 2016, an agreed transaction for ExxonMobil to acquire all outstanding shares of InterOil was announced (ExxonMobil, 2016), with the transaction being completed in February 2017 (OET, 2017). This transferred beneficial ownership of InterOil's 37.03% interest in the Elk-Antelope gas field to ExxonMobil PNG Antelope Limited and ExxonMobil PNG Elk Limited, thus becoming partners in the Papua LNG Project.

In November 2018, TEP PNG and its joint venture partners signed a Memorandum of Understanding (MoU) with the Independent State of Papua New Guinea defining the key terms of

3 This is equivalent to the FEED phase of a project.
4 In the exploration phase, Elk wells were referred to in sentence case (e.g., Elk-1) and Antelope wells were referred to in capitals (i.e., ANT-1). Wellpad names for the Project development phase are all presented in capitals for both reservoirs, e.g., ELK-2 and ANT-4.

ELK-ANTELOPE APPRAISAL WELLS INCLUDING YEAR OF ACTIVITY

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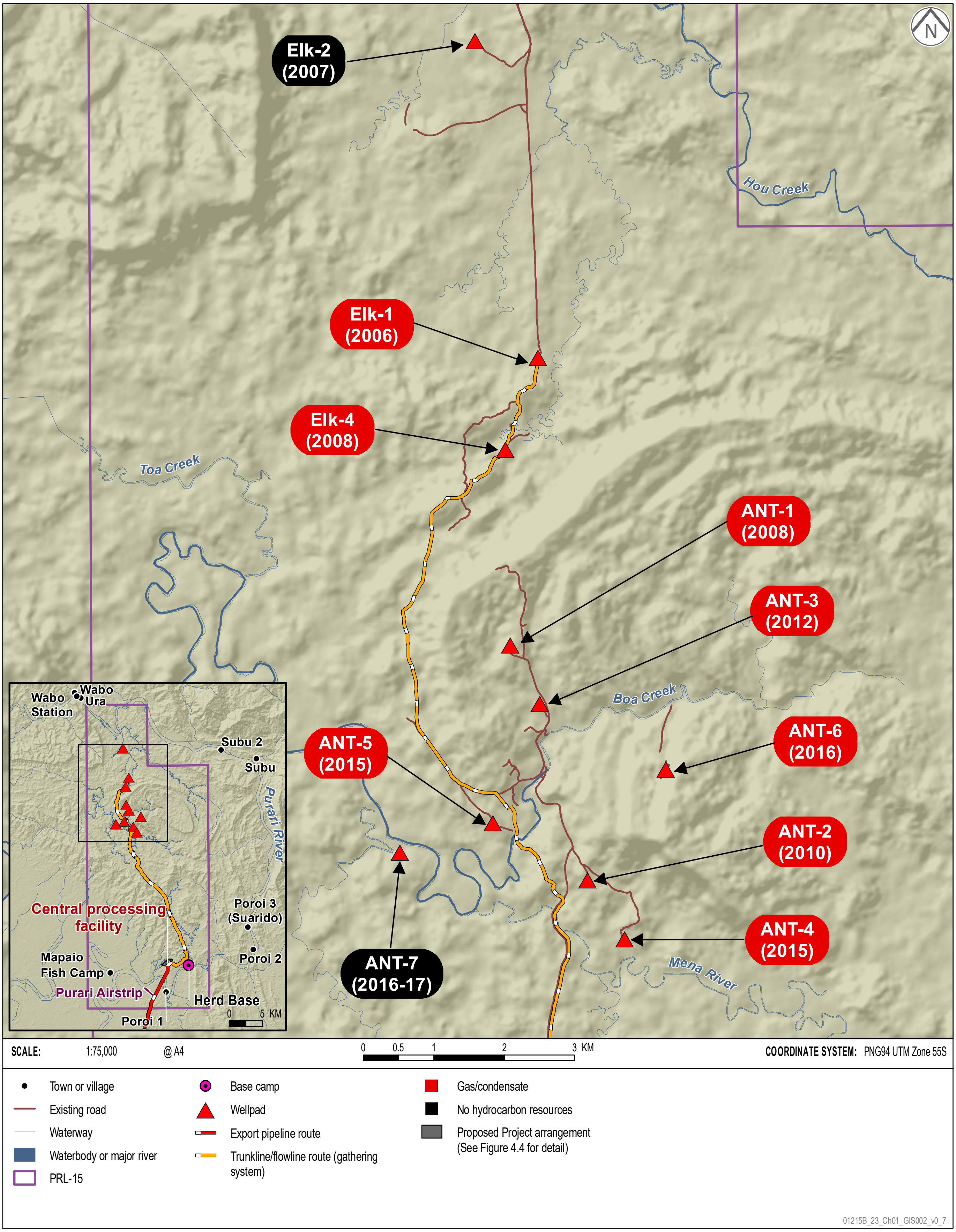
FIGURE 1.3



Note: During the exploration/appraisal phase, Elk wellpads were referred to in sentence case. In the development phase, wellpad names are presented in capitals for both reservoirs (ELK and ANT).

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the Gas Agreement for the Papua LNG Project. In accordance with the *Oil and Gas Act 1998*, the Gas Agreement, executed in April 2019, sets out the definition and extent of the Project, terms for transfer and assignment of the State's equity interest to a company held by the State, additional benefits to the State, and the fiscal regime applicable to the Project.

1.4.2 Scale of the Resource

The Elk-Antelope gas reservoirs contain an initial gas in place ranging from 6.2 to about 7.5 Tcf of hydrocarbon gas with a condensate to gas ratio estimated between 15 and 20 bbl/MMscf. The Elk and Antelope wells will be able to deliver close to 900 million standard cubic feet per day (MMscfd) of raw gas to the CPF which is designed to export about 820 million MMscfd of treated gas at peak (Figure 1.4), along with 15,000 barrels of condensate per day. Assuming a 94% availability of the facilities, this will result in an average production of 840 MMscfd of raw gas and 770 MMscfd of treated export gas on an annual basis.

1.4.3 Objectives and Purpose of Development

The Project objective is to develop the gas and condensate resources in the Elk-Antelope gas field in PRL-15 and export petroleum primarily internationally but also domestically, while considering the environmental, social, political and commercial constraints. Commercializing this gas will enable the significant contribution made by the petroleum sector, and by TEP PNG to date, to the PNG economy to continue. The main environmental and socio-economic[5] objective is for the Project to deliver meaningful benefits to legally recognized landowners, the Project-affected communities and Papua New Guinea with minimal adverse impacts on these communities and the environment.

In line with TEP PNG standards and specifications presented in Chapter 2, the Project will aim to :

- Provide a healthy and safe workplace, pursuing the goal of zero harm to people.
- Comply with all relevant national and local regulations.
- Develop and implement a systematic approach to risk identification and risk reduction.
- Reduce harmful emissions and effluents and where reasonably practicable eliminate them.
- Minimize the environmental footprint, with the highest respect for environmental protection and biodiversity conservation.
- Promote transparency, anti-corruption and respect for human rights and labor standards.
- Maintain constructive relationships with key stakeholders.

1.4.4 Consistency with the State of PNG Development Policy and Strategies

Developing the Project is consistent with the national goals and directive principles of Papua New Guinea, which promote developing its resources through various policies aimed at encouraging investment. The PNG Government encourages foreign investors and allows the development of national resources; simultaneously, it maintains that the people of Papua New Guinea must benefit from any development.

The Project aligns with the PNG Constitution and various PNG Government policies, as described in the following sections.

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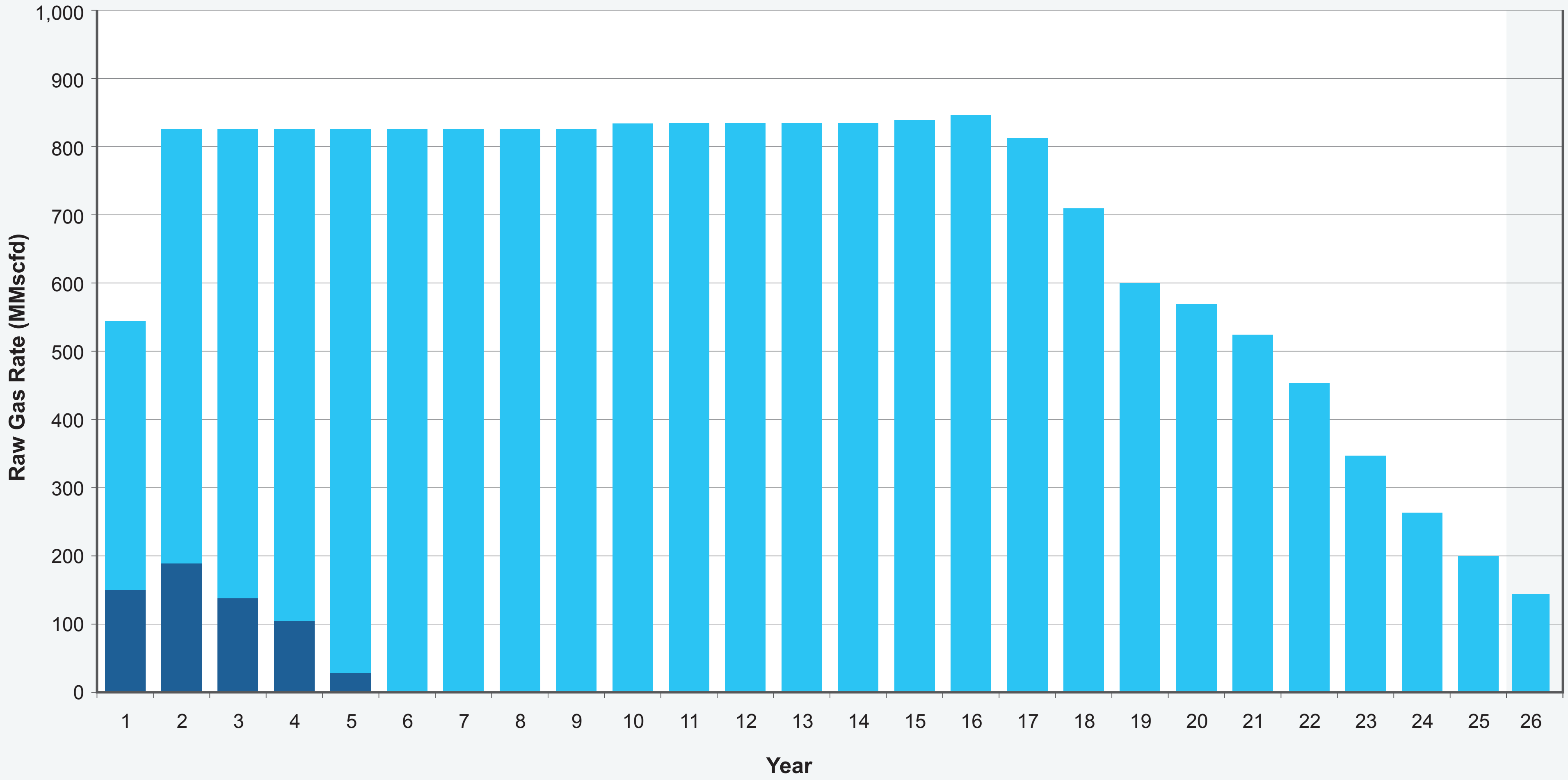
5 The terms socio-economic, societal and social are used interchangeably in this report.

RAW GAS PRODUCTION

Papua LNG Project | Environmental Impact Statement

FIGURE 1.4



MMscfd – Million standard cubic feet per day

Note: At the stage of the Project development when this figure was produced there was some variation in Project duration due to gas pressure.

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1.4.4.1 Constitutional Goals

As outlined in the Constitution of Papua New Guinea (1975), key aspirations and principles for developing the nation are presented in Goals 3 and 4:

> We declare our Third Goal to be for Papua New Guinea to be politically and economically independent, and our economy basically self-reliant.
>
> We declare our Fourth Goal to be for Papua New Guinea's natural resources and environment to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations.

During the Project's life cycle, the PNG economy will benefit from the payment of royalties, and direct and indirect taxation, thus bringing the country a step closer to economic independence. Further, in developing the Elk-Antelope gas field, the Project is expected to contribute to the nation's balance of trade; to provide training and employment opportunities during construction, operations and decommissioning; and to enhance the capacity of the national workforce and infrastructure to support future development projects, which in turn should also contribute to the growth and diversification of the economy, employment opportunities and improvements in infrastructure and services.

1.4.4.2 PNG Vision 2050

Developing the Project aligns with Vision 2050 (NSPT, 2010), a national strategy developed by the National Strategic Plan Taskforce in 2009, where 'wealth creation' and 'human capital development, gender, youth and people empowerment' is one of the key strategic focus areas. The Project will strengthen and support a productive regional economy and provide a potential new source of wealth and growth for Papua New Guinea and provide employment-related training increasing the skills base of the local and/or regional communities.

1.4.4.3 Papua New Guinea Development Strategic Plan

The PNG Department of National Planning and Monitoring (DNPM, 2010) released the Papua New Guinea Development Strategic Plan 2010 to 2030 to support the implementation of Vision 2050. The strategic plan sets out the framework to achieve the government's targets and strategies, particularly those outlined in Vision 2050.

For the petroleum sector, the core goal is to:

> Build a world leading petroleum industry that maximises benefits to PNG and landowners, minimises impacts on the environment and social welfare, and provides PNG with energy security.

In addition to this strategic plan, the DNPM has developed shorter-term initiatives in the form of medium-term development plans that have goals stemming from Vision 2050. The overarching goal of the 2016–2017 development plan is to increase PNG's human development index, and its goal in relation to petroleum and gas is to (DNPM, 2015):

> Maximize socioeconomic and environment benefits from the petroleum and gas industry.
>
> The Project will be developed in a manner that seeks to deliver meaningful benefits to legally recognized landowners, Project-affected communities and Papua New Guinea.

The strategic plan acknowledges the prospective wealth still to be generated by the country's natural gas reserves and states that the number of LNG projects in Papua New Guinea should total at least three by 2030 (DNPM, 2010). The Project development will contribute to this goal.

The Project primarily traverses the petroleum resource area economic corridor (PRAEC), which includes the Southern Highlands and parts of Enga, Gulf and Central provinces, described in the strategic plan (DNPM, 2010). Key objectives specific to the PRAEC include:

- Improve the quality of life for people in the PRAEC zone by investing in the zone.
- Improve the quality of life for people throughout Papua New Guinea by integrating infrastructure and services in the PRAEC with the national network.
- Ensure that gas revenues bring about tangible and sustainable improvements to the living standards of Papua New Guinea's people.
- Replace cash handouts with a well-managed and well-coordinated system of investment to the benefit of affected communities.

The Project development will facilitate the meeting of PRAEC objectives. TEP PNG aims to work with the government of Papua New Guinea, during the Project life cycle, to bring about improvements to the quality of life of the local population including by generating employment, improving the skills and capacity of the local workforce, and implementing tailored community investment projects.

TEP PNG's community relations team aims to build an environment of trust between TEP PNG and the local population through regular engagement with potentially affected stakeholders. Project-affected communities and local, district and provincial governments are regularly consulted to encourage their active participation in Project decision-making to achieve sustainable outcomes. Further information about TEP PNG's stakeholder engagement strategy is provided in Chapter 6.

1.4.4.4 National Strategy for Responsible Sustainable Development

The Constitution of Papua New Guinea directs the country to focus on long-term development to achieve growth, equity and sustainability for the benefit of present and future generations. The National Strategy for Responsible Sustainable Development (DNPM, 2014) has developed strategic issues and policy responses to address these issues, shifting the country's socio-economic growth from the current unsustainable growth strategy towards a future that is responsible and sustainable, and will make Papua New Guinea competitive. The strategy promotes economic growth driven by sustainable clean energy and resource use where carbon emissions and pollution are reduced, and energy efficiency is enhanced. At its simplest, a green economy is 'one that is low carbon, resource efficient and socially inclusive.' (DNPM, 2014). Additionally:

> It promotes the principles of inclusive economic and social growth, inclusive environmental conservation, and innovation that integrates the considerations of the three spheres of growth – economy, social and environment as factors of equal value and importance.

The decision-making processes presented in Chapter 5 describe how key features were avoided to reduce potentially adverse impacts on biodiversity and resources, and the proposed mitigation and management measures, and associated management plans, described in the impact assessment in Chapters 11 to 16 further identify how the Project will avoid and reduce environmental and social risks, and enhance social and economic growth in the Project area.

1.4.4.5 National Biodiversity Strategy and Action Plan

As a contracting party to the Convention on Biological Diversity (see Chapter 2), Papua New Guinea prepared a national biodiversity strategy and action plan in 2007 that is currently in the process of being updated (DEC, 2014). The plan has six main goals of which development of the Project is aligned with (GPNG, 2007):

> Goal 1 To conserve, sustainably use and manage the country's biological diversity.

In particular, the Project is contributing to the program on research and information on biodiversity.

1.4.4.6 National Climate Compatible Development Management Policy

Climate change was addressed in Vision 2050 (Section 1.4.4.1) and the Papua New Guinea Development Strategic Plan 2010 to 2030 (Section 1.4.4.3), and the National Climate Compatible Development Management Policy (OCCD, 2014) has been developed to focus on sustainable development and key policy areas for climate change mitigation and adaptation and provides monitoring and evaluation of these activities.

The policy looks to building a climate-resilient and carbon neutral pathway through sustainable economic development for Papua New Guinea. ‘Particular emphasis is also placed on the promotion and adoption of cost-effective measures to reduce green-house gas emissions driven mainly by abatement measures in Agriculture, Land Use, Land Use-Change and Forestry (LULUCF) sectors and become carbon neutral while investing into low-carbon infrastructure.’ (OCCD, 2014). The Project has undertaken a greenhouse gas and climate change assessment (Chapter 15) that considers emissions in the context of PNG’s ability to comply with the policy.

1.4.5 Impacts and Benefits of the Project

Constructing and operating a project of the magnitude and complexity of the Papua LNG Project will have unavoidable direct and indirect impacts to the biophysical and social environments. The Project is likely to occupy a footprint of approximately 940 ha (see Chapter 04). Construction will involve clearing and ground disturbance, and there will be discharges and emissions to the environment during construction and operations. The Project will require access to customary-owned land to develop facilities and infrastructure.

The Project is expected to generate substantial financial benefits for Papua New Guinea. The preliminary median capital cost estimate for the upstream portion of the Papua LNG Project development costs is estimated at US$4.0 billion in 2018 Real Terms for the initial development, plus approximately US$0.9 billion for the subsequent compression phases. The Gulf and Central provinces will experience direct financial benefits through royalties and development levies, and indirect financial benefits through the stimulation of economic activities.

Legally recognized landowners, as determined under s. 47 (i.e., social mapping and landowner identification studies) of the *Oil and Gas Act 1998*, will receive statutory benefits via the State; and the wider Project-affected communities in the Project area are likely to benefit through Project training, employment or other business opportunities.

The approach to National Content is built around three pillars, aiming at developing a PNG workforce, involving local businesses and assisting with the socio-economic development of communities in the Project area and Papua New Guinea as a whole.

Constructing and operating the proposed facilities will have some negative impacts on the natural and social environment, and the Project is also likely to change the current subsistence-based livelihoods of stakeholders and communities in the Project area; however, TEP PNG expects that these will be managed to be as low as reasonably practicable by implementing best available practicable controls.[6] The Project potential impacts and proposed mitigation and management measures are detailed in Chapters 11 to 18 of this EIS.

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6 An approach based on adopting the best technological controls available to limit adverse impacts, at reasonable cost, during construction and when operating under normal conditions.

1.5 This Document

1.5.1 Statutory Context

Section 50 of the *Environment Act 2000* (*Environment Act*) requires the proponent, on receiving a notice from the Director, to undergo an environmental impact assessment for the Project to support the application for an environment permit. In accordance with that legislation and related regulations, this is a two-step process that commenced with the submission of an environmental inception report (EIR) in October 2016. The Director of Environment approved the EIR in December 2016 and TEP PNG was directed to submit an EIS. The EIS has been prepared with reference to the Information Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (GL-Env/02/2004) (DEC, 2004) and the assessment procedures of the (*Environment Act*).

Attachment 1.1 cross-references the EIS sections to the guidelines and requirements of CEPA, formerly the Department of Conservation and Environment. It also provides a guide between the relevant sections of the EIS and the requirements of the EIS as identified in the EIR.

Additional information about statutory requirements for the Project is provided in Chapter 2, Regulatory Framework, Policy, Standards and Guidelines.

1.5.2 EIS Process Timeline

The EIS process timeline commenced in October 2015 with the submission of the application for an environment permit. It is expected to be completed in 2020, when a decision from the Environment Council and the Minister for Environment and Conservation on whether the Project should proceed and, if so, under what conditions, is made and ultimately an environment permit is issued (Table 1.1).

Table 1.1 – EIS Process Timeline

Date	Report Process
October 2015	Submission of an Application for an Environment Permit
October 2016	Submission of the Papua LNG Project EIR to CEPA
December 2016	Approval of the Papua LNG Project EIR by CEPA
June 2019	Submission of the revised EIR to CEPA
July 2019	Approval of the revised EIR by CEPA
Q4 2019	Submission of the EIS to CEPA
Q1 2020	EIS roadshow

1.5.3 EIS Objectives

The purpose of this EIS is to seek approval to construct, commission and operate the Papua LNG Project upstream facilities. The report is intended to provide CEPA and other stakeholders with a clear and definite description of potential environmental and social impacts on which CEPA and other stakeholders can base their assessment and any subsequent approval may be granted.

1.5.4 EIS Structure

The EIS consists of an executive summary and three volumes:

- Executive summary: Provides an overview of the Project impact assessment process and the key conclusions of the assessment for non-technical readers.
- EIS Main Report (this report, Volume 1): Intended to be understood without reference to the technical studies on which it is based. This report documents the Project's potential biophysical, socio-economic and cultural impacts, and describes the proposed mitigation,

management measures and residual impacts, and any benefits associated with the Project. Stakeholder engagement is also discussed.

- Environment and social baseline (Volume 2): Twenty-two technical study discipline baseline reports, and one additional part that collates the field survey scope and methods document, that are summarized in Volume 1 Chapters 7 to10. These reports document the results of the 13-month field survey baseline program.
- Technical studies for impact assessment (Volume 3): Five targeted, technical reports focused on modeling and technical studies to support the impact assessment in Volume 1. These reports provide additional details regarding the models and technical information used to predict the impacts associated with the Project.

Figure 1.5 provides a guide to the EIS structure and lists the appendices on which the main report is based.

1.5.5 Guide to the Document

1.5.5.1 Referencing

For reading ease, the reference list for each chapter is provided at the end of each chapter, rather than being compiled into one chapter for the entire report and placed at the end of the EIS.

The reference lists are specific to the chapter, e.g., the reference for DEC (2004b) in one chapter may not be the same reference in another chapter.

1.5.5.2 Cross-references

Cross-references refer the reader to another part or parts of the document, such as figures, tables, plates, boxes, sections, chapters, attachments or appendices; and each of these parts will have a unique number. The first cross-reference will contain the part of the document and the unique number, e.g., Plate 7.2 will be the second plate in Chapter 7. Subsequent occurrences of a cross-reference are always in parentheses and preceded by the word ‘see’.

1.5.5.3 Conventions

Key conventions adopted in preparing this report are:

- The EIS does not disclose information that is confidential for cultural or commercial reasons; however, TEP PNG may provide the latter in confidence to CEPA upon request.
- Currency conversions have been made at the exchange rate at 7 March 2019 and are:
  - PGK1 = US$0.30.
  - US$1 = PGK3.37.
  - PGK1 = AU$0.42.
  - AU$1 = PGK2.38.
- Although the Project and its related activities are a proposal, the use of ‘will’ rather than ‘would’ has been adopted for this report.

PAPUA LNG PROJECT UPSTREAM EIS STRUCTURE

Papua LNG Project | Environmental Impact Statement

FIGURE 1.5

Executive Summary

Volume 1

The Project

1. Introduction
2. Regulatory Framework, Policy, Standards and Guidelines
3. Impact Assessment Process and Methods
4. Project Description
5. Project Options and Analysis of Alternatives
6. Stakeholder Engagement

Existing Environment

7. Existing Environment - Terrestrial
8. Existing Environment – Marine
9. Existing Environment – Social, Economic and Cultural
10. Existing Environment – Amenity

Impact Assessment and Mitigation

11. Impacts: Terrestrial
12. Impacts: Marine
13. Impacts: Social
14. Impacts: Cultural Heritage
15. Impacts: Amenity
16. Impacts: Ecosystem Services
17. Cumulative Impacts
18. Major Hazards, Mitigation and Assessment
19. Environmental and Social Management, Monitoring and Reporting
20. Commitments Register

Resources

21. Glossary and Abbreviations
22. Study Team

Volume 2

Environmental and Social Baseline

Part 1 Upstream Geology, Terrain and Soils Baseline Report
Part 2 Upstream Hydrology and Meteorology Baseline Report
Part 3 Upstream Surface Water and Sediment Quality Baseline Report
Part 4 Upstream Groundwater Baseline Report
Part 5 Upstream Freshwater and Estuarine Biodiversity Baseline Report
Part 6 Upstream Terrestrial Biodiversity Baseline Report
Part 7 Upstream Deforestation Baseline Report
Part 8 Upstream Vegetation Regeneration Baseline Report
Part 9 Seabed and Coastal Geomorphology Baseline Report
Part 10 Physical Oceanography Baseline Report
Part 11 Marine Water and Sediment Quality Baseline Report
Part 12 Marine Biodiversity Baseline Report
Part 13 Marine Fisheries and Resources Baseline Report
Part 14 Upstream Community and Demographics Baseline Report
Part 15 Upstream Governance and Economics Baseline Report
Part 16 Upstream Community Health Baseline Report
Part 17 Upstream Cultural Heritage and Archaeology Baseline Report
Part 18 Upstream Land and Natural Resources Baseline Report
Part 19 Upstream Air Quality Baseline Report
Part 20 Upstream Noise Baseline Report
Part 21 Upstream Landscape and Visual Amenity Baseline Report
Part 22 Marine and River Traffic and Transport Baseline Report
Part 23 Field Survey Scope and Methods Documents

Volume 3

Technical Studies

Part 1 Underwater Noise Modeling for Impact Assessment
Part 2 Air Quality Modeling for Impact Assessment
Part 3 Noise Modeling for Impact Assessment
Part 4 Marine Modeling for Impact Assessment
Part 5 Greenhouse Gas and Climate Change Impact Assessment

- Onshore Project activities can occur in one or more of three areas: PRL-15, the export pipeline route or the river transport corridor. Collectively, these areas are referred to as the onshore Project area.
- PRL-15 generally refers to land and communities in and around the PRL-15 license area unless specifically stated.
- The river transport corridor is defined as the rivers that may be used for access to the Project; and the villages along those rivers.
- The baseline reports in Volume 2 of the EIS that characterize the upstream environment are prefixed with ‘Upstream’, except those with a marine component.
- Generally, when referring to the pipeline infrastructure, it is referred to in plural, e.g., onshore export pipelines or trunklines or flowlines; however, typically, the singular form is used when referring to the route or right of way, e.g., onshore export pipeline route, referring collectively to the gas and condensate pipelines that will be located in the one trench. Similarly, the trunkline route refers to the bundle of pipelines and cable in the two trenches along the route.
- The EIS assumes the Project will be developed primarily as described herein based on the pre-Project design at December 2018; however, information presented in the EIS may vary as the design has evolved in parallel with the preparation of this EIS. Additional refinements may occur as additional information (e.g., engineering, environmental, social or commercial) becomes available, subject to the Project management of change process, which is defined in Chapter 3, Impact Assessment and Methods.
- Unique codes, e.g., [ED001], identify embedded Project design controls throughout the document, and are collated in Chapter 4, Project Description.
- Unique codes, e.g., [EM001] (environmental mitigation) or [SM003] (social mitigation), identify mitigations and management measures throughout Chapters 11 to 16, and are collated in Chapter 20, Commitments Register.

Chapter 3, Impact Assessment Methods, and Chapter 21, Glossary and Abbreviations, provide other report conventions that have been used throughout the document.

1.5.6 Public Review and Submissions

The EIS will be made available to the public in accordance with the *Environment Act 2000*, tentatively aiming for the roadshow to be held Q1 2020.

1.6 References

DEC. 2004. Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (GL-Env/02/2004). Department of Environment and Conservation, Port Moresby, Papua New Guinea.

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TEPA. 2013. The Equator Principles. A WWW publication accessed on 5 April 2019 at https://equator-principles.com./wp-content/uploads/2017/03/equator_principles_III.pdf. The Equator Principles Association.

Attachment 1.1.
Cross-reference of CEPA Requirements and Guidelines to EIS Sections

Table 1 provides reconciliation between the contents of the Papua LNG Environmental Impact Statement (this EIS) and the scope of the EIS as described in the Papua LNG Environmental Inception Report (EIR).

Table 1 – Cross-refence Between the EIS and the EIR

EIR	EIS Chapter,Volume (and Part) addressing the Requirement
Consider the potential environmental and socio-economic (including health and cultural) impacts of the Project with respect to their value (i.e., positive or negative), nature (direct, indirect or cumulative), duration (short, medium or long-term), geographical extent (local, regional or national) and magnitude (degree of severity) taking into account the sensitivity of the receptor.	Chapter 11 Chapter 12 Chapter 13 Chapter 14 Chapter 15 Chapter 16 Chapter 17 Chapter 18
Describe measures to mitigate and manage potentially adverse impacts that may occur as a result of the Project. One of the main purposes of the EIS process is to develop mitigation and management measures and these will be based on the mitigation hierarchy of avoid, minimize, reduce and restore. Measures will be developed via an iterative and integrated process with the Project engineering team as the impact assessment progresses and the Project engineering design advances.	
Assess the residual environmental and socio-economic impacts of the Project, once mitigation and management measures have been determined.	

Table 2 provides reconciliation between the contents of the Papua LNG EIS with the Department of Environment and Conservation (DEC) Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (CEPA Guideline) (DEC, 2004). The main EIS chapters where the guidelines' requirement has been primarily addressed are listed. Other EIS sections may address the requirement, but they are not documented in this table.

Table 2 – Cross-reference Between the EIS and CEPA Guideline

	CEPA Guideline	EIS Chapter, Volume (and Part) addressing the Requirement
	Letter of Transmittal or Cover Letter	
	It is important that an Environmental Impact Statement on the proposal must be transmitted to DEC* with a cover letter signed by the responsible company official or its authorised representative (i.e., consultant - engaged by the company to act on its behalf). If an external consultant is used, the letter must also authorise the consultant to make statements and provide further information on behalf of the company in relation to the application.	Submitted with EIS.
1.	***Executive Summary or Overview of Proposal***	
	Information provided in the Executive Summary shall concisely describe the following:	
	♦ The proposed development activity and its objectives.	Executive Summary
	♦ Anticipated bio-physical and socio-economic impacts (direct/indirect, reversible/irreversible) of the activity.	Executive Summary
	♦ Remedial actions that are proposed.	Executive Summary
	♦ All benefits to be derived from the project.	Executive Summary

Table 2 – Cross-reference Between the EIS and CEPA Guideline (cont'd)

	CEPA Guideline	EIS Chapter Volume (and Part) addressing the Requirement
1.	***Executive Summary or Overview of Proposal (cont'd)***	
	♦ The consultation program undertaken by the applicant, including degree of public interest.	Executive Summary
	♦ Rehabilitation and/or end-use plans for the development activity in relation to community needs.	Executive Summary
2.	***Purpose of the Development***	
	This section shall include but not be limited to the following:	
	♦ Describe if the development is in line with the Fourth National Goal and Directive Principle of the National Constitution of PNG.	Chapter 1
	♦ Explain if the proposed development is compatible with National, Provincial and Local Level Government development goals and planning guidelines.	Chapter 1
	♦ Detail the economic benefits to the Nation, Province, Local Level Governments and to the local community being impacted.	Chapter 1 Chapter 13
3.	***Viability of the Project***	
	Provide information on the viability of the proposed development activity. These details shall include but not be limited to the following:	
	♦ Information on the capital cost associated with the development.	Chapter 1
	♦ Details of the proponent's technological expertise and resources.	Chapter 1 Chapter 22
	♦ Results of any feasibility investigations that have been carried out.	Chapter 5
	♦ Information on the extent of landowner and/or resource owner support, including a copy of the formal written approval of their consent.	Chapter 13*
	♦ Details of the life-span and development phases of the project.	Chapter 1 Chapter 4
4.	***Description of the Proposed Development Activity***	
	All relevant details on the proposed development activity required under this section should be provided where it is applicable to the proposal. Details to be provided under this section may include the following:	
	♦ Background information to the proposal, process technologies to be employed etc.	Chapter 1 Chapter 4
	♦ Detailed location maps (drawn to scale), site layout, etc.	Chapter 4
	♦ Information on method of site selection including alternatives investigated, plant or building designs, relevant diagrams and drawings.	Chapter 5
	♦ Detailed flowcharts, mass balances (including feedstocks, products and wastes generated), etc.	Chapter 1 Chapter 4
	♦ Description of nearby development activities that may contribute to additive effects on background pollution levels or other baseline conditions.	Chapter 17
	♦ Information on associated infrastructure/facilities that is to be constructed.	Chapter 4

Table 2 – Cross-reference Between the EIS and CEPA Guideline (cont'd)

	CEPA Guideline	EIS Chapter, Volume (and Part) addressing the Requirement
5.	***Development Timetable***	
	Information on the development timetable provided under this section should be clear and easy for DEC# to understand the different phases in the development proposal. For reasons of clarity, a Flow chart, Gantt or PERT chart should be used where appropriate. Information provided in this section shall include but not limited to the following:	
	♦ Information on funding arrangement for proposed activity or if availability of funds subjected to this or other approvals being granted.	Chapter 1
	♦ Details of pre-construction activities.	Chapter 4
	♦ Information on consultation program with all affected parties (i.e., parties that may be directly and indirectly affected).	Chapter 1 Chapter 3 Chapter 6
	♦ Details of construction schedule, staging, etc.	Chapter 4
	♦ Details of commissioning and operational schedules.	Chapter 4
	♦ Details of infrastructure development schedule.	Chapter 4
	♦ Details of closure and rehabilitation schedule.	Chapter 4
6.	***Characteristics of the Receiving Environment***	
6.1	**Available Environmental Studies and Investigations**	
	Information provided in this sub-section shall include but not be limited to the following:	
	♦ Historic or current baseline data on physical, biological and social systems. ♦ A written estimate of research and/or study time already expended and to be further undertaken.	Chapter 7 Chapter 8 Chapter 9 Chapter 10 Volume 2: Parts 1 to 23
6.2	**Physical Environment**	
	Provide details on the existing physical environment including data on ambient environmental quality of various segments of the environment. Information provided in this sub-section shall include but not be limited to the following:	
	♦ Geomorphological, topographical and geological characteristics.	Chapter 7 Chapter 8 Volume 2, Part 1 Volume 2, Part 9
	♦ Any natural or induced hazard in the area (e.g., flood, earthquake, volcanic zone, etc.).	Chapter 7 Volume 2, Part 1
	♦ Climatic regime (e.g., rainfall, temperature, etc.).	Chapter 7 Volume 2, Part 2
	♦ Air quality and meteorological data set for air dispersion modelling, etc.	Chapter 7 Chapter 10 Volume 2, Part 2 Volume 2, Part 19

Table 2 – Cross-reference Between the EIS and CEPA Guideline (cont'd)

	CEPA Guideline	EIS Chapter, Volume (and Part) addressing the Requirement
	♦ Seasonal surface water quality and hydrological information.	Chapter 7 Chapter 8 Volume 2, Part 3 Volume 2, Part 10 Volume 2, Part 11
	♦ Seasonal ground water quality and flow regime.	Chapter 7 Volume 2, Part 4
	♦ Noise levels.	Chapter 8 Chapter10 Volume 2, Part 20
6.3	**Biological Environment**	
	Detailed information should be provided on the existing biological environment and shall include but not be limited to the following:	
	♦ Presence of a protected area (Conservation Area or Wildlife Management Area), if any.	Chapter 7 Chapter 8 Volume 2, Part 6 Volume 2, Part 12
	♦ Details of any special purpose areas (e.g., wetland area, etc.).	Chapter 7 Volume 2, Part 6
	♦ Aquatic and terrestrial ecology of the area.	Chapter 7 Chapter 8 Volume 2, Part 5 Volume 2, Part 6
	♦ Information on vulnerable (endangered) species.	Chapter 7 Chapter 8 Volume 2, Part 5 Volume 2, Part 6 Volume 2, Part 12
	♦ Other relevant biological information.	Chapter 7 Chapter 8 Volume 2, Part 7 Volume 2, Part 8 Volume 2, Part 12 Volume 2, Part 13
6.4	**Social Environment**	
	Issues that may arise within and outside of the project area should be identified including whether this is a direct or indirect outcome of the physical, biological or socio-economic effects of the proposed development activities. Information provided in this sub-section shall include but not be limited to the following:	
	♦ Demographic information.	Chapter 9 Volume 2, Part 14
	♦ Information on existing infrastructure.	Chapter 9 Chapter 13 Volume 2, Part 14 Volume 2, Part 16
	♦ Information on public health issues (if applicable).	Chapter 9 Chapter 13 Volume 2, Part 16

Table 2 – Cross-reference Between the EIS and CEPA Guideline (cont'd)

	CEPA Guideline	EIS Chapter, Volume (and Part) addressing the Requirement
	♦ Information on present economic status of the project area.	Chapter 9 Chapter 13 Volume 2, Part 13 Volume 2, Part 15 Volume 2, Part 18
	♦ Description of existing social services.	Chapter 9 Chapter 13 Volume 2, Part 14 Volume 2, Part 18
	♦ Details of archaeological, historical, cultural or religious features of the project area under consideration, etc.	Chapter 9 Chapter 14 Volume 2, Part 17
7	***Waste Minimisation, Cleaner Production and Energy Balance***	
	Information detailed in this section should include consideration of options associated with waste minimisation, cleaner production and energy balance and the ability of the proponent to employ these strategies in its proposed activities. Information to be covered in this section shall include but not limited to the following:	
	♦ Details of other alternative "cleaner production" technologies or processes that has been considered.	Chapter 5
	♦ Information on the basis for choosing the proposed technology or process.	Chapter 4 Chapter 5
	♦ Available technical background on the process chosen.	Chapter 4 Chapter 5
	♦ Details of the Waste Minimisation Strategy developed for the proposal.	Chapter 4
	♦ Details of an "energy balance" for the proposal.	Chapter 4 Chapter 15
8.	***Environmental Management, Monitoring and Reporting***	
	Information to be covered in this section shall include but not limited to the following:	
	♦ Details of information on plant operating conditions, including management and monitoring strategy.	Chapter 4
	♦ Information on socio-economic management and monitoring strategy.	Chapter 2 Chapter 13 Chapter 16 Chapter 19
	♦ Mechanism and frequency for reporting monitoring results to DEC* and other stakeholders, especially to directly affected stakeholder groups.	Chapter 6 Chapter 19
	♦ Availability of contingency and/or emergency plans drawn up for the proposal.	Chapter 18 Chapter 19
	♦ Details of Environment Improvement Plan.	Chapter 19
	♦ Details of Waste Minimisation and/or Management Plans.	Chapter 4 Chapter 11 Chapter 15 Chapter 19

Table 2 – Cross-reference Between the EIS and CEPA Guideline (cont'd)

	CEPA Guideline	EIS Chapter, Volume (and Part) addressing the Requirement
	♦ Information on potential rehabilitation issues and its strategies including Rehabilitation Plan.	Chapter 4 Chapter 7 Chapter 11 Chapter 19 Volume 2, Part 8
9.	***Other Statutory Decisions***	
	Provide detailed information on other statutory decision(s) that are relevant to this proposed development activity. Provide the draft or finalised Project Development Contract, Memorandum of Agreements or other similar legal decisions that are relevant to the proposal.	Chapter 2
10.	***Confidential Information***	
	Details of classified information relating to a manufacturing or industrial process or trade secret used in carrying on or operating any particular undertaking or equipment or information of a business or financial nature in relation to the proposed activity should be clearly defined. Such information would be classified as "confidential information" and excluded from the EIS before the document is made available for public review.	Noted
11.	***References***	
	Provide details of reference materials used in sourcing information and/or data used in the EIS.	References are provided at the end of Chapters 1 to 19, relevant to each chapter.
12.	***Acknowledgements***	
	Detail relevant acknowledgments.	Chapter 22
13.	***References***	
	Provide detailed information on persons who assisted in the conduct of the environmental impact assessment study and compilation of the EIS.	Chapter 22

Notes: * Addressed via the approach described in Chapter 13. # Now CEPA.

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 2: Regulatory Framework, Policies, Standards and Guidelines

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TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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Chapter

Tables

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2. Regulatory Framework, Policies, Standards and Guidelines

2.1 Introduction

This chapter describes the main laws, regulations and policies applicable to the Project at the date of this report, and good practice standards and guidelines that have informed the preparation of this document, namely:

- The PNG legislation and regulations that apply to the approvals and environmental permitting of the Project under the *Environment Act 2000* (*Environment Act*) and the requirements for licensing of the Project under the *Oil and Gas Act 1998 (Oil and Gas Act)*.
- PNG legislation and guidelines relevant to regulating the Project's development.
- International standards and agreements to which Papua New Guinea (PNG) is a signatory and which are applicable to the Project.
- International environmental and social conventions, standards and guidelines, including the International Finance Corporation (IFC) performance standards, which have informed the preparation of this Environmental Impact Statement (EIS) and influenced Project design.
- Total E&P PNG Ltd (TEP PNG) environmental and social standards relevant to the Project.

The most stringent requirements will be applied when there is a conflict between PNG and other requirements, or an absence in PNG requirements. This is further elaborated where relevant in the respective impact assessment chapters (i.e., Chapters 11 to 16).

2.2 Legislation Governing Project Approval

Two key pieces of legislation regulate oil and gas development projects in Papua New Guinea; the *Environment Act* and the *Oil and Gas Act*. The *Environment* Act sets out requirements for approvals and environmental permitting of oil and gas developments, including the baseline data collection as part of impact assessment, and is supplemented by various regulations and guidelines. The *Oil and Gas Act* governs the licensing of petroleum exploration and development activities and infrastructure.

2.2.1 *Environment Act 2000*

The *Environment Act* and supporting *Environment (Prescribed Activities) Regulation 2002 (Environment (Prescribed Activities) Regulation)* regulate the environmental and social effects of major projects in Papua New Guinea and are administered by the Conservation and Environment Protection Authority (CEPA), formerly the PNG Department of Environment and Conservation (DEC).

The *Environment (Amendment) Act 2014* documents amendments to the *Environment Act*, including some changes to the environmental impact assessment (EIA) process; however, at the time of writing, these changes had not been enacted into law. Thus, the discussion in the following subsections aligns with the *Environment Act*.

2.2.1.1 Environment Permit and Approvals

The *Environment Act* requires project proponents to obtain an environmental permit before undertaking activities that may cause environmental harm. *The Environment (Prescribed Activities) Regulation* classifies activities as Level 1, 2 or 3 depending on the extent to which they cause environmental harm.

The Project is classified as a Level 3 activity as it will undertake activities that '(a) may result in serious environmental harm, or (b) may have a negative or significant negative impact on a matter of national importance' (s. 42). Thus, it will require an EIA (s. 50). As part of this process, CEPA may seek input from other PNG government authorities as appropriate. For the purposes of s. 5 of the *Environment (Prescribed Activities) Regulation*, approvals are also required for several categories of Level 2 activities that are subsidiary to the Project. Table 2.1 lists the Level 3 and 2 prescribed activities relevant to the Project.

Table 2.1 – Level 3 and Level 2 Prescribed Activities Relevant to the Project

Activity Number	Prescribed Activity
Level 3	
18.1	Recovery, processing, storage or transportation of petroleum products requiring the issue of a petroleum development licence or a pipeline licence under the *Oil and Gas Act*.
Level 2	
1.1	Drilling of oil and gas wells.
5.2	Pipeline transport and storage using facilities with a holding capacity of more than 0.5 million liters.
7.4	Quarrying involving the extraction of more than 100,000 tonnes per year.
10.2	Operation of fuel-burning power stations with a capacity of more than 5 megawatts but not including emergency generators.
11.4	Incineration, reprocessing, treatment or disposal of industrial waste of a capacity greater than 10 tonnes per year.
12.4	Construction of aerodromes or airfields except unpaved airstrips more than 10 km from an urban area.
12.6	Construction of electricity transmission lines or pipelines greater than 10 km in length.
13.1	Damming or diversion of rivers or streams.

Source: *Environment (Prescribed Activities) Regulation*.

Figure 2.1 shows the steps of the EIA approvals process for this Project.

To date, TEP PNG has submitted the following documents in accordance with the requirements set out in the regulation, and the following additional requirements stipulated in the associated Guideline for Preparation of an Environmental Inception Report (EIR) (GL-Env/01/2004) (DEC, 2004a):

- Notification of Intent to carry out preparatory works (s. 48) (submitted October 2015).
- Environment permit application (s. 60) (submitted October 2015). Subsequently, the Director advised the Project is classified as a Level 3 Activity Sub-Category 18: Petroleum and gas production and processing, and that an EIA would be required (s. 50).
- Submission of an EIR (s. 52) (submitted October 2016). The Director approved the EIR in December 2016. The EIR was revised and resubmitted in June 2019.[1]

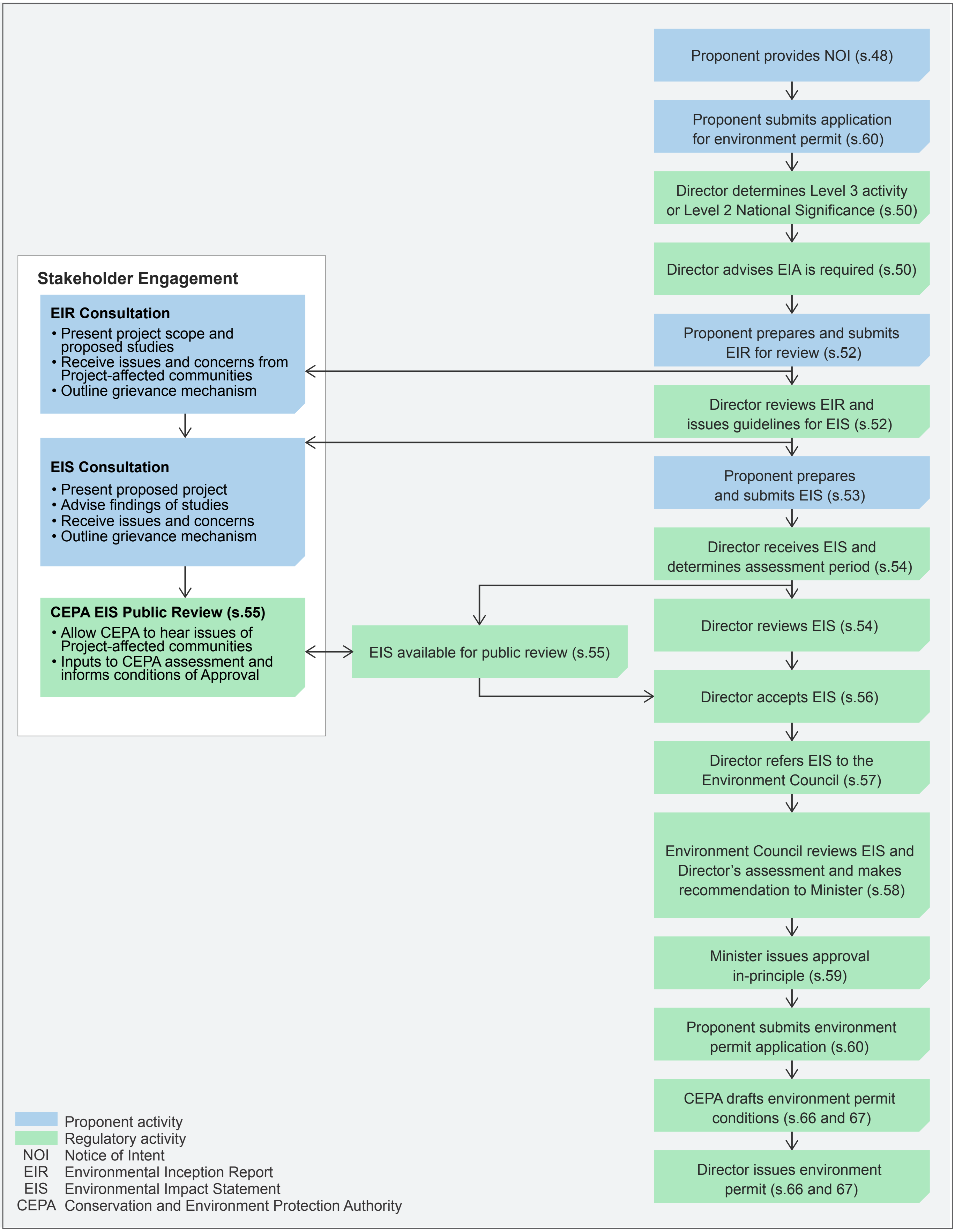
The next step in the EIA process is to undertake the environmental and social impact assessment studies and to prepare the EIS (this document), according to the Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (DEC, 2004b), and to address the issues set out in the EIR. Attachment 1.1 presents a cross-reference with this guideline and the EIR.

1 The EIR was revised to update details regarding the Project proponent in relation to upstream and downstream facilities and some associated activities.

PAPUA NEW GUINEA ENVIRONMENT PERMIT AND APPROVALS PROCESS

Papua LNG Project | Environmental Impact Statement

FIGURE 2.1



Note: Consultation aligns with International Finance Corporation (IFC) for Informed Consultation and Participation (ICP) Process. This process aligns with the PNG *Environment Act 2000*, as the *Environment (Amendment) Act 2014* has not to-date been enacted into law.

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Considering the potential social and economic impacts is an integral part of the *Oil and Gas Act* and the EIA process under the *Environment Act,* a socio-economic impact assessment is a specific requirement under the *Oil and Gas Act* to support the grant of a petroleum development licence (see Section 2.2.2).

Once the EIS is submitted to CEPA (s. 53), the Director will make a preliminary assessment (s. 54) within 30 days, before making it available for public review (s. 55). Following public review, the Director will accept the EIS in the event the Director is satisfied (s. 56), and the Director's assessment report and any public submissions will be referred to the Environment Council (Council), a multi-disciplinary panel of experts appointed under s. 57. The Council has 90 days to decide whether it is satisfied with the EIS. If the Council is not satisfied, the EIS is returned to the proponent for revision and resubmission. If the Council is satisfied, it will advise the Minister for Environment, Conservation and Climate Change (the Minister) to approve the proposed activity in principle (s. 58 and 59).

Once the Minister has issued approval in principle for the Project, CEPA will then finalize the conditions of the environment permit and grant the permit under s. 66 and s. 67 of the *Environment Act* respectively.

2.2.1.2 Other CEPA Guidelines

The former DEC published several technical guidelines that provide additional information and have been used to support specific discipline assessments and inform this EIS. The key documents are:

- IB-ENV/02/2004: Technical Guideline (Additional Information): Air Discharges – describes the information that should be provided as part of an application for an Environment (waste discharge) permit where air emissions may be generated (DEC, 2004c).
- IB-ENV/03/2004: Technical Guideline (Additional Information): Noise Discharges – describes the information that should be provided as part of an application for an Environment (waste discharge) permit where noise emissions may be generated (DEC, 2004d).
- IB-ENV/04/2004: Technical Guideline (Additional Information): Land and Water Discharges – describes the information that should be provided as part of an application for an Environment (waste discharge) permit where emissions to land or water may be generated (DEC, 2004e).

The standards and guidelines comprising qualitative measures and quantitative emission criteria (i.e., noise, air quality, water) that the Project will meet are described where relevant in the individual discipline impact assessments presented in Chapters 11 to 16.

2.2.2 *Oil and Gas Act 1998*

Papua New Guinea has a concessionary petroleum regime where rights to petroleum are owned by the State but are assigned to private interests set out in legislation. The *Oil and Gas Act* is the principle law governing the exploration, licencing, development, production, processing and transportation of petroleum in Papua New Guinea. The PNG Department of Petroleum and Energy (formerly the Department of Petroleum) administers the Act. Pursuant to the Act, the Project requires the following licences to regulate activities:

- Petroleum prospecting licence (PPL).
- Petroleum retention licence (PRL) covering nine blocks (i.e., PRL-15); granted in 2010 and issued from the PPL.
- Petroleum development licence (PDL) covering a portion of PRL-15; to be applied for in the future.

- Pipeline licence(s) (PL) covering the raw gas trunklines from the Elk and Antelope fields to the CPF, and the condensate and gas export pipelines from the CPF to the downstream Papua LNG facilities in Caution Bay; to be applied for in the future.
- Petroleum processing facility licence(s) (PPFL) covering the upstream central processing facilities and the downstream Papua LNG facilities and shared facilities in Caution Bay; to be applied for in the future.

The *Oil and Gas Act* also sets out specific requirements relating to land access following the award of a petroleum licence over a defined tenement.

2.2.2.1 Licences

Consideration of environmental and social aspects is required prior to a petroleum licence being issued. Prior to the issue of a PDL, the Minister for Petroleum must be satisfied that the Project will '…provide adequately for the protection of the environment and the welfare of the people of the area' (s. 57(2)(b)(iv)).

The Project was granted PRL no. 15 (PRL-15) on 30 November 2010 and will, in the future, seek a PDL, PL and PPFL. An environment permit is typically a prerequisite to PDL approval.

A PDL is granted for an initial period of 25 years, with rights to extend for a period, or consecutive periods of up to 20 years.

2.2.2.2 Land Access

Access to land required for petroleum extraction and infrastructure development is granted under the terms and conditions of the *Oil and Gas Act* via the award of a petroleum licence. Once granted, licencees have the right to enter the land and use that land to the extent reasonably necessary to conduct the operations for which the licence has been granted. Such rights of access are conditional upon providing appropriate compensation to the lawful owners and rightful occupiers of the land.

Before granting any petroleum licence, the Minister for Petroleum may authorize access to the land under s. 116(1) for surveying, gathering data or undertaking other temporary operations. The Minister for Petroleum may also allow activities in preparation for construction under s. 116(1A). The duration of authorization under either section is at the Minister's discretion.

2.2.2.3 Identifying Landowner Beneficiaries

Under the *Oil and Gas Act*, project-area landowners, affected provincial and local-level governments, and the national government may be entitled to Project benefits. To determine which landowners are entitled to Project benefits, s. 47 of the Act requires applicants to conduct social mapping, landowner identification (SMLI) studies and socio-economic studies, as a prerequisite to a licence being granted.

A development forum (s. 48) is required prior to a PDL being granted and will not be convened until an EIS, including a socio-economic impact study (s. 49) and a full-scale SMLI study (s. 47), has been submitted to the Minister and the Minister is satisfied that the landowners are correctly represented.

The socio-economic impact assessment that is documented in Chapter 13 of this EIS will be provided to the Department of Petroleum to satisfy the requirements identified above. TEP PNG has carried out a full-scale SMLI study according to s. 47 of the Act. The full-scale SMLI study will be reported to the Department of Petroleum separate to this EIS.

2.3 Other PNG Legislation and Guidelines

Table 2.2 summarizes other important PNG legislation and guidelines relevant to regulating environmental and socio-economic performance of Project development and operational activities. Table 2.3 lists additional legislation related to environment and health, land acquisition and compensation, employment and industrial relations, and planning and infrastructure that, while not exhaustive, may nonetheless influence the Project.

Table 2.2 – PNG Legislation and Guidelines Relevant to Environmental and Social Performance

Legislation	Description	Discipline Reference
Environment (Water Quality Criteria) Regulation 2002	This regulation sets water quality criteria to preserve freshwater and marine aquatic life. Any use or discharge into water shall not cause lowering of the water quality below the prescribed criteria (see Schedule 1) unless permitted by this regulation or the terms of a permit. Project activities and wastewater treatment plant discharge must comply with water quality criteria. Criteria for a range of parameters (e.g., arsenic, boron, copper, lead, mercury and nickel) have been set for freshwater and marine aquatic life environments.	Surface water and sediment quality (Part 3 of Volume 2). Marine water and sediment quality (Part 11 of Volume 2).
Fauna (Protection and Control) Act 1966 and *Fauna (Protection and Control) (Amendment) Act 2014*	This Act governs the protection, control, harvesting and destruction of native fauna. It lists restricted or protected species of conservation significance in Papua New Guinea.	Freshwater and estuarine biodiversity (Part 5 of Volume 2). Terrestrial biodiversity (Part 6 of Volume 2).
	The Act also provides for the declaration of sanctuaries, protected areas and wildlife management areas.	Marine biodiversity (Part 12 of Volume 2).
Conservation Areas Act 1978 and *Conservation Areas (Amendment) Act 2014*	This Act provides for the declaration of conservation areas, which serve as another form of protected area in Papua New Guinea. The 2014 amendment of the Act requires a permit to develop land in a conservation area (s. 31 to 36).	Freshwater and estuarine biodiversity (Part 5 of Volume 2). Marine biodiversity (Part 12 of Volume 2).
International Trade (Fauna and Flora) Act 1979 and *International Trade (Fauna and Flora) (Amendment) Act 2014*	This Act promotes the sustainable use of fauna and flora and implements Papua New Guinea's obligations as a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	Freshwater and estuarine biodiversity (Part 5 of Volume 2). Terrestrial biodiversity (Part 6 of Volume 2).
Technical Guideline (Additional Information) Water & Land Discharges (DEC, 2004e)	This guideline supplements the Guideline for Submission of an Application for an Environment Permit to Discharge Waste (GL-ENV/03/2004) (DEC, 2004f). It sets out the information that should be provided, as part of an application for an environment permit where water or land discharges may be generated.	Hydrology and meteorology (Part 2 of Volume 2). Surface water and sediment quality (Part 3 of Volume 2). Freshwater and estuarine biodiversity (Part 5 of Volume 2). Marine biodiversity (Part 12 of Volume 2).

Table 2.2 – PNG Legislation and Guidelines Relevant to Environmental and Social Performance (cont'd)

Legislation	Description	Discipline Reference
Technical Guideline (Additional Information) Air Discharges (DEC, 2004e)	This guideline assists with completing the application for an Environment Permit to Discharge Waste and is intended to assist applicants in submitting the relevant technical information in the permit application, addressing both existing air emissions and potential impacts.	Air quality (Part 19 of Volume 2).
Technical Guideline (Additional Information) for Noise Discharges (DEC, 2004d)	This guideline assists with completing the application for an Environment Permit and is intended to assist applicants in submitting the relevant technical information in the permit application, addressing both background noise and Project noise predictions.	Noise (Part 20 of Volume 2).
Draft Environmental Guideline for Sewerage Treatment and Disposal (DEC, 2009)	This draft guideline assists in the planning and management of sewerage treatment and disposal facilities in Papua New Guinea, and in understanding the various roles and responsibilities of sanitation management organizations.	Surface water and sediment quality (Part 3 of Volume 2). Marine water and sediment quality (Part 11 of Volume 2). Waste (Chapter 10 of this EIS).
Environmental Code of Practice for PNG Vehicle & Machinery Workshops Petroleum Storage, Resale and Usage Sites (DEC, 1997)	This code of practice provides guidance on the use of hydrocarbon-based materials in an environmentally sound manner.	Waste (Chapter 10 of this EIS).
Marine Pollution (Sea Dumping) Act 2013 and *Marine Pollution (Sea Dumping) Regulation*	This Act regulates the incineration and dumping of waste and other matter at sea, and implements the London Dumping Protocols. It requires a sea dumping permit to place certain waste material in marine waters. The regulation provides contaminant guidelines for dredged material disposed of at sea.	Surface water and sediment quality (Part 3 of Volume 2). Seabed and coastal geomorphology (Part 9 of Volume 2). Physical oceanography (Part 10 of Volume 2). Marine water and sediment quality (Part 11 of Volume 2). Marine biodiversity (Part 12 of Volume 2).
Marine Pollution (Preparedness and Response) Act 2013	This Act makes provisions for the effective response to and control of spills of oils, chemicals or any other pollutants from vessels in PNG waters. The Act mandates a comprehensive system for responding to and cleaning up oil spills and other marine pollution incidents in Papua New Guinea and provides for cooperation with neighboring countries in the event of major pollution emergencies. It requires applicants for new petroleum-related facilities and for proposed new port facilities to undertake a marine pollution risk assessment as part of an EIS.	Marine and river traffic and transport (Part 22 of Volume 2).

Table 2.2 – PNG Legislation and Guidelines Relevant to Environmental and Social Performance (cont'd)

Legislation	Description	Discipline Reference
Marine Pollution (Ships and Installations) Act 2013	This Act makes provisions for the prevention and control of marine pollution from any vessel and any offshore installation in PNG waters and from any PNG vessel or offshore installation wherever it may be; and it incorporates into the law of Papua New Guinea, relevant provisions of the International Convention on the Control of Harmful Anti-fouling Systems on Ships (IMO, 2001) and the International Convention for the Prevention of Pollution from Ships (IMO, 1973) which relates to marine pollution prevention and control.	Marine and river traffic and transport (Part 22 of Volume 2).
Marine Pollution (Ballast Water Control) Act 2013	This Act incorporates relevant provisions of the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (IMO, 2004). It makes provisions to control the introduction of harmful aquatic organisms or pathogens.	Marine and river traffic and transport (Part 22 of Volume 2).
National Museum and Art Gallery Act 1992	The PNG National Museum and Art Gallery, through this Act, is required to maintain a register of cultural heritage and archaeological sites identified during planning and development, and to ensure that sites are not illegally damaged or destroyed.	Cultural heritage and archaeology (Part 17 of Volume 2).
National Cultural Property (Preservation) Act 1965 and *National Cultural Property (Preservation) Regulation 1965*	This Act applies to pre-European-contact and post-European-contact sites on land, and underwater/ maritime archaeological sites. The Act covers 'any property, movable or immovable, of particular importance to the cultural heritage of the country' and 'any object, natural or artificial, used for, or made or adapted for use for, any purpose connected with the traditional cultural life of any of the peoples of the country, past or present'.	Cultural heritage and archaeology (Part 17 of Volume 2).
Public Health (Drinking Water) Regulation 1984	This regulation sets out criteria for ensuring water is suitable for human consumption. There are no specific groundwater assessment criteria in PNG legislation; therefore, groundwater quality is assessed with respect to water quality standards relevant to potentially sensitive receptors (i.e., human receptors and aquatic life).	Surface water and sediment quality (Part 3 of Volume 2). Groundwater (Part 4 of Volume 2).
Maritime Zones Act 2015	This Act provides for the protection of the marine environment through the designation of marine protected areas, prescribing measures for preventing accidents and emergencies that may pollute the marine environment and for the design, construction and operation of in-sea infrastructure (Part XI). The Act also manages activities related to underwater cultural heritage within the PNG maritime cultural zone (Part XIII).	Marine water and sediment quality (Part 11 of Volume 2). Cultural heritage and archaeology (Part 17 of Volume 2).

Table 2.2 – PNG Legislation and Guidelines Relevant to Environmental and Social Performance (cont'd)

Legislation	Description	Discipline Reference
Fisheries Management Act 1998, Fisheries Management Regulation 2000 and *Fisheries Management (Amendment) Regulation 2016*	This Act regulates fishing activity. Commercial fisheries are managed under separate 'sectors', most of which are defined by fishery management plans that set out total allowable catch, fishing areas and other arrangements. Relevant management plans under the Act include the Gulf of Papua Prawn Fishery Management Plan, the Torres Strait and Western Province Tropical Rock Lobster Fishery Management Plan, the National Bêche-de-mer Fishery Management Plan, and the Barramundi Fishery Management Plan.	Marine fisheries and resources (Part 13 of Volume 2).
Environmental Code of Practice for Sanitary Landfill Sites (DEC, 2001)	This code of practice aims to protect the existing natural environment from negative impacts of uncontrolled waste management; it assists with the planning and design of new landfills; and promotes approaches to waste reduction.	Waste (Chapter 10 of this EIS).
Forestry Act 1991 (and amendments 1993,1996, 2000, 2005 and 2010)	This Act covers commercial forestry. It allows landowners to assign their timber rights to the PNG government, which issues permits to forest industry participants.	Terrestrial Biodiversity (Annex 1D - Forestry) (Part 6 of Volume 2). Deforestation (Part 7 of Volume 2).

Table 2.3 – Other PNG Legislation Potentially Relevant to the Project

Topic	Legislation and Regulations
Environment and health	♦ *Environment (Ozone Depleting Substances) Regulation 2007*. ♦ *Plant Disease and Control Act 1953* (Chapter 220). ♦ *Environment (Registration of Contaminants and Hazardous Contaminants) Regulation 2011*. ♦ *National Water Supply and Sanitation Act 2016* and the *Public Health (Sewerage) Regulation 1973.*
Land acquisition and compensation	♦ *Land Act 1996, Land (Amendment) Act 2013.* ♦ *Land (Ownership of Freeholds) Act 1976.* ♦ *Land Registration Act 1981.* ♦ *Land Disputes Settlement Act 1975.* ♦ *Land Titles Commission Act 1962.* ♦ *Land Regulation 1999.* ♦ *Valuation Act 1967* (Chapter 327). ♦ *Land Groups Incorporation Act 1974* and the *Land Groups Incorporation Regulation 1974.*
Employment and industrial relations	♦ *Employment Act 1978* and *Employment Regulation 1980*. ♦ *Employment of Non-citizens Act 2007, Employment of Non-citizens (Amendment) Act 2007* and the *Employment of Non-Citizens Regulation 2008.* ♦ *Industrial Organizations Act 1962* and the *Industrial Organizations Regulation 1963.* ♦ *Industrial Relations Act 1962* and the *Industrial Relations Regulation 1972.* ♦ *Workers' Compensation Act 1978* and the *Workers' Compensation Regulation 1983.* ♦ *Discriminatory Practices Act 1963.* ♦ *Industrial Safety, Health and Welfare Act 1961.*

Table 2.3 – Other PNG Legislation Potentially Relevant to the Project (cont'd)

Topic	Legislation and Regulations
Buildings, transport, planning and infrastructure	♦ *Building Act 1971.* ♦ *Roads Maintenance Act 1971* and the *Roads Maintenance Regulation 1973.* ♦ *Physical Planning Act 1989* and the *Physical Planning Regulation 1990.* ♦ *Inflammable Liquid Act 1953.* ♦ *Fire Service Act 1962.* ♦ *Explosives Act 1953.* ♦ *Customs Act 1951.* ♦ *Licensing of Heavy Vehicles (Repeal) Act 2017.*

2.4 International Conventions, Standards and Guidelines

In addition to the PNG legislation in Tables 2.2 and 2.3, TEP PNG has considered the requirements of international standards and guidelines that may be relevant to the Project's environmental and social performance.

Conventions, standards and guidelines of relevance include:

- International conventions ratified by the Government of Papua New Guinea (in addition to those outlined in Table 2.2).
- IFC performance standards on environmental and social sustainability (IFC, 2012) and World Bank Group Environmental, Health and Safety Guidelines (IFC, 2007); to which the project will align.
- Good international industry practice e.g., the International Petroleum Industry Environmental Conservation Association (IPIECA) guidelines relevant to biodiversity and ecosystem services, health, social responsibility and water.

2.4.1 International Conventions

Table 2.4 presents international conventions (i.e., conventions, memoranda of understanding, covenants and agreements) the PNG government has ratified that may be relevant to this Project and identifies those aspects of the Project to which they may be relevant. In general, these conventions are effective in local law only after implementing legislation has been enacted in a signatory country. Elements of these conventions may relate to managing the Project's environmental and social impacts in those instances where the PNG Government has passed local laws to fulfill its statutory obligations.

Table 2.4 – International Conventions

Title	Description/Objective	Relevance to the Project
Conservation and Biodiversity		
International Plant Protection Convention (1952) with associated Plant Protection Agreement for the Asia and Pacific Region (1956) as amended	The convention promotes international cooperation to control the introduction and spread of pests and diseases of plants and plant products.	Construction and operational hygiene and minimizing disturbance.
Convention on Biological Diversity (1992)	The convention covers conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from using genetic resources, including sharing by appropriate access to genetic resources; and by appropriate transfer of relevant technologies, taking into account all	Minimizing Project impacts on biodiversity.

Table 2.4 – International Conventions (cont'd)

Title	Description/Objective	Relevance to the Project
Conservation and Biodiversity (cont'd)		
Convention on Biological Diversity (1992) (cont'd)	rights over those resources and to technologies; and by appropriate funding.	Minimizing Project impacts on biodiversity.
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region related Protocols (SPREP) (Nouméa, 1986)	The convention obliges parties to endeavor to take all appropriate measures to prevent, reduce and control pollution from any source and to ensure sound environmental management and development of natural resources, using the best practicable means at their disposal.	Minimizing pollution resulting from Project activities.
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention) (1971)	The convention's mission is the conservation and wise use of all wetlands through local and national actions, and international cooperation, as a contribution towards achieving sustainable development throughout the world.	Avoidance of wetlands for Project activities where possible. Minimizing disturbance of migratory shorebirds in the Purari River delta.
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (1979)	The convention aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental convention concerned with conserving wildlife and habitats on a global scale.	Minimizing Project impacts on migratory species.
Convention Concerning the Protection of World Cultural Heritage and Natural Heritage (1972)	The convention is aimed at the protection of indigenous cultural and environmental heritage.	Managing Project impacts on cultural heritage sites, traditions and natural features.
Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) (1973)	The convention's objective is to ensure the international trade in wild animal and plant specimens does not threaten the survival of the species in the wild. It accords varying degrees of protection to more than 35,000 animal and plant species.	Minimizing public or unauthorized access to forests in and surrounding the Project area.
Memorandum of Understanding for the Conservation of Cetaceans and their Habitats in the Pacific Island Region (2006)	The Memorandum of Understanding provides an international framework for coordinated efforts to conserve cetaceans and their habitats (including migratory corridors) in the Pacific Island region.	Minimizing Project impacts on cetaceans and their habitats.
Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (2001)	The Memorandum of Understanding aims to 'maintain and recover marine turtle populations by promoting cooperation among governments and other organizations that share this common objective. Recognizing that marine turtles have a myriad of socio-economic values, the memorandum seeks to assure that any consumptive or non-consumptive use of turtles for the benefit of human beings is sustainable well into the future'.	Minimizing Project impacts on marine turtles and their habitats.

Table 2.4 – International Conventions (cont'd)

Title	Description/Objective	Relevance to the Project
Emissions and Climate Change (cont'd)		
Vienna Convention for the Protection of the Ozone Layer (the Vienna Convention) (1985)	The convention provides frameworks for international reductions in the production of chlorofluorocarbons.	Minimizing Project use of chlorofluorocarbons.
United Nations Framework Convention on Climate Change (1992)	The convention aims to 'stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It focuses on reducing negative changes to the earth's climate, with a particular focus on greenhouse gases. It places the onus on industrialized countries to reduce emissions.	Minimizing Project contributions to greenhouse gas emissions.
Pollution Prevention		
International Convention for the Prevention of Pollution from Ships (1973) (as modified by the London Protocol of 1978) (MARPOL)	The convention requires member states to minimize the risk of marine pollution from ships, in particular, oil tankers.	Managing marine pipelaying vessel operations, ballast water disposal, shipping pollution and emergency plans for LNG carriers.
International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004)	All international sea going ships under the Convention must implement a 'Ballast water management plan' that enables the ship to manage their ballast water and sediment discharge to a certain standard.	Managing ballast water discharges from Project marine vessels, e.g. supply ships, construction vessels and service craft, to prevent the transfer of harmful aquatic organisms and pathogens.
The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) (1972)	The convention aims to control pollution of the sea by dumping and to encourage regional agreements supplementary to the convention. It covers the deliberate disposal at sea of wastes or other matter from vessels, aircraft and platforms.	Minimizing discharges to the marine environment from Project activities.
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989)	The convention's objective is to protect human health and the environment against the adverse effects of hazardous wastes, through encouraging reduced generation of hazardous wastes, environmentally sound waste management, and restriction and regulation of transboundary hazardous wastes movements.	Minimizing and managing hazardous wastes resulting from Project activities.
Convention to Ban the Importation into Forum Island Countries of Hazardous Wastes and Radioactive Wastes, and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region (Waigani Convention) (1995)	The convention aims to reduce and eliminate transboundary movements of hazardous and radioactive waste, to minimize the production of hazardous and toxic wastes in the Pacific region, and to ensure that disposal of wastes in the Convention area is completed in an environmentally sound manner.	Minimizing and managing the generation and transport of hazardous waste.

Table 2.4 – International Conventions (cont'd)

Title	Description/Objective	Relevance to the Project
Pollution Prevention (cont'd)		
Stockholm Convention on Persistent Organic Pollutants (POPs) (2001)	The convention aims to protect human health and the environment from a range of persistent organic pollutants (POPs), via requiring signatories to ban the production, use, import and export of these. The convention also requires waste management to reduce or eliminate releases of POPs into the environment.	Avoiding the use of POPs and minimize release to the environment.
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1992)	The convention provides compensation for pollution damage to the extent that the protection afforded by the 1969 Civil Liability Convention is inadequate.	Providing provisions for compensation to states or persons who suffer from pollution damage, if required.
Resource Use		
United Nations Convention on the Law of the Sea (UNCLOS) (1982)	The convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment and the management of marine natural resources.	Minimizing impacts to marine resources and the marine environment.
International Tropical Timber Agreement (ITTA) (Geneva, ITTA2 1994, ITTA3 2006).	The convention promotes the expansion and diversification of international trade in tropical timber from sustainably managed and legally harvested forests, and promotes the sustainable management of tropical timber-producing forests.	Managing access to the Project area to prevent illegal forestry.
Labor		
International Labor Organization conventions (1976 – 2000)	These conventions collectively provide protection to workers against anti-union discrimination and encourage collective bargaining. They aim to suppress the use of forced labor in all its forms, set a minimum age for employment and support action against child labor, encourage equal remuneration for men and women, and consider the rights of migrant workers.	Respecting worker's rights in employment of local and international workers.
UN Convention on the Rights of the Child, Article 32.1	This human rights convention sets out the civil, political, economic, social, health and cultural rights of children. The convention defines a child as any human being under the age of eighteen, unless the age of majority is attained earlier under a state's own domestic legislation.	
UN Convention on the Protection of the Rights of all Migrant Workers and Members of their Families	The convention takes into account the principles embodied in the basic instruments of the United Nations concerning human rights and those of the International Labor Organization. The convention defines a migrant worker as 'a person who is to be engaged, is engaged or has been engaged in a remunerated activity in a State of which he or she is not a national'.	

Table 2.4 – International Conventions (cont'd)

Title	Description/Objective	Relevance to the Project
Human and Civil Rights		
International Covenant on Civil and Political Rights (1966)	The covenant recognizes that the inherent dignity and the equal and inalienable rights of all members of the human family are the foundation of freedom, justice and peace in the world.	Providing opportunities for men and women from all races, backgrounds and abilities.
International Covenant on Economic, Social and Cultural Rights (1966)	The covenant commits its parties to work toward the granting of economic, social, and cultural rights to the Non-Self-Governing and Trust Territories, and individuals, including labor rights and the right to health, the right to education, and the right to an adequate standard of living.	Providing opportunities for men and women from all races, backgrounds and abilities are provided by the Project.
Convention on the Elimination of All Forms of Discrimination Against Woman (1979)	The convention takes an important place in bringing women into the focus of human rights concerns. The spirit of the convention is rooted in the goals of the United Nations.	
International Convention on the Elimination of All Forms of Racial Discrimination (1965)	The convention proclaims that everyone is entitled to all the rights and freedoms set out therein, without distinction of any kind, in particular as to race, color or national origin.	
Convention on the Rights of Persons with Disabilities (2006)	The convention is intended to protect the rights and dignity of persons with disabilities. Parties to the convention are required to promote, protect, and ensure the full enjoyment of human rights by persons with disabilities and ensure that they enjoy full equality under the law.	

2.4.2 Equator Principles and IFC Performance Standards

The Equator Principles (2013) comprise a risk management framework that financial institutions have adopted for determining, assessing and managing environmental and social risk in projects, and are primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making. They provide a means for financial institutions to ensure that the projects they finance are developed in a manner that is socially responsible and consistent with sound environmental management practices. Papua New Guinea is a non-designated country under the Equator Principles for which compliance with applicable IFC performance standards (IFC, 2012) and World Bank Group environmental, health and safety guidelines (IFC, 2007a) is required.

The IFC performance standards '…are designed to help avoid, mitigate, and manage risks and impacts (while also enhancing development opportunities) as a way of doing business in a sustainable way' (IFC, 2012). The performance standards apply to all clients seeking direct investment from the IFC and other international finance institutions also apply them.

The IFC performance standards address stakeholder engagement and disclosure obligations of the client in relation to project-level activities. In the case of IFC's direct investments (including project and corporate finance provided through financial intermediaries), IFC requires its clients to apply the performance standards to manage environmental and social risks and impacts so that development opportunities are enhanced.

The standards are:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts.
- Performance Standard 2: Labor and Working Conditions.
- Performance Standard 3: Resource Efficiency and Pollution Prevention.
- Performance Standard 4: Community Health, Safety, and Security.
- Performance Standard 5: Land Acquisition and Involuntary Resettlement.
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources.
- Performance Standard 7: Indigenous Peoples.
- Performance Standard 8: Cultural Heritage.

The IFC performance standards are supplemented by environmental, health and safety guidelines, known as the EHS Guidelines, that provide performance levels and criteria for general and industry-specific good international industry practice, specifically in relation to management of EHS risks or issues that may arise due to certain project activities.

The World Bank Group, of which IFC is one of five member organizations, requires borrowers or clients to apply the relevant levels or measures of the EHS Guidelines. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are required to achieve whichever is more stringent.

The EHS guidelines provide, for example, criteria for acceptable air quality emissions, noise levels and drinking water quality. See Table 2.5 for EHS Guidelines that are likely to be relevant to the Project. Some of those draw on World Health Organization guidelines, also referred to in Table 2.5 where relevant.

Table 2.5 – Relevant IFC General and Industry-specific EHS and Other Guidelines

IFC Guideline	Description
General EHS Guidelines (IFC, 2007a)	♦ Environmental (2007). ♦ Community Health and Safety (2007). ♦ Construction and Decommissioning (2007).
Industry-specific EHS Guidelines	♦ Shipping (IFC, 2007b). ♦ Waste Management Facilities (IFC, 2007c). ♦ Water and Sanitation (IFC, 2007d). ♦ Onshore Oil and Gas Development (IFC, 2007e). ♦ Offshore Oil and Gas Development (IFC, 2015). ♦ Ports, Harbors, and Terminals (IFC, 2017). ♦ Construction Materials Extraction (IFC, 2007f). ♦ Telecommunications (IFC, 2007g).
Other Guidelines	♦ Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (IFC, 2013). ♦ Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets (IFC, 2007h). ♦ Good Practice Note: Addressing the Social Dimensions of Private Sector Projects (IFC, 2003). ♦ Projects and People: A Handbook for Addressing Project-Induced In-Migration (IFC, 2009a).

Table 2.5 – Relevant IFC General and Industry-specific EHS and Other Guidelines (cont'd)

Other Guidelines (cont'd)	♦ Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (IFC, 2013). ♦ Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets (IFC, 2007h). ♦ Good Practice Note: Addressing the Social Dimensions of Private Sector Projects (IFC, 2003). ♦ Projects and People: A Handbook for Addressing Project-Induced In-Migration (IFC, 2009a). ♦ Addressing Grievances from Project Affected Communities (IFC, 2009b) ♦ UN Guiding Principles on Business and Human Rights and IFC Sustainability Framework (UN, 2012). ♦ Air quality guidelines (WHO, 2005). ♦ Guidelines for community noise (WHO, 1999). ♦ Guidelines for drinking water quality (WHO, 2017).

2.4.3 Other Guidelines

Good international industry practice guidelines also relevant to the EIS include:

- Biodiversity and ecosystem services fundamentals. Guidance documents for the oil and gas industry (IPIECA, 2016).
- Oil spill preparedness and response guidelines (IPIECA, 2015a and b).
- Integrating Human Rights into Environmental, Social and Health Impact Assessments: A Practical Guide for the Oil and Gas Industry (IPIECA and DIHR, 2013).
- A Guide to Social Impact Assessment in the Oil and Gas Industry (IPIECA, 2004).
- Health Impact Assessment: A guide for the oil and gas industry (IPIECA and IOGP, 2016).
- Human Rights Due Diligence Process: A practical guide to implementation for oil and gas companies (IPIECA, 2012a).
- Indigenous Peoples and the Oil and Gas Industry: Context, Issues and Emerging Good Practice (IPIECA, 2012b).

2.5 TEP PNG Standards and Specifications

TEP PNG is the proponent of this EIS. TOTAL, as TEP PNG's ultimate parent company, sets high corporate social responsibility standards for itself, its affiliates, its suppliers and contractors, and accordingly has taken a set of commitments, developed standards and specifications:

- TOTAL Group Code of Conduct (TOTAL, 2018), further elaborated under:
  - TOTAL Group Guide on Human Rights (TOTAL, 2015).
  - TOTAL Charter of Principles and Guidelines Regarding Indigenous and Tribal Peoples (CH-GR-SBS-001).
- TOTAL Fundamental Principles of Purchasing (TOTAL, 2016).
- TOTAL Safety Health Environment Quality Charter (TOTAL, 2014).
- Integrating Climate into TOTAL's strategy (TOTAL, 2018).
- TOTAL and Biodiversity, Commitments and actions (TOTAL, 2018).

TOTAL standards and specifications, based upon the good international industry practice referred to in Section 2.4, which have underpinned the Project design and EIS process, include:

- TOTAL General Specification: Environmental Requirements for Project Design and E&P Activities (GS EP ENV 001).
- TOTAL General Specification: Environmental specification for onshore pipeline construction (GS EP ENV 011).
- TOTAL General Specification: Environmental Baseline and Monitoring Studies: Onshore Sites (GS EP ENV 111).
- TOTAL General Specification: Environmental Baseline and Monitoring Studies: Offshore and Nearshore Sites (GS EP ENV 112).
- TOTAL General Specification: Environmental Impact Assessment of E&P Activities (GS EP ENV 120).
- TOTAL General Specification: Social Baseline Study (GS EP SDV 101).
- TOTAL General Specification: Social Impact Assessment (GS EP SDV 102).

  TOTAL General Specification: Human Rights Impact Assessment (GS EP SDV 103).
- TOTAL General Specification, Landfill design and operation for E&P sites (GS EP SDV 421).
- TOTAL General Specification, Hygiene on onshore bases and offshore living quarters (GS EP MED 062).
- TOTAL General Specification, Temporary construction camps and associated facilities (onshore) (GS EP CIV 403).
- TOTAL General Specification, Onshore permanent accommodation base and associated facilities (GS EP CIV 407).

In line with TOTAL’s commitments, TEP PNG has a non-compromising attitude towards health, safety and environment. TEP PNG also places its societal commitment at the core of its responsibility as an industrial operator.

The related commitments have been detailed in the following documents (Attachment 2.1):

- TEP PNG Health Safety and Environment Charter (L0-CHT-MAN-01-R0).
- TEP PNG Biodiversity and Ecosystem Services Charter (L0-CHT-MAN-02-R0).
- TEP PNG Societal Policy (L1–POL–MAN–05-R0).

2.6 References

DEC. 1997. Environmental Code of Practice for PNG Vehicle & Machinery Workshops Petroleum Storage, Resale and Usage Sites. PNG Department of Environment and Conservation, Port Moresby.

DEC. 2001. Environmental Code of Practice for Sanitary Landfill Sites. PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004a. Guideline for Preparation of Environmental Inception Report (GL-ENV/01/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004b. Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (GL-ENV/02/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004c. Technical Guideline (Additional Information): Air Discharges (IB-ENV/02/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004d. Technical Guideline (Additional Information): Noise Discharges (IB-ENV/03/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004e. Technical Guidelines (Additional Information): Water and Land Discharges (IB-ENV/04/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004f. Guideline for Submission of an application for an environment permit to discharge waste (GL-ENV/03/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2009. Draft Environmental Guideline for Sewerage Treatment and Disposal. Volume No. 1. PNG Department of Environment and Conservation, Port Moresby.

Equator Principles Association. 2013. The Equator Principles. A WWW publication accessed on 21 February 2019 at https://equator-principles.com/.

IFC. 2003. Good Practice Note Addressing the Social Dimensions of Private Sector Projects. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007a. Environmental, Health and Safety General Guidelines. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007b. Environmental, Health and Safety Guidelines. Shipping. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007c. Environmental, Health and Safety Guidelines for Waste Management Facilities. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007d. Environmental, Health and Safety Guidelines. Water and Sanitation. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007e. Environmental, Health and Safety Guidelines for Onshore Oil and Gas Development. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007f. Environmental, Health and Safety Guidelines. Construction Materials Extraction. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007g. Environmental, Health and Safety Guidelines for Telecommunications. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2007h. Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2009a. Projects and People: A Handbook for Addressing Project-Induced In-Migration. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2009b. Good Practice Note Addressing Grievances from Project-Affected Communities. Guidance for Projects and Companies on Designing Grievance Mechanisms. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2012. Performance Standards on Environmental and Social Sustainability. International Finance Corporation, World Bank Group, Washington, D.C. IFC. 2013. Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private

Sector in Emerging Markets. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2015. Environmental, Health and Safety Guidelines. Offshore Oil and Gas Development. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2017. Environmental, Health and Safety Guidelines. Ports, Harbours and Terminals. International Finance Corporation, World Bank Group, Washington, D.C.

IMO. 1973. International Convention for the Prevention of Pollution from Ships as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997. International Maritime Organization, London, United Kingdom.

IMO. 2001. International Convention on the Control of Harmful Anti-fouling Systems on Ships. International Maritime Organization, London, United Kingdom.

IMO. 2004. International Convention for the Control and Management of Ships' Ballast Water and Sediments. International Maritime Organization, London, United Kingdom.

IPIECA. 2004. A Guide to Social Impact Assessment in the Oil and Gas Industry. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.

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IPIECA. 2012b. Indigenous Peoples and the Oil and Gas Industry: Context, Issues and Emerging Good Practice. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.

IPIECA. 2015a. Tiered preparedness and response: Good practice guidelines for using the tiered preparedness and response framework. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.

IPIECA. 2015b. Response strategy development using net environmental benefit analysis (NEBA): Good practice guidelines for using the tiered preparedness and response framework. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.

IPIECA. 2016. Biodiversity and ecosystem services fundamentals: Guidance document for the oil and gas industry. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.

IPIECA and DIHR. 2013. Integrating Human Rights into Environmental, Social and Health Impact Assessments: A Practical Guide for the Oil and Gas Industry. International Petroleum Industry Environmental Conservation Association (London) and The Danish Institute for Human Rights (Copenhagen).

IPIECA and IOGP. 2016. Health Impact Assessment. A guide for the oil and gas industry. International Petroleum Industry Environmental Conservation Association and The International Association of Oil & Gas Producers, London, United Kingdom.

UN. 2012. Guiding principles on business and human rights. Implementing the United Nations 'Protect, Respect and Remedy' framework. United Nations Human Rights, Office of the High Commissioner. United Nations, New York and Geneva.

WHO, 1999. Guidelines for Community Noise. World Health Organization (WHO), Geneva.

WHO. 2005. Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide – Global Update 2005. World Health Organization. Copenhagen, Denmark.

WHO. 2017. World Health Organization. Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First Addendum. Geneva.

Attachment 2.1
TEP PNG Health, Safety and Environment Charter, Biodiversity and Ecosystem Services Charter, and Societal Policy

TOTAL E&P PNG LIMITED

HEALTH, SAFETY AND ENVIRONMENT CHARTER

THE TOTAL GROUP AND TOTAL E&P PNG LIMITED HAVE A NON-COMPROMISING ATTITUDE TOWARDS HEALTH, SAFETY AND ENVIRONMENT.
WE ARE THEREFORE COMMITTED TO:

- **HEALTH AND SAFETY OF PERSONNEL.**
- **ENVIRONMENTAL PROTECTION.**

…………………………………………………………………………………….

As a Papua New Guinean company, we shall fulfil our commitment to the nation working in a transparent and open manner with all stakeholders to continuously improve HSE for all.

We consider that a high standard of HSE performance by everyone working for or with us is critical to the success of our business. Accordingly, we expect our suppliers and partners to share and enforce our values and goals.

TO DEVELOP A STRONG HSE CULTURE, WE ARE DETERMINED TO FOSTER:

- Transparency and communication within the company and with the authorities, our partners, and our stakeholders.
- Management's leadership through exemplarity.
- Active supervision of all HSE matters promoting HSE as a core value of our business.
- Commitment from all personnel to our 12 'Golden Rules', 'Stop Card' and 'One-MAESTRO HSE Principles'.
- Vigilance and professionalism of everyone at all times.

October 2018

Jean-Marc Noiray
Managing Director

IN ORDER TO ACHIEVE OUR STANDARDS WE SHALL, IN ALL OUR ACTIVITIES:

- Develop ambitious, measurable HSE objectives and key performance indicators as a means of measuring and improving our performance.
- Maintain a culture in which each person is clearly aware of his or her own responsibility in HSE matters, and acts in accordance to our Golden Rules.
- Commit ourselves to an open, honest and long-term dialogue with our stakeholders.
- Comply with National Acts and Regulations and with Total group policies.
- Perform appropriate HSE assessments in order to identify, minimise and manage the risks to personnel, the environment and assets.
- Plan and supervise the execution of all our activities considering HSE as a paramount priority.
- Protect the environment (forest, land, sea, ecosystems…) in all our operations and prevent pollution.
- Promote the selection of industrial and business partners on the basis of their internal HSE Management System and their ability to comply with our HSE policy.
- Maintain and develop the competencies of our personnel through appropriate trainings.
- Ensure effective preparedness for any emergency situation.
- Maintain a high level of reporting and analysis for every anomaly and incident that may occur, in order to implement corrective actions.
- Continuously improve our management system through regular monitoring, audits and inspections, and ensure its implementation.

…………………………………………………………………………………….

In order for everyone to share a strong HSE culture within Total E&P PNG limited, the involvement, the vigilance and exemplarity of each one are required.

Yumi olgeta mas wok bung wantaim sapos yumi laik gat strongpela pasin bilong HSE insait long Total E&P PNG Limited.

TOTAL

TOTAL E&P PNG LIMITED

BIODIVERSITY and ECOSYSTEM SERVICES CHARTER

Commitment

Total E&P PNG Limited (TEP PNG), as operator of the Papua LNG Project (the "Project"), recognises that it is operating in an area of high biodiversity and ecosystem services ("BES") values. TEP PNG shall endeavour to safeguard these values for the long term, and is seeking to achieve a **No Net Loss of Natural Habitat** and a **Net Positive Impact on Critical Habitat**-qualifying biodiversity. TEP PNG will comply with all national legislation, align with International Finance Corporation ("IFC") Performance Standards, and follow Total group's *Code of Conduct*, *Safety Health Environment and Quality Charter* and *Biodiversity Policy* in operating the Project. TEP PNG's ambition is to be recognised as a leading operator in Papua New Guinea for its management of the Project's impacts on BES values.

Approach

TEP PNG will plan and conduct all of its Project onshore and offshore activities in alignment with IFC Performance Standards requirements, in particular following the **Mitigation Hierarchy** to:

- **Avoid** impacts to BES values wherever feasible;
- **Minimise** any unavoidable impacts on BES values;
- **Restore** or **rehabilitate** impacts on BES values;
- **Offset** any unavoidable significant residual impacts on BES values; and
- **Improve the knowledge** of BES by supporting research initiatives.

TEP PNG will partner with local and international experts throughout the Project to maximise opportunities for stakeholders' participation and input.

Implementation, monitoring and reporting

TEP PNG will follow the above approach throughout the Project life cycle and, for any offsets, as long as Project impacts remain. TEP PNG will develop this approach in a Project BES Strategy, which will be implemented through a Biodiversity Action Plan that is integrated into the Company's Environmental and Social Management System.

March 2019

Jean-Marc Noiray

Managing Director

Total E&P PNG Limited
SOCIETAL POLICY

Ambition

While respecting the laws and regulations of Papua New Guinea, Total group values and international standards, Total E&P PNG Limited ("TEP PNG") ambition is to act and be recognized as:

- An industrial operator with a strategy centered on respect, listening, dialogue and stakeholder involvement;
- An accountable operator exemplary in its management of impacts related to its activities;
- A partner in the sustainable social and economic development of its host Local Communities and Papua New Guinea;
- A company that is setting the benchmark for the promotion of access to energy.

Commitments and undertaking

Stakeholders and Local Communities

TEP PNG commits to developing transparent and constructive relationships with its stakeholders.

TEP PNG will act as a good neighbour and strive to understand and respect local communities' rights, traditions, customs, culture and dignity while conducting its operations in a safe and environmentally responsible manner.

TEP PNG will work closely with local stakeholders to ensure early, regular and Informed Participation, through an on-going presence in communities. Local communities' and landowners' consent is to be pursued through Good Faith Negotiation: key components thereof being informed consultation and participation of potentially affected people and the obtaining of free, prior and informed consent of directly affected communities.

Impacts Management

TEP PNG commits to limiting the negative socio-economic impacts of its operations within its Area of Influence, and will design such activities with a view:

- to avoiding the likelihood that they will have significant adverse impacts on directly affected communities;
- and, when it is not possible to avoid such impacts, to minimising, mitigating and compensating for any unavoidable impacts, in consultation with affected communities and people through appropriate Information Disclosure.

Socio-economic Development

TEP PNG shall contribute to the socio-economic development of the people of its Area of Influence in particular and of Papua New Guinea in general.

As a partner in the sustainable social and economic development of host communities, TEP PNG seeks to act as a catalyst, maximising the positive impacts of its presence by:

- Preferably recruiting locally and relying on national and local contractors to the extent compatible with its operational constraints;
- Developing training programs and providing support to small and medium enterprises and other key economic actors;
- Contributing to human development by reinforcing the health and education of directly affected communities and vulnerable people, and strengthening local skills and capacities;
- Promoting the value of the historical, natural and cultural heritage of Local Communities and Papua New Guinea;
- In all its development initiatives, TEP PNG wishes to promote partnership with stakeholders including civil society, international organisations, national, provincial and district administrations and authorities.

May 2016

Philippe Blanchard

Managing Director

TOTAL E&P PNG LIMITED

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 3: Impact Assessment Process and Methods

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

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Chapter

Tables

Figures

3. Impact Assessment Process and Method

This chapter describes the impact assessment process and methods used to characterize and assess the environmental and social impacts of the Papua LNG Project (the Project). The assessment of the Project's potential impacts is intended both to satisfy PNG regulatory requirements for the preparation of an environmental impact statement (EIS) under the *Environment Act 2000*, which is necessary to obtain an environment permit for the Project, and to align with International Finance Corporation (IFC) performance standards and guidelines, and TOTAL general specifications. These requirements are described in detail in Chapter 2.

IFC performance standards and guidelines require a comprehensive, full-scale environmental and social impact assessment (ESIA) for greenfield projects and for projects that are likely to generate significant adverse environmental and social risks and impacts. This chapter describes the main stages in the ESIA process, including the impact assessment methods used in this report (Section 3.1), the approaches used to assess impacts associated with potential major hazards/unplanned events (Section 3.1.4.5), and cumulative impacts (Section 3.1.4.6). Section 3.2 outlines the adaptive impact assessment and management process as the Project design evolves from FEED into detailed design and execution.

3.1 ESIA Process Overview

Figure 3.1 shows the main stages of the ESIA process that have been implemented to prepare this EIS, which are:

- Screening of environmental and social values, and potential impacts, at a high level.
- Scoping and defining the Project area of influence (PAOI) and study area. This includes an analysis of alternatives.
- Characterizing the baseline environmental and social setting.
- Impact assessment, including identifying potential Project impacts, determining mitigation measures, and assessing the significance of residual impacts. The impact assessment includes evaluating potential cumulative impacts.
- Reporting of the ESIA process (this report) to align with PNG regulatory requirements and IFC standards, including definition of the Project's proposed environmental and social management framework implemented to manage, monitor and report on the Project's performance in the future (Chapter 19).

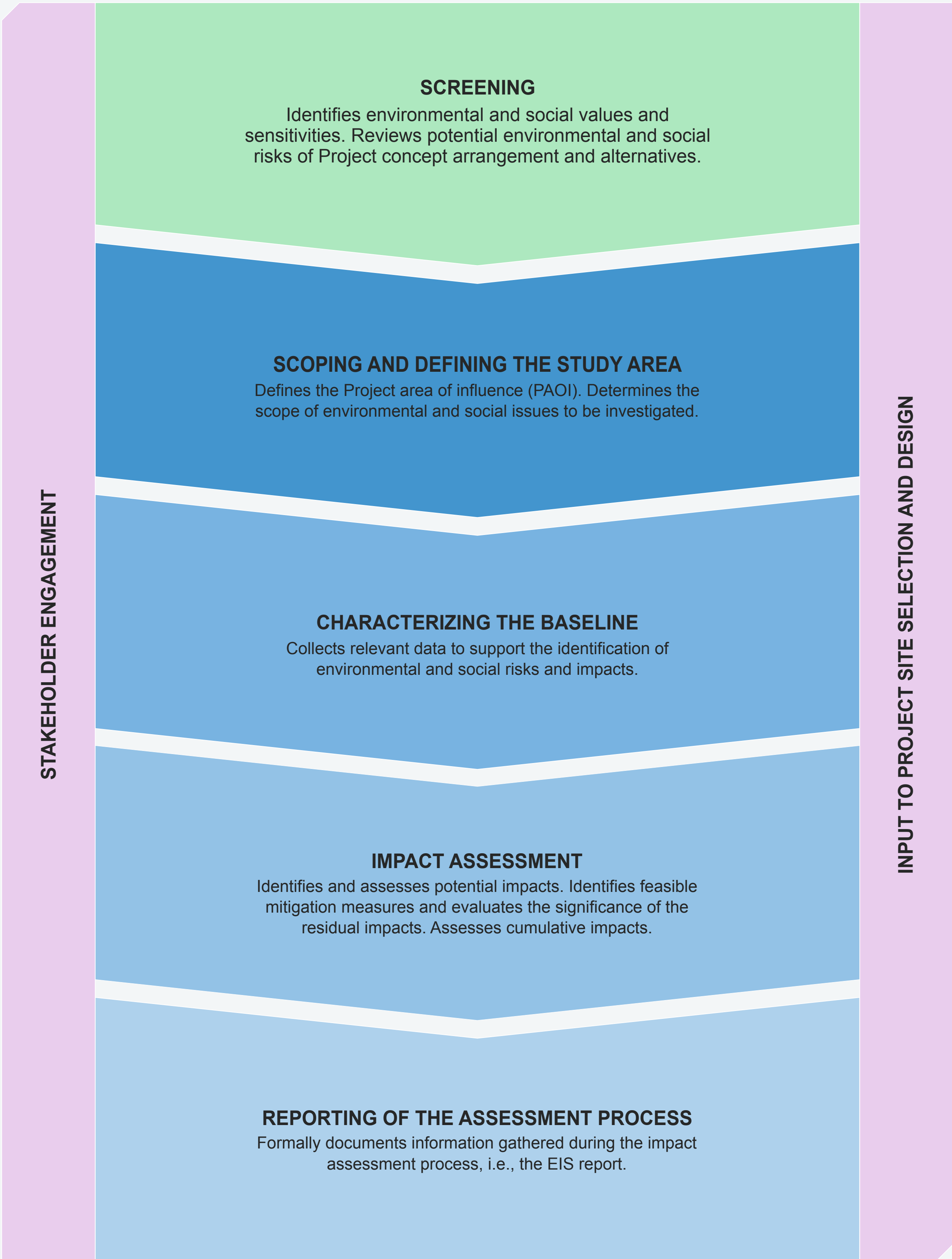
As illustrated in Figure 3.1, stakeholder engagement is necessary throughout the ESIA process, as is ongoing communication with Project design engineers, to allow meaningful exchange of information on potential impacts and proposed mitigation to take place during the ESIA process. Chapter 6 discusses the stakeholder engagement process for ESIA and as an ongoing process for the Project.

Project-specific activities undertaken in the main stages of the ESIA process are described in the following sections.

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT PROCESS

Papua LNG Project | Environmental Impact Statement

FIGURE 3.1



EIS Environmental impact statement

ERIAS Group | 01215B_23_F3.1_v3

3.1.1 Screening

Identifying potential environmental and social values, sensitivities and constraints, and screening potential impacts is an essential initial stage in the ESIA process. Between 2014 and 2015, TEP PNG undertook a comprehensive societal and environmental screening study of the Project's early conceptual design, including alternative site locations for key process and infrastructure components.

The screening study involved:

- A desktop study, including a bibliographic review of available information, such as published scientific, social, legal and government agency data, relevant to the Project design and site alternatives.
- A field reconnaissance survey to verify or update the findings of the desktop study through on-site observations and preliminary stakeholder engagement. TEP PNG Project personnel and leading environmental and social specialists completed this field survey.

The screening study identified at a high level the Project area's key environmental and social values, and sensitivities and constraints in relation to the initial Project design and alternative sites for key facilities. This study informed TEP PNG decisions on the siting of the central processing facility (CPF) and the alignment of the export pipeline corridor, including the final kilometers of the onshore approach to Orokolo Bay. Chapter 5 describes alternatives for the CPF site and export pipeline corridor.

The information collected during the screening phase contributed to the identification of key environmental and societal values at risk of adverse impacts from Project development. This information was used to scope and plan the subsequent detailed baseline studies for the Project impact assessment.

3.1.2 Scoping and Defining the Study Area

The focus of the scoping phase was to identify the potential environmental and social issues to be investigated during the Project impact assessment and to establish the terms of reference for that process.

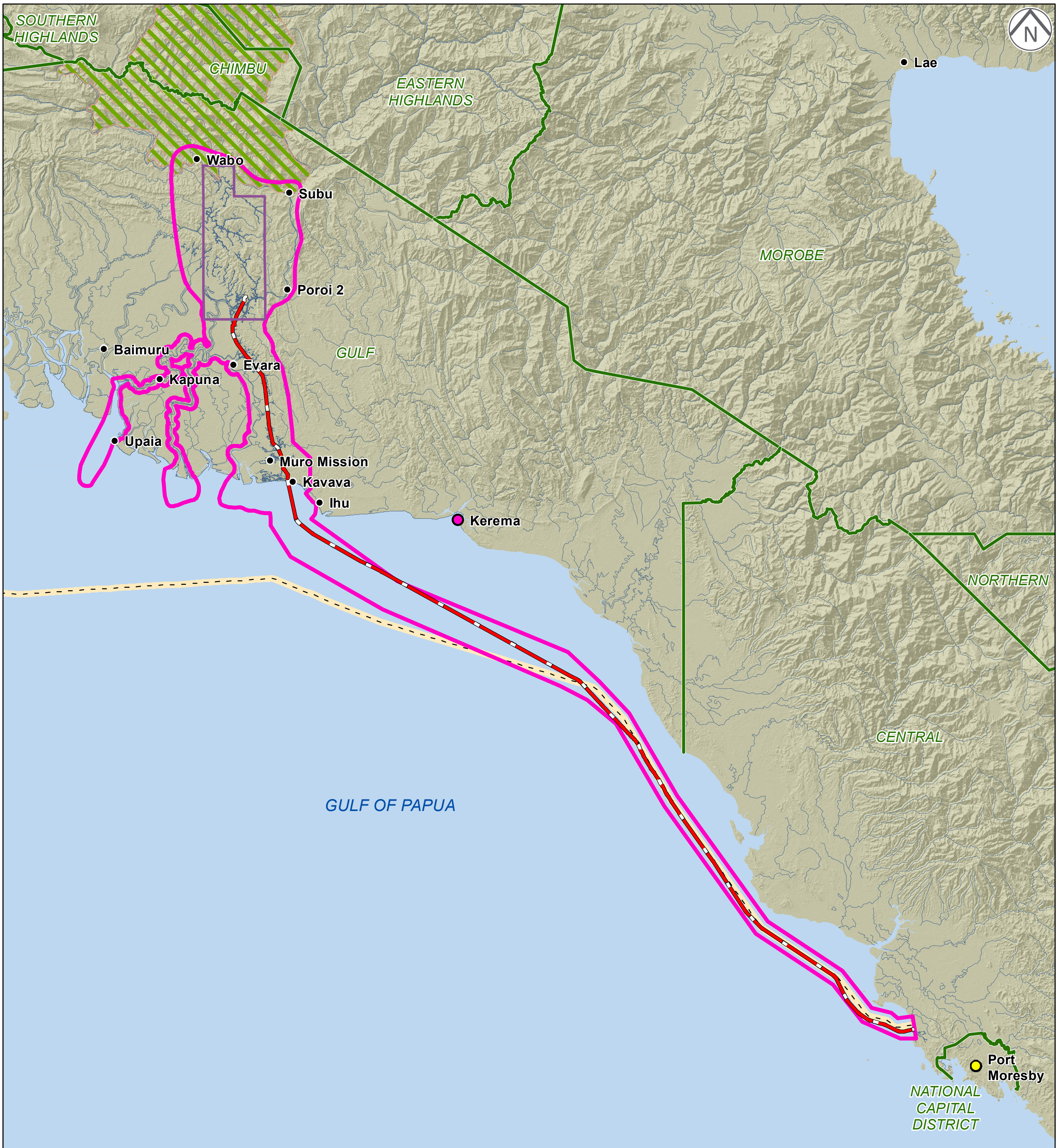
A fundamental element in the scoping phase was to define the extent of the impact assessment study area. In this regard, the EIS has been guided by the IFC Performance Standard 1 (IFC PS1) (IFC, 2012) definition of the 'project area of influence' (PAOI), which is the area that is likely to be affected by the Project, by its activities and by facilities that are directly owned, operated or managed by the upstream Project. This definition includes direct, indirect (or induced), predictable but unplanned, and cumulative impacts arising from the Project.

The PAOI definition considered environmental and social criteria, such as terrain features, land and vegetation type, and the affected communities' occupation and use of the land and natural resources, and the potential impacts to these values arising from Project development. Figure 3.2 shows the PAOI that was used to guide the ESBS. Although not shown in the figure, the PAOI also includes the marine transport route between Caution Bay and the upstream riverways route to PRL-15, Project associated developments and activities such as quarries, logistical wharfs/terminals not operated by the Project, and considers the potential for induced in-migration (and associated implications). As depicted, the PAOI considers potential social and environmental impacts of the Project's logistics transport routes in the Purari delta, the upstream gasfield development and CPF within PRL-15 and the export pipeline corridor.

PROJECT AREA OF INFLUENCE

Papua LNG Project | Environmental Impact Statement

FIGURE 3.2



SCALE: 1:1,750,000 @ A4

0 12.5 25 50 75 km

COORDINATE SYSTEM: PNG94 UTM Zone 55S

Capital city

Provincial capital included in the Project area of influence

Town or village

Province boundary

Waterway

PRL-15

Export pipeline route

PNG LNG Gas Pipeline

Project area of influence

Crater Mountain Wildlife Management Area

01215B_23_Ch03_GIS001_v0_5

The PAOI, as defined, is conceptual and remains dynamic, as greater definition of or changes to the Project design may alter the PAOI. For example, as the Project definition is refined and alternative sites are eliminated from consideration in the design basis, the spatial extent of the PAOI may decrease.

The PAOI was used to define the study areas for each impact assessment discipline. Secondary data sources and the characteristics specific to the discipline were used to inform study area selection and to appropriately characterize the area most likely to be affected by the Project. The study area for all disciplines either correlated with or was in the PAOI. The PAOI is referred to in the baseline environmental and social chapters of this report (i.e., Chapters 7 to 10) as appropriate.

The scoping phase of the impact assessment provided the information to:

- Prepare the Environmental Inception Report (EIR) (ERIAS Group, 2016[1]) used to obtain the Conservation and Environment Protection Authority's (CEPA's) approval to undertake the proposed environmental and social baseline studies as part of the formal EIS process. Section 2.2 describes the regulatory requirements of the EIS environmental permitting in detail.
- Design, plan and undertake the detailed environmental and social baseline studies, including the data collection method, e.g., using desktop study reviews and field surveys. Part 23 of Volume 2 collates the detailed method for each discipline study.

3.1.3 Characterizing the Baseline

The baseline data collection stage characterized the existing values and conditions of the receiving physical, biological, and social environments of the Project area, thus the risks and impacts identified and assessed were based on recent environmental and social baseline data at an appropriate level of detail.

The main objectives of the baseline characterization phase were to:

- Describe the existing environmental and social conditions in the Project area using desktop studies and field surveys.
- Provide information and data to comprehensively identify and support the assessment of potential Project-related impacts.
- Identify pre-existing sensitivities and values, including potentially sensitive receptors, Project-affected persons and Project-affected communities, in the Project area that may constrain or that require consideration in Project development.
- Inform Project design at an early stage.

The baseline characterization field survey program was undertaken over 13 months from January 2016 to February 2017 when 12 surveys campaigns were completed. Twenty-two technical baseline studies and one additional report that collates the field survey scope and methods, which are presented in Volume 2 of the EIS, were completed to establish existing conditions and characterize the environmental and social settings of the Project area (Table 3.1).

1 The EIR was updated and submitted to CEPA in July 2019 (see Chapter 1).

Table 3.1 – Baseline Reports and Associated Part Number

ESBS Discipline	Report Name	Report Author	Vol. 2
Geology, terrain and soils	Upstream Geology, Terrain and Soils Baseline Report	SLR Consulting Australia Pty Ltd	Part 1
Hydrology and meteorology	Upstream Hydrology and Meteorology Baseline Report	BMT WBM Pty Ltd	Part 2
Surface water and sediment quality	Upstream Surface Water and Sediment Quality Baseline Report	BMT WBM Pty Ltd	Part 3
Groundwater	Upstream Groundwater Baseline Report	SLR Consulting Australia Pty Ltd	Part 4
Freshwater and estuarine	Upstream Freshwater and Estuarine Biodiversity Baseline Report	BMT WBM Pty Ltd	Part 5
Terrestrial biodiversity	Upstream Terrestrial Biodiversity Baseline Report	ERIAS Group	Part 6
Deforestation	Upstream Deforestation Baseline Report	Booyong Forest Science PNG Pty Ltd	Part 7
Vegetation regeneration	Upstream Vegetation Regeneration Baseline Report	Booyong Forest Science PNG Pty Ltd	Part 8
Seabed and coastal geomorphology	Seabed and Coastal Geomorphology Baseline Report	BMT WBM Pty Ltd	Part 9
Physical oceanography	Physical Oceanography Baseline Report	BMT WBM Pty Ltd	Part 10
Marine water and sediment quality	Marine Water and Sediment Quality Baseline Report	BMT WBM Pty Ltd	Part 11
Marine biodiversity	Marine Biodiversity Baseline Report	BMT WBM Pty Ltd	Part 12
Marine fisheries and resources	Marine Fisheries and Resources Baseline Report	ERIAS Group	Part 13
Community and demographics	Upstream Community and Demographics Baseline Report	SIA & Development	Part 14
Governance and economics	Upstream Governance and Economics Baseline Report	SIA & Development	Part 15
Community health	Upstream Community Health Baseline Report	NewFields Companies, LLC	Part 16
Cultural heritage and archaeology	Upstream Cultural Heritage and Archaeology Baseline Report	Dr Robert Skelly in collaboration with Social Research Institute	Part 17
Land and natural resources	Upstream Land and Natural Resources Baseline Report	Booyong Forest Science PNG Pty Ltd	Part 18
Air quality	Upstream Air Quality Baseline Report	SLR Consulting Australia Pty Ltd	Part 19
Noise	Upstream Noise Baseline Report	SLR Consulting Australia Pty Ltd	Part 20
Visual amenity	Upstream Landscape and Visual Amenity Baseline Report	SLR Consulting Australia Pty Ltd	Part 21
Marine and river traffic and transport	Marine and River Traffic and Transport Baseline Report	EnviroGulf Consulting	Part 22
All (except hydrology and meteorology, physical oceanography, air quality and visual amenity)	Field Survey Scope and Methods Documents	As above	Part 23

Extensive community consultation and stakeholder engagement occurred during the baseline studies to alert Project-affected communities about the conduct of baseline surveys and as part of the social and cultural heritage surveys themselves. Chapter 6 describes stakeholder engagement activities for the EIS.

3.1.4 Impact Assessment Methods

3.1.4.1 Identification of Potential Impacts

The identification of potentially significant impacts arising from proposed Project-related activities includes:

- Identifying the potential impact resulting from the Project.
- Predicting and analyzing the resulting changes to the environmental and social values identified in the baseline characterization phase.

The impact identification process systematically considered all the Project's spatial components and the timing of changes that may have an impact on the environment or that present potential hazards, taking into account the existing environment, as characterized during the baseline studies. This assessment identified only the potential impacts of credible scenarios and considered all Project development phases (i.e., construction (including early works), operations and decommissioning) for the Project described in Chapter 4.

The assessment has addressed the impacts associated with the export pipeline route, TEP PNG, however, is seeking approval for a 4-km-wide pipeline construction corridor, i.e., 2 km either side of the pipeline route centerline to allow for minor tactical realignments to avoid yet unknown environmental and social sensitivities (e.g., chance finds) that may be encountered during preconstruction surveys, and during construction, and also to achieve optimal design constructability. The baseline environmental and social studies include this corridor as it is within the PAOI.

3.1.4.2 Assessing Potential Impacts

The following impact assessment methods have been applied in this EIS:

- Compliance standard assessment for predicted impacts where appropriate quantitative criteria and guidelines exist against which to evaluate risk, e.g., air quality, noise, water quality.
- Significance assessment for expected impacts where quantitative assessment criteria do not exist.
- Assessment of unplanned, accidental or abnormal impacts.

The sections below present the impact assessment methods, with discipline-specific approaches presented in applicable sections of the impact assessment chapters (Chapters 11 to 16) of this report.

Compliance Standard Assessment Method

Impacts associated with Project activities, such as air quality emissions, surface water in waterbodies receiving wastewater discharges and ambient noise levels, can be readily evaluated by a quantitative assessment and comparison with objective, quantitative criteria, guidelines or standards. This approach has been adopted for the assessment of predicted Project-derived emissions where such values or thresholds exist. Predicted Project-derived emissions have been modeled considering the implementation of technically and commercially feasible mitigation measures and the results evaluated by comparison with relevant established PNG, International

Finance Corporation, World Health Organization or other international or good industry practice criteria, guidelines or standards (see EIS Volume 3 Technical Studies).

Significance Assessment Method

The significance assessment method was adopted where a qualitative assessment was required. This method allows the most suitable and practicable mitigation measures to be developed, as it focuses on credible impacts with a likelihood of occurring and impacts of particular concern to stakeholders. Residual impacts have been assessed by considering both the magnitude of the impact after the successful application of impact avoidance or management measures (Section 3.1.4.3) and the sensitivity of the value being impacted. While the definitions of the various magnitude and sensitivity categories are, to some degree, subjective, the use of a matrix provides an element of transparency that may otherwise be absent from qualitative impact assessments.

Magnitude of Impact

The criteria used to define the magnitude of an impact reflect the size and nature of the change based on several elements:

- Impact nature: whether the change from the existing condition due to the impact is positive or negative.
- Impact type: the direct, indirect, induced and cumulative effects of the impact, where:
  - Direct impacts: impacts that result from primary planned interactions between a planned Project activity and environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity.
  - Indirect impacts: impacts that are subsequent to the primary planned interactions between the Project and its environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity with subsequent impact on health of fish species and economic livelihood of fishing dependent villagers.
  - Induced impacts: successive impacts that have no direct relationship to a planned Project activity, but may nonetheless result from flow on activities associated with the Project, e.g., in-migration, increased hunting.
- Severity: the scale or degree of positive or negative change from the existing condition due to the impact.
- Geographical extent: the spatial extent of the impact where this is defined as site (which may be localized to all, parts or a part of the site), local, regional or widespread (e.g., provincial, national or trans-boundary).
- Duration: the timescale of the effect, such as short, medium or long term (i.e., effectively permanent), and whether the impact is reversible or irreversible.

Magnitude has been categorized as very high, high, medium, low, minimal and positive (where applicable) (Table 3.2) and the discipline-specific magnitudes are defined in applicable sections of the impact assessment chapters (Chapters 11 to 16) of this report.

Sensitivity of Value

The criteria used to define the sensitivity of a value has been determined based on a range of factors:

- Formal status, which may be assigned by statutory or regulatory authorities or by appropriately recognized national or international organizations. This can involve legislation, regulations or international conventions or other mechanisms that attribute a particular status to a value.
- Rarity or uniqueness in and beyond the immediate area of interest, i.e., its vulnerability, and the capacity for the value to be replaced.
- Capacity to adapt to change without adverse effects on the value's inherent attributes, i.e., its resilience.
- Importance to local communities and society, and its iconic or symbolic importance to cultural value systems.

Sensitivity has been ranked as very high, high, medium, low or minimal (Table 3.2) and the discipline-specific sensitivities are defined in applicable sections of the impact assessment chapters (Chapters 11 to 16) of this report.

Impact Significance

The significance of an impact on a value is determined by combining the likely magnitude of the impact on that value with its sensitivity via a matrix based on discipline-defined criteria. This approach is shown in Table 3.2.

Table 3.2 – Significance Assessment Matrix

Magnitude of Impact	Sensitivity of Value				
	Very High	High	Medium	Low	Minimal
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible
Positive	Positive	Positive	Positive	Positive	Positive

The magnitude of an impact is assessed after the application of mitigation and management measures (see Section 3.1.4.3) such as, avoidance and minimization that are expected to change the impact's severity, geographical extent or duration. The magnitude of an impact is combined with the value's sensitivity, which generally remains unaltered unless proposed actions or activities reduce the susceptibility of that value to adverse effects. This approach assesses the significance of the residual impacts, i.e., the credible impacts associated with project development, assuming that embedded design controls (Section 3.1.4.3) and mitigation and management measures are effectively applied. The result is a significance rating for the residual impact.

In this EIS, an initial assessment of potential impacts has been undertaken without consideration of the embedded design controls and mitigation measures for the social and cultural heritage disciplines in addition to the residual impact assessment (Chapters 13 and 14).

3.1.4.3 Impact Mitigation

A basic step in an impact assessment process is identifying measures that a project will take to mitigate its impacts.

Mitigation measures have been applied to potential impacts by implementing the mitigation hierarchy in accordance with relevant PNG legislative requirements and in accordance with IFC Performance Standard 1 (IFC, 2012):

> To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and, where residual impacts remain, compensate/offset for risks and impacts to workers, Affected Communities, and the environment.

The hierarchy establishes the preferential order for applying management measures to most effectively reduce the magnitude of an impact, considering good international industry practice, and potentially the sensitivity of a receptor, as far as practicable. In some instances, mitigation can be incorporated into the Project design (i.e., built-in mitigation) to avoid or reduce the negative impacts, or to enhance the positive impacts.

Chapter 4 identifies the embedded design controls built-in to the Project design to address the potential impacts of the Project, e.g., location that has avoided sensitive environmental or social receptors, bunding for hazardous material storage tanks or drainage networks to manage hydrocarbon-contaminated water. Mitigation and management measures to further avoid and minimize the impacts are then identified, as needed, in each impact assessment chapter (Chapters 11 to 16). In some cases this also includes measures to enhance or optimize potential benefits of the Project.

This Project's impact assessment process has therefore involved identifying where significant impacts could occur and then working with the Project design team to identify and develop technically and commercially feasible means of mitigating the impacts to levels that are deemed acceptable.

3.1.4.4 Residual Impacts

The significance assessment method assesses residual impacts considering the implementation of the embedded design controls and the mitigation and management measures (see Section 3.1.4.3) via a significance matrix using the magnitude of the predicted impact and the sensitivity of the environmental or social value being impacted (Table 3.2). Residual impacts with a significance rating of moderate or above are considered significant. This provides a focus for Project resources and planning, although Project management plans (Chapter 19, Environmental and Social Management, Monitoring and Reporting) will address all potential impacts and identified mitigations measures.

Where significant impacts remain, additional opportunities for mitigation will be explored during the FEED Project phase. Additional requirements related to offsetting or compensation (see Chapter 19, Environmental and Social Management, Monitoring and Reporting) will be designed where appropriate, and in consultation with relevant communities, stakeholders and government agencies, as required.

Residual impacts will be managed through adaptive management once the Project moves into construction and operations.

3.1.4.5 Assessment of Major Hazards

Total identified and assessed major hazards associated with accidental, upset or abnormal events (also referred to as unplanned impacts) in a social and environmental aspects and impacts identification (SENVID) study and hazard identification (HAZID) studies.

The purpose of the SENVID was to identify, at an early stage, the aspects that can potentially impact the environment or society including major hazards. The SENVID examined all Project phases to identify the components and activities that may cause environmental and social harm due to major accidental, upset or abnormal events. .The HAZID followed a similar approach to the SENVID, but focused on upstream operations. Measures (also called actions) to prevent, control or mitigate unplanned impacts were also identified.

The assessment of major hazards or risks associated with accidental, upset or abnormal events is discussed further in Chapter 18.

3.1.4.6 Assessing Cumulative Impacts

Cumulative impacts are due to the successive, incremental accrual or combined effects of a project, its activities or its facilities, when considered in the broader context of the region and combined with other existing, planned and reasonably anticipated future developments, other human activities and natural environmental stressors.

The assessment of cumulative impacts in this EIS is guided by the Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (IFC, 2013). Under this guidance, priority for assessing and managing cumulative impacts is limited to those impacts generally recognized as important due to scientific concerns or concerns of Project-affected communities. Thus, this assessment considers only those cumulative impacts identified as important.

The current environmental and social baseline in the Project area includes impacts and disturbances of past and present anthropogenic activities that have changed, in places, the original natural conditions to the present-day conditions. The cumulative impacts assessment (Chapter 17) considers current and potential, reasonably-defined, developments that could act together with the proposed Project to impact on common receptors.

3.1.5 Reporting of the Assessment

The impact assessment process concludes with the reporting of the environmental and social findings and outcomes of the assessment, including stakeholder inputs. These findings are included in the main report (i.e., chapters) of this EIS, which is supported by the specialist technical reports (i.e., Volumes 2 and 3 of the EIS).

3.2 Project Evolution and Adaptive Management

Figure 3.1 shows that, from the start of the impact assessment process, the EIS Study Team collaborated with the Project design team and considered environmental and social sensitivities and risks in Project planning and design. These interactions informed decisions on the optimal siting of key Project facilities and infrastructure to avoid or minimize potential impacts on environmental and social values that were identified in the initial screening and later detailed baseline surveys, including the concerns of Project-affected communities noted during stakeholder engagements.

As with any complex development project, refining the Project design is an ongoing process that will evolve from front-end engineering and design through to detailed design. The final, as-built, Project design will be refined through tactical on-site adjustments during construction. The Project has a management of change process to manage and track such design amendments, which is also intended to assess potential consequences with respect to environmental and social impacts. Major changes, if they occur, will be communicated to CEPA and other relevant authorities, and appropriate actions in terms of regulatory requirements will be determined in conjunction with CEPA and those other authorities.

To accommodate potential late changes in the design process beyond the term of this report, the EIS Study Team has applied a conservative approach in the assessment of likely residual impacts to develop appropriate mitigation measures that address any uncertainties.

The management of change process will be incorporated into the Project management system, and the implementation and success of mitigation will be monitored and adapted as part of the Project’s environmental and social management planning, which is described in Chapter 19 (Environmental and Social Management, Monitoring and Reporting).

3.3 References

ERIAS Group, 2016. Papua LNG Project: Environmental Inception Report. Version 5. Report prepared by ERIAS Group for Prepared by Total E&P PNG Limited, Port Moresby.

IFC. 2012. Performance Standard 1. Assessment and Management of Environmental and Social Risks and Impacts. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2013. Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets. International Finance Corporation, World Bank Group, Washington, D.C.

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 4: Project Description

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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Chapter

Tables

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Plates

4. Project Description

4.1 Introduction

This chapter describes the hydrocarbon resource, how the Project will produce gas and condensate, and how they will be transported to the liquefied natural gas (LNG) facilities. The key Project elements and activities described in this chapter are (see Figure 1.1):

- Development of the Elk-Antelope gas fields, which hosts the hydrocarbon that will be commercialized into gas and condensate products.
- The main Project components to develop the resource, namely:
  - Wellpads and wells where the reservoir fluids will be produced, and the flowlines and trunklines that will transport the reservoir fluids to a gas processing facility.
  - The central processing facility (CPF) where the reservoir fluids will be separated into gas, water and condensate, and processed and the acid gas will be removed.
  - Export pipelines, which will comprise a 40-inch diameter gas pipeline and a 10-inch diameter condensate pipeline. There will be 60 km of onshore and 260 km of offshore pipelines to transport the products from the CPF to the LNG facilities.
  - Infrastructure, which includes the new Logistics Base, incorporating wharfing facilities, the construction and operations accommodation camps, the access road network, the Purari Airstrip extension, landfills, quarries, laydown areas and stockpiles.
- The key activities described relate to the Project phases, as follows:
  - Early works, including the logistics necessary to transport materials, aggregates, equipment and people by sea and river, air and road.
  - Construction.
  - Drilling.
  - Operations, including maintenance.
  - Decommissioning.

Engineering studies are in progress and will continue through the FEED and detailed design Project phases. Throughout these phases, final decisions on design will be made, and some aspects of the Project design described in this chapter (including layout and hence footprint and therefore the disturbance area detailed in Section 4.10.7) may change. An overview of the Project management of change process is provided in Chapter 3 (Impact Assessment Process and Methods).

This chapter also identifies ongoing Project management measures and the major embedded design (also known as in-built design or design controls) features that are intended to mitigate potential environmental and social Project impacts, which are either typical of similar development projects or have been identified during the conceptual and pre-Project design phases. Section 4.13.3 summarizes the embedded design features.

4.2 Gasfield and the Resources

4.2.1 Geology and Reservoirs

The Elk-Antelope gas field covers approximately 14 km by 7 km, within which the two discrete gas reservoirs are separated by a thrust fault. A schematic of the reservoir geological cross-section is provided in Figure 4.1. Section 7.2 provides additional information on the regional geology.

The gas-bearing reservoir comprises limestone and dolostone, including the Upper Limestone, Dolostone, Intra Limestone and Lower Limestone reservoir units, which overlie Mesozoic deposits (Figure 4.1). The limestone geology of the reservoir is capped by shales known as the Orubadi Formation. The following features characterize the lithology, as shown in Figure 4.2:

- The top 100 m consists of geological strata known as Era Beds (sands).
- From 100 m to 1,600 m depth, the strata consist of shales known as the Orubadi Formation.
- The carbonate reservoir is situated in strata comprising 800 vertical meters of limestone and dolostone.

The hydrocarbons in place comprise an estimated 6.2 to 7.5 trillion cubic feet of hydrocarbon gas and with a condensate to gas ratio estimated between 15 and 20 bbl/MMscf. More than 95% of the combined Elk-Antelope hydrocarbons in place are from the Antelope field. The reservoir pressure is 244 to 256 bar and fluids are between 86 and 106°C.

4.2.2 Gas

Table 4.1 summarizes the Antelope and Elk hydrocarbon gas composition. The main difference between the two fields is that Antelope contains higher hydrogen sulfide concentrations than the Elk field. The two fields are separate (see Figure 4.1) and the gases are unlikely to mix.

Table 4.1 – Summary of Antelope and Elk Gas Compositions

Compound	Concentration	Reservoir	
		Antelope	Elk
Methane	%	86.7	90
Ethane	%	3.6	2.6
Propane	%	1.2	0.6
Other C1-C35 hydrocarbons	%	<1	<1
Carbon dioxide	%	5.7	5.2
Nitrogen	%	0.4	0.4
Hydrogen sulfide	ppm	140 to 200	5
Benzene	ppm	340	340
Toluene	ppm	340	340
Ethylbenzene	ppm	40	40
Xylenes	ppm	880	880
Mercury (in elemental state)	µg/Nm^3	1	1
Arsenic compounds*	µg/Nm^3	To be confirmed	To be confirmed

*Arsenic compound concentrations are being verified with further analysis.

SCHEMATIC OF ELK-ANTELOPE GEOLOGICAL CROSS SECTION

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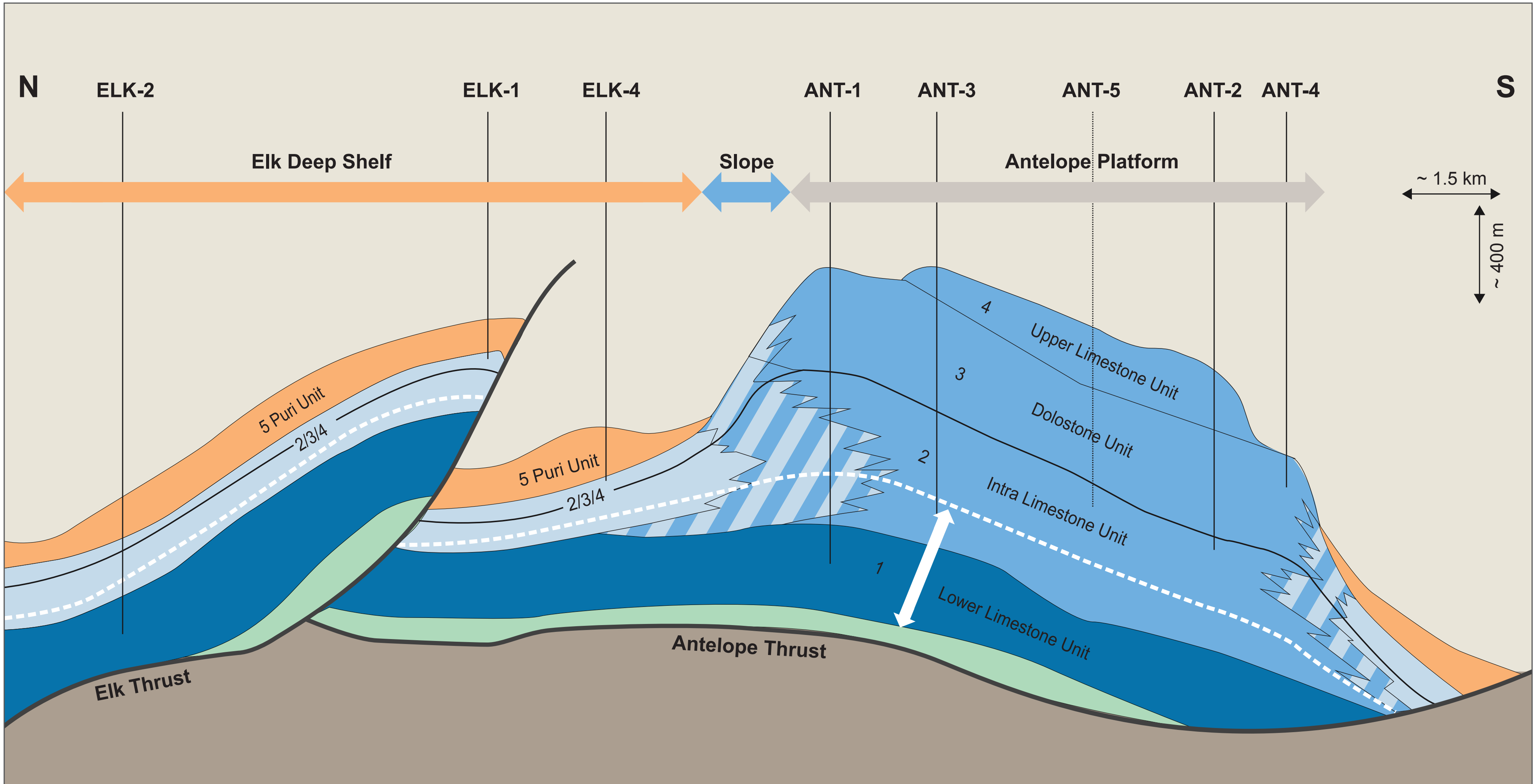
FIGURE 4.1



Cenozoic silicoclastics (Era and Orubadi Formations)

Puri Formation Middle-Late Miocene

2/3/4 Puri Formation Early Miocene

Slope: Transition Darai-Puri Formation

2/3/4 Darai Formation Oligocene to Early Miocene

1 Mendi Formation Eocene to Oligocene

Mesozoic Deposits

Undifferentiated

Not to scale

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TYPICAL LITHOLOGY OF THE ELK-ANTELOPE FIELD

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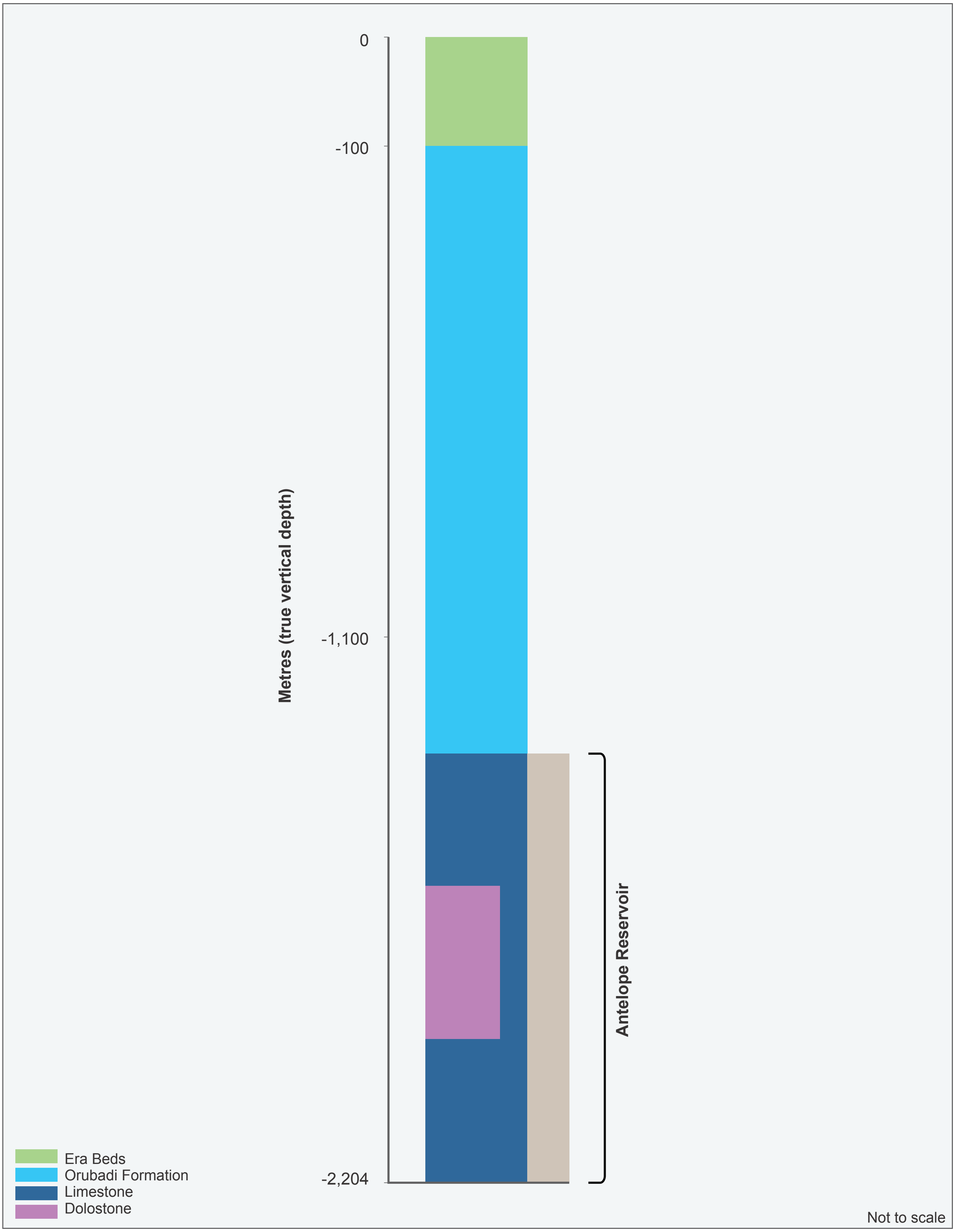
FIGURE 4.2



4.2.3 Condensate

Condensate from the Elk-Antelope fields has a specific gravity of 0.78 and comprises a mixture of hydrocarbons, including propane, butane, pentane and hexane. The condensate contains some sulfur compounds (0.23% by weight), including hydrogen sulfide and mercaptans,[1] which are considered to be impurities. The condensate also contains aromatic organic compounds. These comprise benzene (1.1%), toluene (4.3%), ethylbenzene (0.5%) and xylenes (7.1%). Naturally occurring radioactive material (NORM) is not expected to occur.

4.2.4 Produced Water

Produced water is extracted from a reservoir as a byproduct during the gas extraction process. It can be produced from the condensation of water previously saturated in the gas or from an aquifer associated with the reservoir. The Elk and Antelope reservoirs are unlikely to produce aquifer water based on their characteristics; therefore, the produced water will be condensation water only.

4.2.5 Production Profiles

The production profiles for the gas, condensate and produced water are provided in Figure 4.3.

The Elk and Antelope wells will be able to deliver close to 900 million standard cubic feet per day (MMscfd) of raw gas to the CPF, which is designed to export about 820 MMscfd of treated gas at peak along with 15,000 barrels per day of condensate. Assuming a 94% availability of the facilities, this result in an average production of 840 MMscfd of raw gas and 770 MMscfd of treated export gas on an annual basis. Part of the raw gas will be used as fuel gas to power gas turbines to produce electrical power for the CPF and wellpads.

4.3 Wells and Wellpads

4.3.1 Number, Location and Footprint

The Elk-Antelope fields will be developed with up to nine wells and three wellpads as summarized in the Table 4.2.

Table 4.2 – Summary of Wells and Wellpads

Field	Elk	Antelope	
Wellpad	ELK-10*	ANT-10	ANT-11#
Area† (ha)	1.6	5.0	1.6
Number of producer wells	1	7	–
Number of acid gas disposal wells	1##	–	–
Number of produced water wells	–	–	1
Number of acid gas liquid effluent disposal wells††	–	–	1
Total number of wells	1	7	1**

* Existing Elk-1 modified and refurbished. # Existing ANT-1 modified and refurbished. † Footprint including vegetation clearing area. ## Converted producer well. †† Only required until Elk reservoir is depleted. ** A single well used for both purposes.

1 Organosulfur compound.

GAS, CONDENSATE AND WATER PRODUCTION PROFILES

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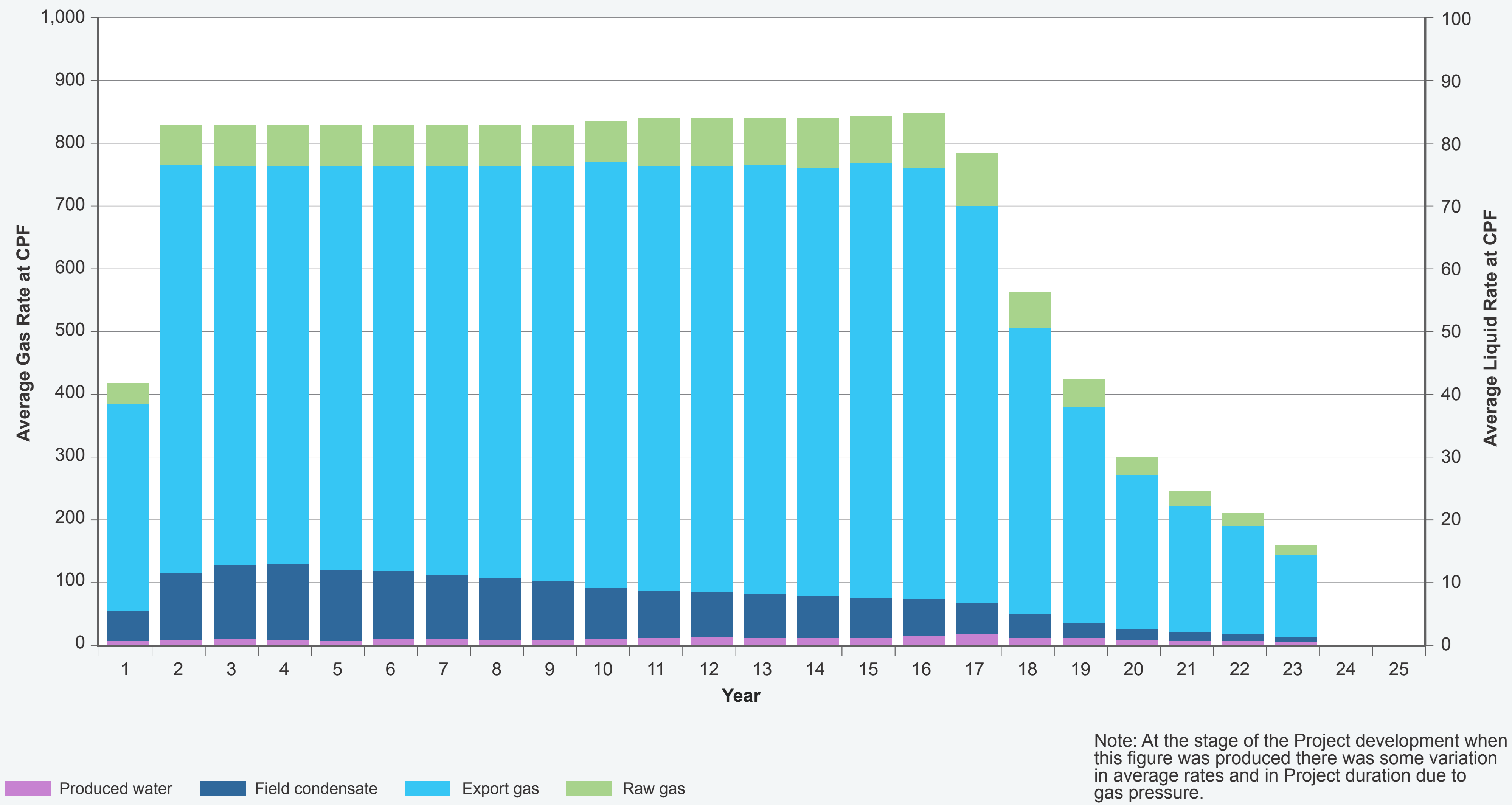
FIGURE 4.3



Note: At the stage of the Project development when this figure was produced there was some variation in average rates and in Project duration due to gas pressure.

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The Elk field will be developed with one production well drilled from the existing Elk-1 wellpad, which will be upgraded and renamed ELK-10. When the Elk reservoir is depleted – after approximately four years of production, – the production well and wellpad will be converted for acid gas disposal. No water injection is planned for the Elk field.

The Antelope field will be developed with a new wellpad, named ANT-10, located near the existing ANT-5 wellpad. Seven producer wells will be drilled from this wellpad. The well on the existing ANT-1 wellpad will be converted to a produced water/acid gas liquid effluent disposal well, and the wellpad will be renamed ANT-11. The location of the wellpads in relation to the field, the gathering system and the CPF is provided in Figure 4.4.

4.3.2 Wellpads and Gathering Systems

Each wellpad will have a wellhead control panel, transformer and technical room. The technical room will house such equipment as batteries, electrical distribution panels, process and electrical control systems, alarms and remotely operated fire extinguishing systems.

The producer wellpads will have systems to inject chemicals into the reservoir fluids. The chemicals will be stored at the CPF and, when needed, will be transported in drums or cubi-containers by road to the wellpad (Section 4.11.1.2).

Buried flowlines on the wellpads will transport the reservoir fluids from each wellhead to the flowline or trunkline.

4.4 Flowlines and Trunklines

4.4.1 Characteristics of the Flowlines and Trunklines

The flowlines and trunklines comprise the gathering system that conveys the reservoir fluids from the wellheads to the CPF, and produced water back to the wellheads. As required by the PNG *Oil and Gas Regulation 2002*, the pipelines are designed in accordance with Australian Standard AS 2885. The key characteristics of the flowlines and trunklines are summarized in Table 4.3. The design life is 25 years.

Table 4.3 – Key Characteristics of Flowlines and Trunklines

Pipeline	Fluid	Design Capacity	Material	Length (km)†	Diameter (inches)	Design Pressure (bar)	Design Temperature (°C)
Elk flowline*	Reservoir fluids#	200 MMscfd	Carbon steel	36.0	14	219	100
Antelope trunkline #1	Reservoir fluids	450 MMscfd		28.0	22	219	100
Antelope trunkline #2	Reservoir fluids	450 MMscfd		28.0	22	219	100
Water injection flowline	Produced water	3,000 bpd		31.1	4	219	83

* Will be known as acid gas injection flowline when the Elk reservoir is depleted and the flowline is used to transport acid gas. # Acid gas will be transported via this pipeline after the Elk reservoir is depleted and the pipeline will be suitable for both uses. † Length may vary slightly due to minor changes in design.

OVERALL LAYOUT IN PRL-15

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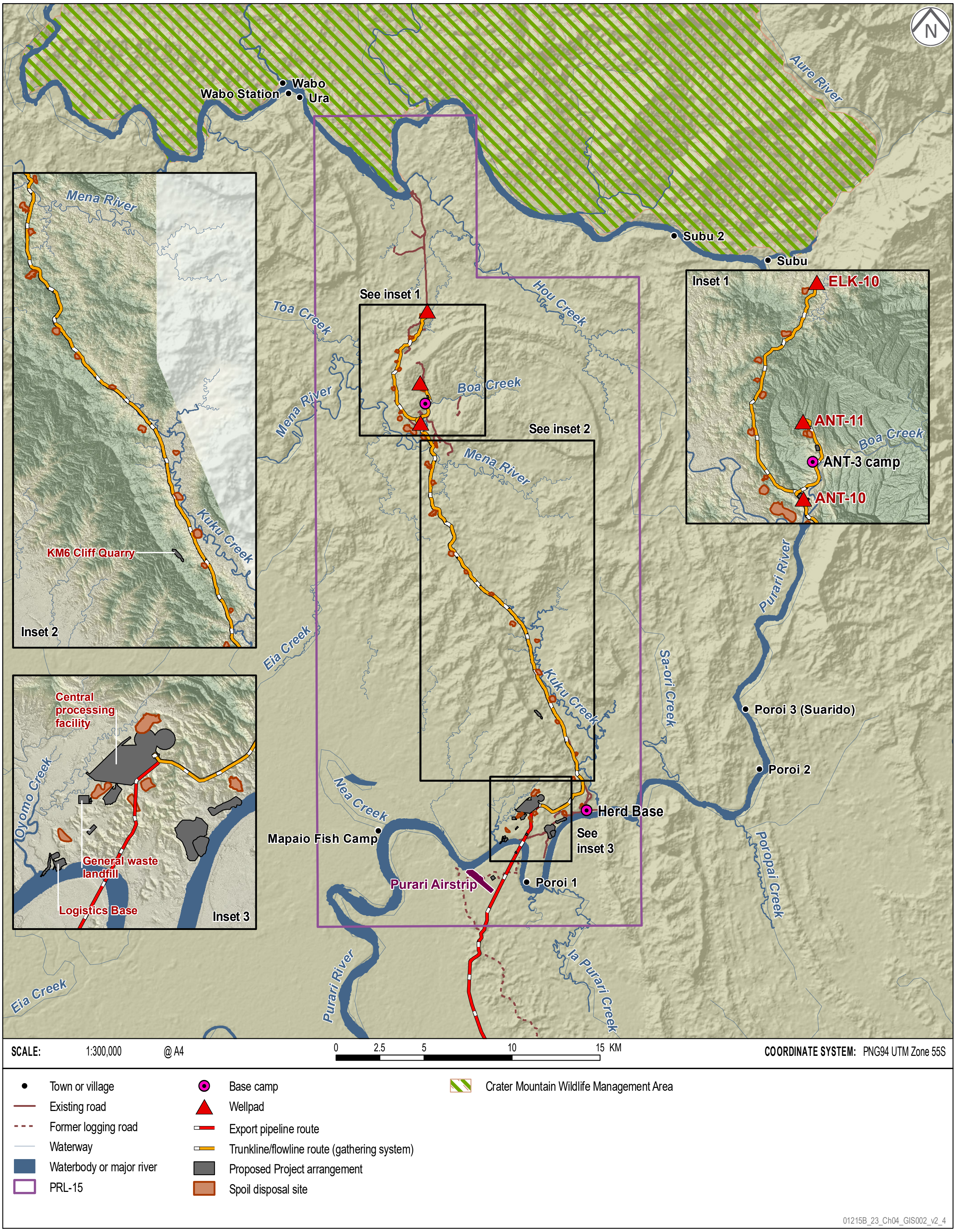
FIGURE 4.4



4.4.2 Routing of the Flowlines and Trunklines

Flowline and trunkline routing has been selected based on the result of multidisciplinary studies, with an iterative process accounting for various constraints, e.g., environmental and societal, geohazards, pipeline constructability and cost (Section 5.4.1).

The key features of the routes are as follows:

- Avoiding communities and sensitive cultural sites.
- Avoiding areas of active landslides.
- Avoiding narrow and eroding ridges.
- Crossing the fewest geohazard zones and following a relatively homogenous slope setting for the flowline.
- Avoiding the sensitive alluvial forest south of the Kuku Ridge and the Pie River catchment for the trunklines.
- Combining Project roads to the wellpads with the pipeline right of way, where practicable, to reduce the disturbance footprint.

The route of each gathering system pipeline is shown in Figure 4.4. The key features of the routes are summarized in Table 4.4.

Table 4.4 – Key Features of the Flowline and Trunkline Routes

Route	Length (km)	Length of Existing Tracks Followed (km)	Number of Waterway Crossings	Number of Major/ Secondary Fault Lines Crossed
Elk flowline*	8.0	2.8	12	0/0
Water injection/acid gas liquid effluent flowline*	3.1	2.1	1	0/5
Antelope trunklines	28.0	21.5	94	0/5

* Not counting the length shared with the Antelope trunklines.

4.5 Gas Processing Facilities

4.5.1 Generalities

The reservoir fluids will be processed before being transported to the PNG LNG Facilities. Processing is to separate the gas from the condensate and to remove carbon dioxide, water and hydrogen sulfide so that the gas and condensate compositions comply with the LNG plant specifications.

4.5.2 Proposed Site

The CPF will be located in PRL-15 near the Purari River, and approximately 30 km south of the ANT-10 wellpad and 40 km from the ELK-10 wellpad (see Figure 4.4). It will be close to a new Logistics Base (Section 4.8.6) and 5 km west of the existing Herd Base (Section 4.8.2).

The site is in a hilly area adjacent to the Purari River alluvial plain with elevations from 50 to 400 m above sea level. The land is covered with dense tropical forest.

The Project will acquire approximately 600 ha of land to site the CPF, the operations camp, the Logistics Base, temporary construction areas (including the construction camp) and restricted zones. A security fence will be installed around individual areas once the boundaries are finalized during FEED. The land to be cleared of vegetation for the CPF facilities and operations camp will be approximately 100 ha.

The northern part of the site is in a hilly area that will require terracing, leveling and grading; however, the site layout and earthworks have been designed to maximize the reuse of cut material and minimize the need for spoil disposal (Section 4.10.2.7). Positioning the processing areas on higher ground reduces the flood risk and the adverse impact of potential earthquakes, and will be advantageous for constructing drainage networks. The temporary construction areas and the operations camp will be sited on the low ground between the hills and the river.

4.5.3 General Description of the CPF

4.5.3.1 General Layout

The layout of the CPF and adjacent operations camp is illustrated in Figure 4.5. The facilities will comprise the following main areas: operations camp, flares, vents and stacks, production facilities (processing, utilities and services), and area for future expansion (e.g., future medium pressure and low pressure compressors). During construction, a temporary construction area will be used for the concrete batching plant, laydown areas, prefabrication and construction facilities (such as contractors' offices, temporary workshops and warehouses). A temporary construction camp will be located adjacent to this area.

4.5.3.2 Services Area

The services area will include the central control room, main office buildings, firefighting equipment, workshop, warehouse and laboratory.

4.5.3.3 Processing Area

The processing facilities will comprise a single gas processing train with the following functions: separation of gas, water and condensate, cooling of fluids, removal of acid gas, dew pointing and metering. A liquid stabilization train will produce stabilized condensate. Other processing units will comprise the acid gas management and gas (i.e., Elk and CO_2) compression units. These processes are described in more detail in Section 4.11.1.

4.5.3.4 Utilities Area

The utilities area will be located upwind from the processing area. Part of the area will be accessible to trucks; and a second area will be dedicated to supply all necessary utilities, which will include compressed air, nitrogen, fresh water, demineralized water, electricity and a heating medium.

4.5.3.5 Condensate Storage Facilities

A storage area for condensate and off-specification condensate will be located next to the utilities area.

4.5.3.6 Flare and Vents

During normal operations, other than native $CO_{2,}$ there will no be flaring or venting; however, flares and vents will be necessary occasionally for specific situations such as start-up, maintenance and upset processing situations (Section 4.11.1.2). The buffer zone around the CPF facilities has been sized to include the vents and flares restricted area.

CENTRAL PROCESSING FACILITY SITE LAYOUT

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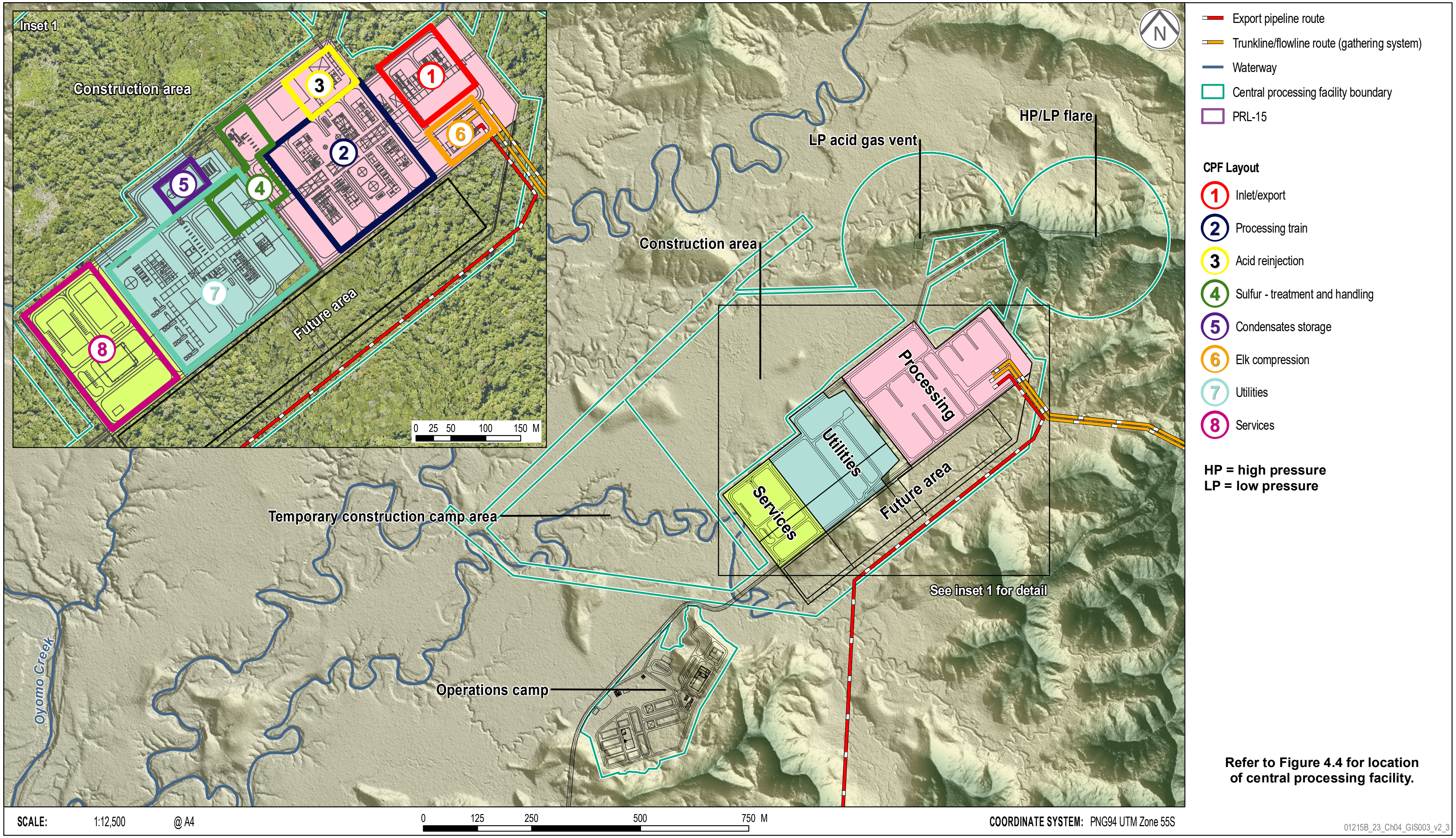
FIGURE 4.5



4.6 Transporting the Gas

4.6.1 Export Pipelines

This section describes how the Project will transport gas and condensate from the CPF to the downstream facilities in Caution Bay. The Project components described comprise the onshore and offshore sections of the gas and condensate export pipelines and associated infrastructure. The gas and condensate pipelines will be parallel, following the same route, approximately 60 km of which will be onshore and approximately 260 km of which will be offshore. Two pipeline shore crossings are described: the upstream crossing at Orokolo Bay and the downstream crossing at Caution Bay. The pipelines connect to the PNG LNG Facilities at a tie-in point inside the PNG LNG project lease boundary. The description in this section provides the technical characteristics of the components and describes the main activities required for constructing, operating, maintaining and decommissioning the pipelines. LNG facilities inside the PNG LNG project lease boundary are excluded from the scope of this EIS and consequently are not included in the Project description; this also includes any proposed PNG LNG jetty extension.

General Characteristics

The pipelines have been designed in accordance with Australian Standard AS 2885, as required by the PNG *Oil and Gas Regulation 2002*. Indicative key pipeline characteristics are summarized in Table 4.5.

Table 4.5 – Summary of Indicative Key Characteristics of Gas and Condensate Export Pipelines

Parameter	Unit	Gas	Condensate
Material	N/A	Carbon steel	Carbon steel
Design life	years	40	40
Outside diameter	inches	40	10.75
Corrosion allowance	mm	1.5	3.0
Design pressure	bar	129	110
Design temperature	°C	57	77
Operating pressure	bar	85 to119	49
Operating temperature	°C	32	62
Design capacity (gas)	MMscfd	820	N/A
Design capacity (condensate)	bblpd	N/A	15,000
Onshore section length	km	60	60
Offshore section length	km	260	260
Maximum water depth	m	85	85

Notes: The above-ground sections of the pipelines will not be thermally insulated. The gas pipeline will have an internal coating to minimize corrosion during construction and pre-commissioning, and to aid drying after hydrotesting. Offshore sections of the pipeline will have a concrete coating for stability when necessary, and sections of the onshore pipeline in a swampy area will have a concrete coating.

4.6.2 Onshore Pipelines

4.6.2.1 Routing

The pipeline route has been selected based on the result of multidisciplinary studies, with an iterative process accounting for various constraints, e.g., environmental and societal, geohazards, pipeline constructability and cost (Section 5.4.2). The proposed onshore export pipeline route is shown in Figure 4.6.

ONSHORE EXPORT PIPELINE ROUTE

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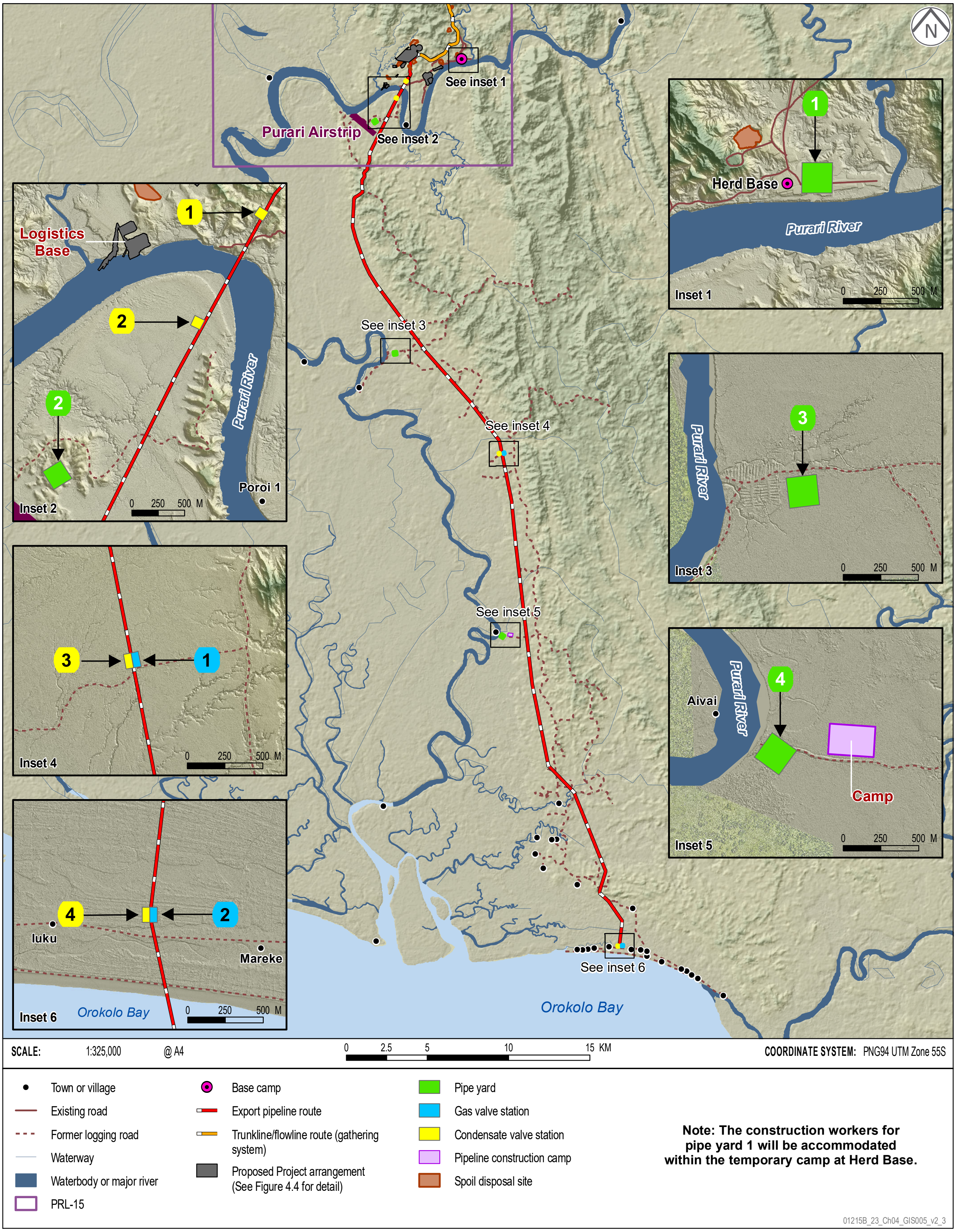
FIGURE 4.6



Note: The construction workers for pipe yard 1 will be accommodated within the temporary camp at Herd Base.

The key features of the route south from the CPF are as follows:

- Crossing of the Purari River (Section 4.10.5.3) – situated immediately south of the CPF.
- Crossing of a range of hills – over 3 km with slopes of 10 to 15° and areas exposed to shallow landslide risks.
- Crossing an alluvial plain over 38 km – several tectonic faults along the route (Section 4.9.3.3).
- Crossing a hilly area over 10 km – some areas with steep slopes.
- Approaching the shore of Orokolo Bay – crosses a flat waterlogged area with a stretch of sand dunes forming an almost parallel series of ridges oriented northwest–southeast that needs to be crossed in a south-north orientation.
- Combining the pipeline right of way with existing area of disturbance, where practicable, to reduce the disturbance footprint.

The route crosses 79 waterways.

4.6.2.2 Infrastructure

The permanent infrastructure required for the onshore pipeline section comprises 63 km of new access road that will follow the pipeline from south of the Purari River to Orokolo Bay, valve stations for gas and condensate pipelines, and facilities for cathodic protection. Compression stations will not be required. Communication facilities are expected to be located at the valve stations.

The onshore export pipelines will be equipped with six valve stations as follows:

- Condensate valve station on the north side of the Purari River (CVS1).
- Condensate valve station on the south side of the Purari River (CVS2).
- Condensate valve station (CVS3) and gas valve station (GVS1), 30 km south of the Purari River.
- Condensate valve station (CVS4) and gas valve station (GVS2) at the Orokolo Bay shore crossing.

The locations of the valve stations are shown in Figure 4.6. Valve stations will be designed during FEED; however, usually in addition to the facilities for stopping the flow of gas/condensate, a valve station will also include a communications building and tower, and possibly solar power facilities. The total area occupied by each valve station is expected to be approximately 1 ha.

Pipelines are protected against corrosion using cathodic protection. The system is likely to comprise several cathodic protection stations positioned along the pipeline including at the valve stations. The number and location of the cathodic protection stations are yet to be defined. Cathodic protection prevents corrosion by keeping the pipeline at a negative electrical potential (i.e., less than 1 volt). The total area of each cathodic protection station and cleared surrounds could be up to 0.5 ha.

The running track/access road adjacent to the pipeline (Section 4.10.5.1) will be constructed concurrently with the pipeline.

4.6.3 Offshore Pipelines

The selected offshore export pipeline route is shown in Figure 4.7. The route selection has been driven by the need to minimize the overall length, avoid geohazards, maximize the use of the existing PNG LNG pipeline route (with a separation distance of approximately 50 m), and find suitable solutions for the shore crossing at Orokolo Bay and the approach to Caution Bay. The offshore pipelines will be situated at least 5 km from the coast to avoid encroaching on customary land; consequently, the pipelines will need to cross the existing PNG LNG Gas Pipeline to achieve this. From Orokolo Bay, the offshore pipeline route runs in a general southeasterly direction in marine continental waters up to approximately 76 m deep. It crosses the PNG LNG Gas Pipeline approximately 110 km from Orokolo Bay. Two approaches to Caution Bay are being considered and both are assessed in this EIS approximately up to the PNG LNG lease boundary. A decision on the approach will be made during FEED.

4.7 Personnel and Accommodation

4.7.1 Worker Requirements

4.7.1.1 Construction Phase

The approximate number of workers required during construction for the upstream facilities ranges from 50 people during the initial stages of the early works up to approximately 6,000 during the period of peak activities, noting that these numbers are estimates and subject to change.

The different construction activities include preparatory works, early works, drilling, and site preparation and building of the CPF and pipelines; although, not all these activities will take place simultaneously. The construction workers will be demobilized once construction is completed.

4.7.1.2 Operations Phase

The operation of the upstream facilities (e.g., wellpads, trunklines, flowlines, CPF and export pipelines) will require operations, maintenance and security workers. The work is likely to take place 24 hours per day, 7 days per week on a rotation basis with 28 days on/28 days off, with all workers living and remaining onsite in the operations camp during their rotation.

4.7.1.3 National Content

Expatriate specialists will provide an experienced core team during construction and to conduct initial operations, coupled with trained new and experienced-hire PNG nationals. The number of expatriates employed on the Project is expected to decline steadily over time as PNG nationals acquire competency and experience, and in accordance with training and localization plans approved by the PNG Government.

The Project will develop technical and vocational education and training initiatives to facilitate local workforce participation in the Project construction phase.

OFFSHORE EXPORT PIPELINE ROUTE

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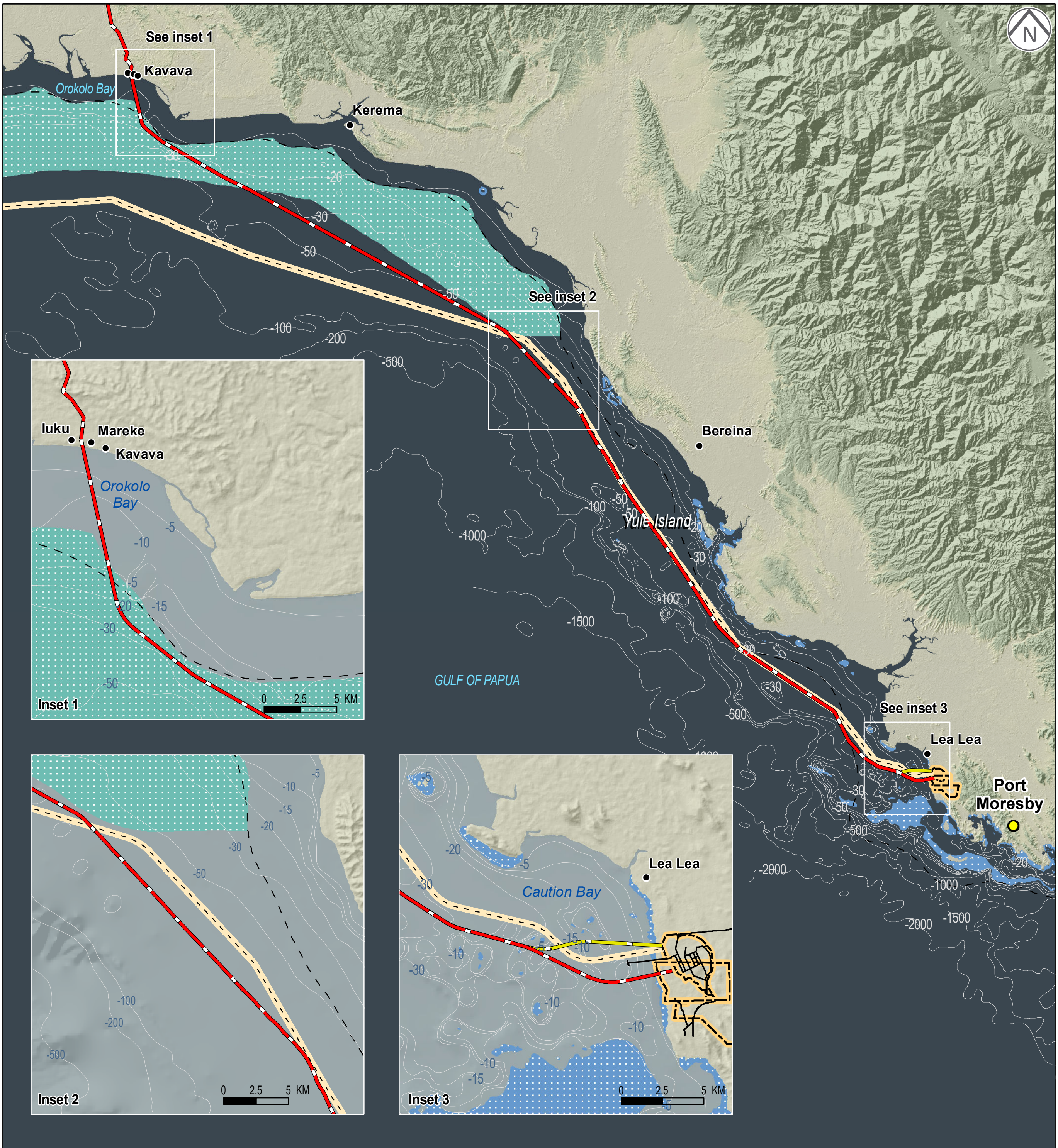
FIGURE 4.7



SCALE: 1:1,365,000 @ A4 | 0 12.5 25 50 75 KM | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Capital city
- Town or village
- Province boundary
- 5 km coastal limit
- Bathymetry (depth contours)
- Coral reef
- Prawn fishery area
- Export pipeline route
- Alternative Caution Bay approach
- PNG LNG Gas Pipeline
- PNG LNG Facilities

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4.7.2 Accommodation Facilities

The accommodation facilities required by the Project during construction and operations, and the key characteristics are summarized in Table 4.6. Camp design and location will be defined during FEED.

The operations camp will obtain power from the CPF power supply, and generator sets will supply power to other temporary accommodation facilities. A sewage treatment plant in the CPF area will treat sewage to the required water discharge specifications, with any water discharges managed in accordance with the PNG environment (water discharge) permit and IFC requirements. Sewage from the temporary construction camps will be treated to the required specifications in containerized sewage treatment plants and disposed of locally under a water and land discharge permit. Sewage treatment and disposal will be further defined during FEED.

Nearby freshwater sources, i.e., rainwater, the Purari River or smaller streams will supply water for accommodation facilities, and on-site treatment plants will treat the water prior to use.

4.8 Infrastructure

Project infrastructure will be a combination of existing facilities, such as port facilities at Port Moresby and Herd Base, and newly constructed infrastructure, such as roads in PRL-15, a new Logistics Base, an extension to the existing Purari Airstrip and waste facilities.

4.8.1 Facilities at Port Moresby

Equipment for Project construction and operations, imported from outside Papua New Guinea, is likely to transit through existing port facilities near Port Moresby. No new port facilities will be required at Port Moresby. The Project is considering using the following facilities:

- Motukea Port (Plate 4.1, photos A and B), where equipment and materials can be directly transferred from ocean-going vessels to barges or landing-craft type vessels that will transport the equipment to the wharf facility at the Logistics Base site on the Purari River.
- Avenell Engineering Systems Ltd (AES) supply base (see Plate 4.1, photos A and C), located 3 km southwest of Motukea Port. This supply base is equipped with a suitable wharf and laydown areas, and the quay was extended in 2017. TEP PNG currently uses this base.

4.8.2 Herd Base

Herd Base, shown in Plate 4.1, photo D, is situated on the north bank of the Purari River, some 10 km upstream from the proposed Logistics Base. The base started operation in 2015 and has supported all past Elk-Antelope fields exploration and surveys. The Project will use Herd Base as a logistics base at during the preparatory works phase and the start of the early works phase while the new Logistics Base and the temporary construction accommodation camp at the CPF site are constructed, and to support the drilling campaign if necessary. This will require enlarging existing storage areas and upgrading unloading equipment. The main facilities at Herd Base are a 700-m^2 warehouse and a 1,500-m^2 pipe yard (pipe yard 1), lifting and handling facilities, a quay and ramp for offloading barges on the Purari River and accommodation for 250 to 300 people.

Herd Base will eventually provide backup facilities to the new Logistics Base during operations but would be progressively decommissioned, as appropriate.

Table 4.6 – Accommodation Facilities

Facility	Temporary/ Permanent	Existing/ New	Project Phase	Capacity (Approximate Number of People)	Area (ha)	Comment
ANT-3 camp	Temporary	Existing	Drilling	100	No new Disturbance	This existing camp will be used by the drilling teams as it is close to the drill sites. The Project will refurbish the camp.
Herd Base	Permanent	Existing	Construction and operations	250 to 300	No new disturbance	During the initial stages of the preparatory works, construction workers will be accommodated at the existing Herd Base facilities. Herb Base will also be used as a general support to the Project.
	Temporary	New	Construction	500	No new disturbance	The workers for the airstrip extension will be accommodated within a temporary accommodation camp at Herd Base and will be transported to the airstrip worksite and back every day by bus and ferry.
CPF construction camp	Temporary	New	Construction	4,500	14.3	Comprises laydown and storage areas, offices, and accommodation.
Pipeline construction camp (see Figure 4.6)	Temporary	New	Construction	500	4.0*	Colocated with pipe yard 4 (the furthest south and closest to the mouth of the Purari River is the principle accommodation area for the export pipeline construction). Construction workers associated with pipe yard 1 will be accommodated at the temporary accommodation camp associated with or near Herd Base.
Operations camp (see Figure 4.5)	Permanent	New	Operation	250#	7.1	The camp area will be fenced and have a controlled entry point. The camp will be guarded with CCTV monitoring. The camp will comprise dormitories, dining room, recreation areas, medical center and offices.

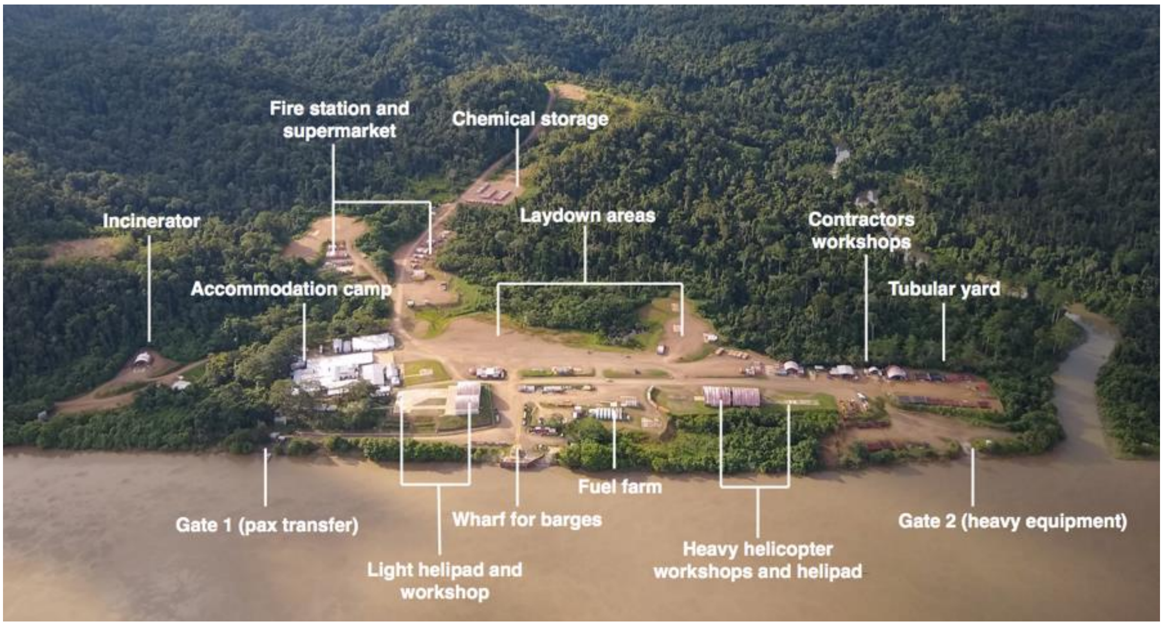
* Area represents both the pipe yard and the accommodation camp.

Plate 4.1 – Existing Infrastructure Facilities Used by the Project

A. Port Moresby Harbour and nearby facilities. Photo: Google Earth (2019).

B. Motukea Port. Photo: ERIAS Group.

C. AES supply base. Photo: Google Earth (2019).



D. Herd Base. Photo: TOTAL.

4.8.3 Roads

The roads that will be constructed by the Project are listed in Table 4.7 and shown in Figure 4.8. The roads will be paved with gravel and have a 25-year design life. Roads, including bridges and culverts, will be designed and built in accordance with the PNG Road Design manual (1985) for the rural roads in a hilly area category.

Table 4.7 – Summary of Project Roads

Road No.	Road Description	Road Type	Length (km)	Width (m)	Maximum Gradient (%)	Design Speed (km/h)
R1	CPF to vents and flares (construction phase only)	Heavy haul	0.9	10	10	30
R2	Logistics Base to CPF	Heavy haul	2.3	25*	5	30
R4	Herd Base to CPF	Standard	4.6	10	12	30
R5[#]	Herd Base to ANT-10	Standard	25.8	10	12	30
R6	ANT-10 to ANT-11	Standard	2.9	10	12	30
R7	ANT-10 to ELK-10	Standard	7.8	10	12	30

* Initial width 12 m; the width will be revised during the FEED phase to a likely width of 25 m to accommodate transporting the CPF modules. [#] An existing road that will be upgraded.

The roads will be designed accounting for major landform hazards to reduce risks to safety during construction and during subsequent use.

Flooding is a risk that has been considered; consequently, access roads R2 and R5 will be leveled at 15 m above the floodplain, and bridges and culverts will be placed along the road to avoid water accumulation.

Heavy or prolonged rainfall is the main cause of landslides, and this will be mitigated by constructing effective drainage systems on slopes where landslide has the potential to adversely affect roads.

An access track (Figure 4.8) along the pipeline right of way (ROW) will be retained for surveillance and maintenance purposes only (Section 4.10.5.2).

4.8.4 Quarries

The quarries situated in PRL-15 are Herd Base quarries A, C and D and KM6 Cliff Quarry (Figure 4.9). These quarries may supply construction backfill material for the Project. The need for additional quarries will be investigated.

4.8.4.1 Herd Base Quarries A, C and D

Four quarries are sited near Herd Base. The Project has selected three of these; Herd Base quarries A, C and D for use.

Quarry A is an existing quarry 1.6 km to the southwest of Herd Base by road and 1.8 km from the CPF. The quarry has a 7-ha footprint and materials available comprise conglomerate deposits interbedded in fine-grained material. This quarry will supply the Project with approximately 451,000 m^3 of material comprising general fill material, impervious materials and granular material for pavement layers. Quarries C and D are provisional and, if needed, will be developed. These quarries are located adjacent to each other, approximately 200 m southwest of Quarry A. They have a conservative footprint of approximately 27 ha and 8 ha, respectively.

PROJECT LAYOUT AND ROAD NETWORK

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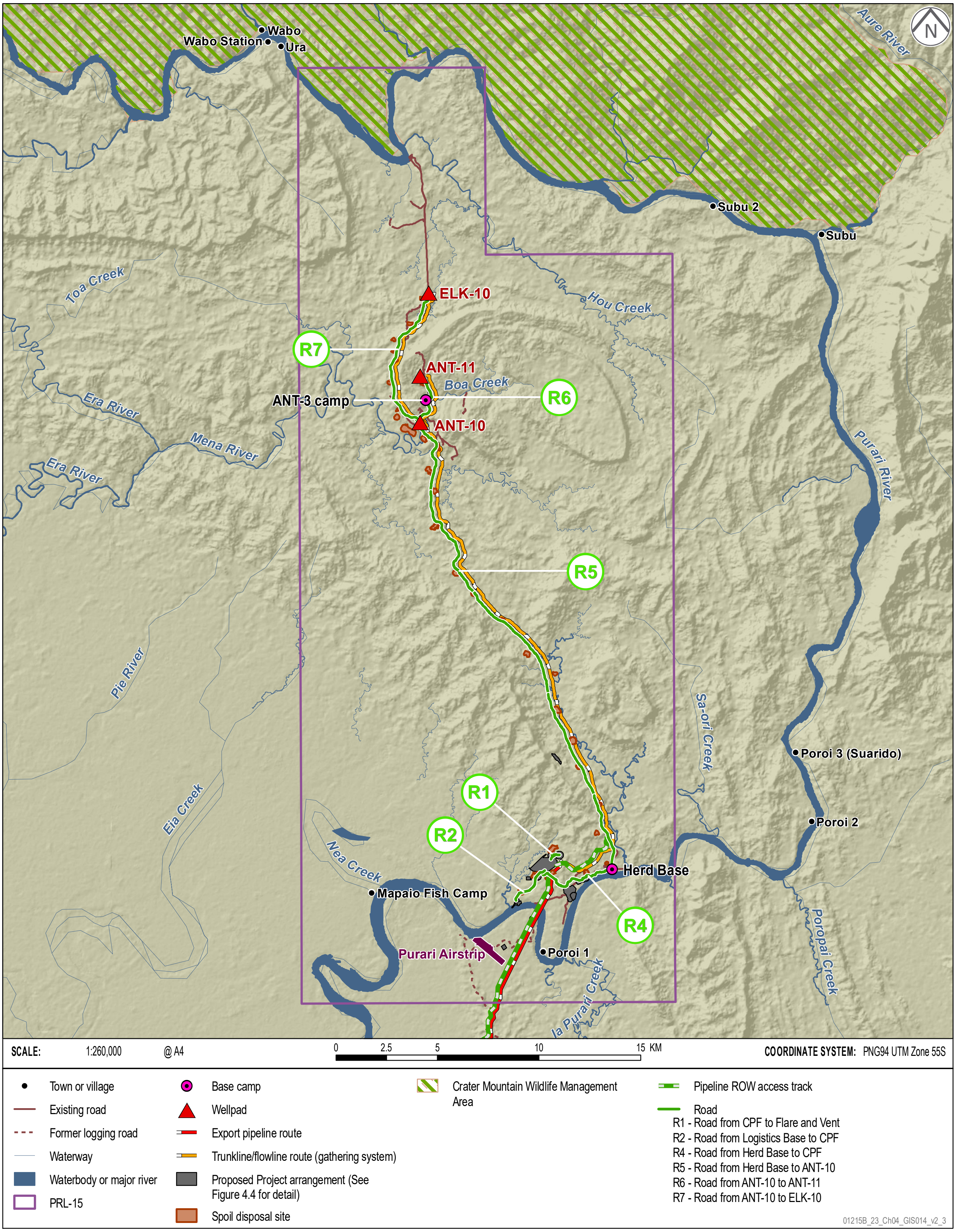
FIGURE 4.8



LOCATION OF KM6 QUARRY AND HERD BASE QUARRIES A, C AND D

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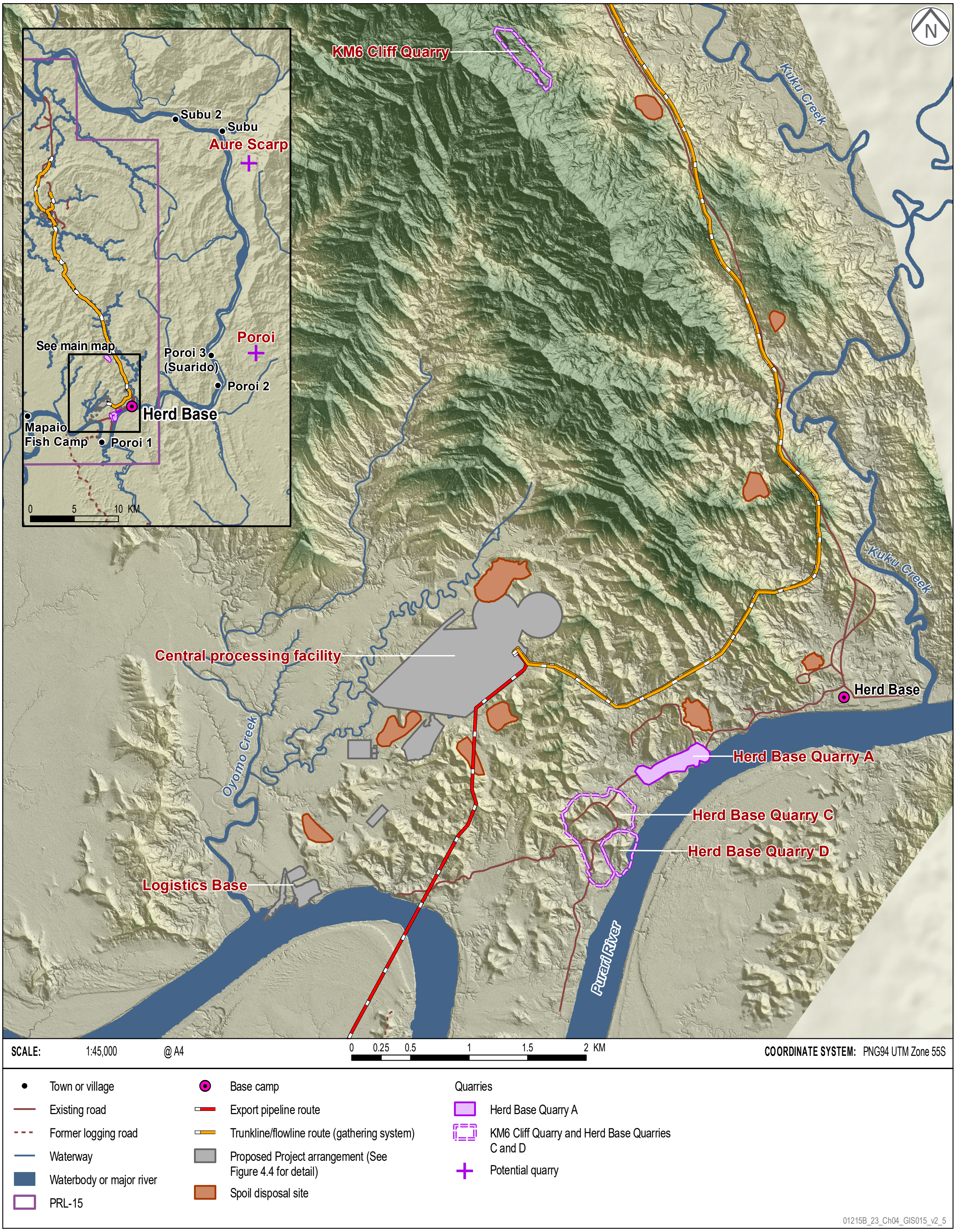
FIGURE 4.9



4.8.4.2 KM6 Cliff Quarry

KM6 Cliff Quarry (also called KM6 Quarry) will be a new quarry. The quarry site is located about 7 km northwest of Herd Base by existing roads and about 10 km from the CPF. The quarry has a footprint of 9 ha, and materials available comprise boulders of coarse sandstone, conglomerate, siltstone and very fine-grained sandstone. The quarry is also provisional and might not be developed, as it is unlikely to provide a sufficient volume of the required construction materials to meet Project needs.

4.8.4.3 Other Quarries

The Herd Base quarries do not have enough rocky material to meet the Project’s requirements; therefore, rocky material will need to be supplied from other quarries in PRL-15 or possibly off-site quarries. Specific rocky material is required, which comprises granular material for drainage and stability, and general fill material for roads, and the pipeline ROW. Rocky blocks for construction of platform drainage and flood channels are also needed.

Two off-site quarries are currently being investigated east of the Purari River; one along the Aure Scarp and one to the northeast of Poroi 2. Geotechnical surveys are in progress to assess the suitability of the rock present, the volume of rocky material available, and the logistics and access requirements. Only one of these quarries would be developed, if both proved feasible. Approximately 500,000 to 1,500,000 m^3 of rocky material would be extracted from the quarry and the footprint of the quarry would be approximately 25 ha.

Pre-construction environmental and social surveys (Section 4.10.2.1) shall be undertaken of the selected quarry, access route and logistics/wharf facilities once geotechnical surveys are complete and confirm the suitability of materials for Project use.

Off-site existing commercial quarries, such as the Kopi quarry in the Kikori River delta, the Punomo quarry in Kerema, and the Monier and GBCL quarries near Port Moresby, could also be used if no suitable quarry sites in the Project area can be found. In the case that the off-site quarries are used, the material will be barged to the site.

4.8.5 Waste Management

4.8.5.1 General Waste Management

The Project will manage its waste during all Project stages from preparatory works to decommissioning in alignment with TOTAL’s general specifications, relevant PNG legislation and guidelines, and relevant international conventions (see Chapter 2). Strategies will be implemented to avoid or minimize waste production. Where this cannot be achieved, options to reduce, reuse and recycle/recover waste will be implemented. Waste disposal is the least preferred option.

The key elements of the waste management strategy, which may involve the export of select wastes, are as follows:

- Reduce – where possible, reduce waste volumes at the source by selecting processes, products and procedures that generate the least waste possible.
- Reuse – where possible, packaging materials will be returned to suppliers for reuse, e.g., empty drums and containers, cardboard and unused products.
- Recycle and recover – where possible, hazardous and non-hazardous wastes, e.g., scrap metal, rubber tires, batteries, empty gas cylinders, will be reprocessed into useful materials or products by third parties.

- Treatment and disposal – if waste materials are still generated after the implementation of feasible waste avoidance, reduction, reuse, recycling and recovery measures, waste materials will be treated and disposed of, and measures taken to minimize potential impacts to human health and the environment.

A preliminary review of existing waste management facilities suggests that limited waste management capacity exists in Papua New Guinea.

A preliminary estimate of some waste types and quantities for the Project is provided in Table 4.8; more comprehensive waste quantities will be determined during FEED. Wastes will be characterized according to composition, source, and type, e.g., hazardous vs. non-hazardous, and managed in appropriately segregated and bunded areas as required. All waste storage areas will be regularly inspected for integrity issues, emissions and leaks; and all waste generated will be tracked by type and volume including transport to its disposal destination.

Waste management requirements (e.g., waste inventory, segregation, storage, disposal, tracking, recording, third-party responsibilities) will be detailed, for various waste types, e.g., liquid, solid, hazardous and non-hazardous wastes, during FEED, and management plans will be prepared for waste-producing or waste-managing facilities and activities in the Project during construction, including preparatory and early works, operation and decommissioning.

Table 4.8 – General Waste Types and Estimated Total Quantities

Waste Stream	**Classification**	**Estimate of Total Waste Generated (m^3)***	
		Early Works/ Construction (5 Years)	**Operations (20 Years)**
Batteries	Hazardous	225	92
Container, drums, paints, solvents	Hazardous	450	184
Electrical waste	Non-hazardous	300	120
Food and domestic waste	Non-hazardous	7,461	2,920
Glass	Non-hazardous	400	164
HDD# drill cuttings	Non-hazardous	48,500	—
Medical waste	Hazardous	35	14
Oily debris	Hazardous	500	204
Paper and cardboard	Non-hazardous	65,000	26,581
Plastics	Non-hazardous	20,000	8,179
Rubber and tires	Non-hazardous	5,000	2,045
Scrap metal	Non-hazardous	31,500	12,882
Scrap wood	Non-hazardous	50,000	20,447
Waste oil	Hazardous	4,750	1,942
Chemical waste from gas processing	Hazardous	—	80
Oil sludge from gas processing	Hazardous	—	164
Solvents, chemicals, paints	Hazardous	0.9	4
Total estimate per phase		**234,122**	**76,022**
Total with 10% contingency		**257,534**	**83,624**
		341,158	

* Decommissioning wastes are excluded from the table.
\# Horizontal directional drilling.

4.8.5.2 Incinerator

Due to limited existing waste management capacity and the Project's remoteness, a suitably sized, purpose-built, high-temperature, industrial incinerator, designed to internationally recognized standards as IFC Environmental, Health and Safety Guidelines for Waste Management Facilities (IFC, 2007), will be used to reduce the volume of waste for disposal. The high temperature (870 to 1,200°C) will reduce the risk of emissions associated with incomplete burning of hazardous and non-hazardous wastes, and the residual ash disposed of in a landfill. The high-temperature incinerator shall be available during the early works.

The incinerator will be sited at the general waste management area (Section 4.8.5.3), is proposed to incinerate liquid and solid wastes including hydrocarbons and other combustible hazardous materials to reduce waste volumes and will be managed in accordance with IFC requirements. Additionally, smaller incinerator units may be used at the smaller temporary construction camps for non-hazardous combustibles (e.g., food waste and packaging). Any excess waste or incinerator ash from the temporary construction camps will be bought back to the general waste landfill near the CPF for disposal.

4.8.5.3 General Waste Landfills

Landfilling is the least desired option, for disposing of waste that cannot be recycled or incinerated; however, two general waste landfills, which will provide options for segregating hazardous/non-hazardous and/or construction/operations waste, will be located near the CPF approximately 220 m and 450 m west and southwest of the operations camp, respectively (see Figure 4.4). These landfill areas will incorporate designated areas for waste segregation and laydown. The general waste management area and incinerator will be associated with the larger landfill site. The landfills will be designed to comply with TOTAL's general specification for landfills and the IFC guidelines for waste management facilities (IFC, 2007), and will be designed, located, constructed and operated in general accordance with the intent of the PNG Code of Practice for Sanitary Landfill Sites (DEC, 2001). The landfills will be used for ash disposal from the incinerator and other waste that is not incinerated, reused or recycled. The landfills are likely to be divided into different cells to separate wastes with different properties, e.g., hazardous/non-hazardous waste.

4.8.6 Logistics Base

The current logistics base, Herd Base, will support the preparatory works and the beginning of the early works phase, with a small upgrade until the construction of the new Logistics Base is complete. The new Logistics Base will then be used for the remainder of the Project. The base will be constructed on the northern bank of the Purari River, just over 2 km south of the CPF and 5 km downstream from Herd Base.

The Logistics Base will consist of offices, parking area, roads, warehouse, water pumping station, aggregate storage area, container yard, fuel storage and refueling station, a new quay, a small ramp to allow passengers to disembark from river transport vessels and a larger ramp for offloading equipment from barges. The layout of the base and the alignment of the roads to the CPF and Herd Base are provided in Figure 4.10.

The base will occupy approximately 7 ha.

4.8.7 Existing Purari Airstrip and Extension

During the Project, workers will be transported to and from the Project site by fixed wing aircraft to and from Jacksons International Airport, Port Moresby. The numbers of workers transported per month will vary, but the peak will be during construction when there will be a maximum of 6,000 workers on the site (see Section 4.7.1).

INDICATIVE LOGISTICS BASE LAYOUT

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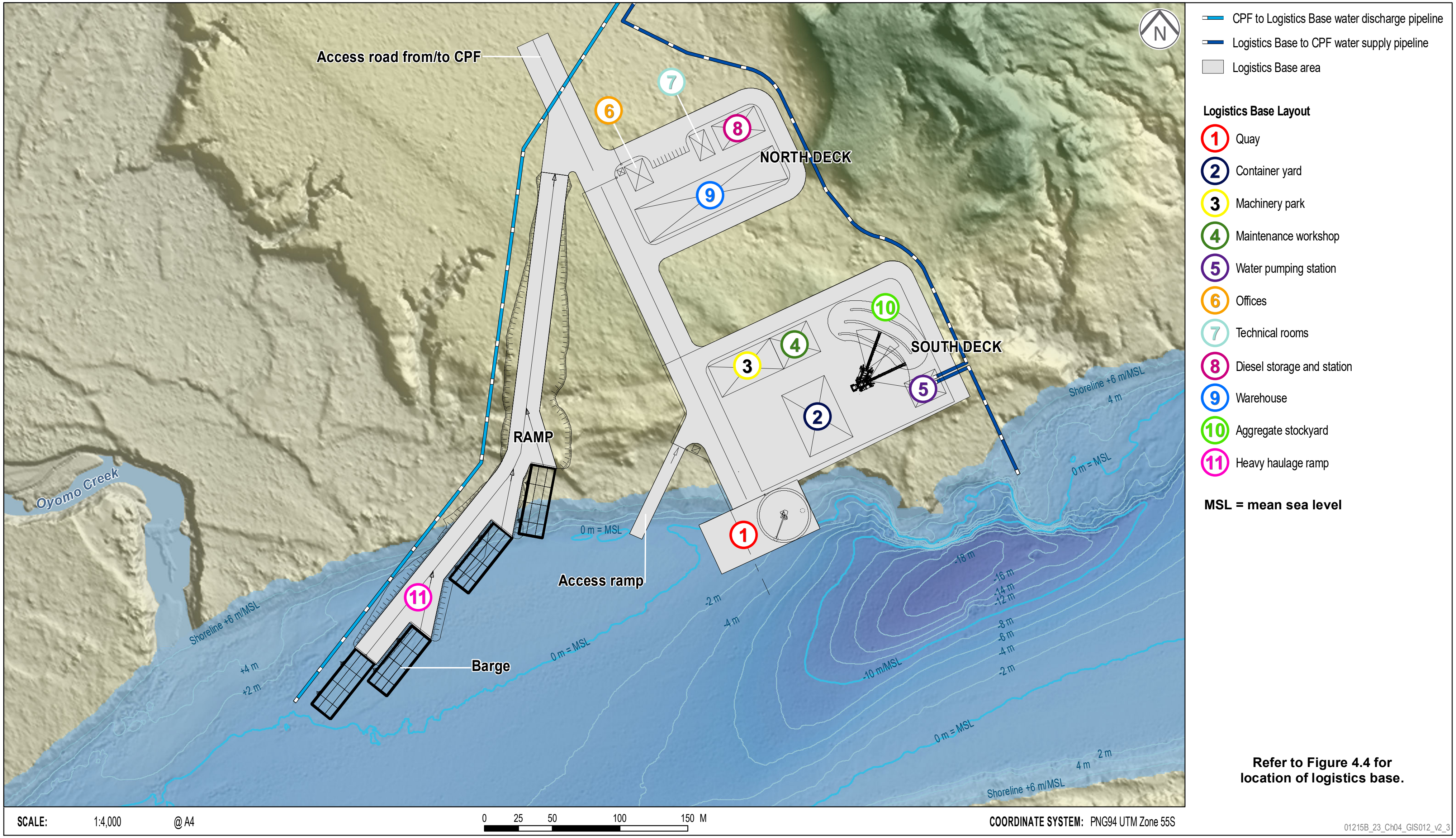
FIGURE 4.10



The existing Purari Airstrip has a terminal building, two helipads, and a dirt track runway 12 m wide and 1,150 m long. The existing operation is carried out using a Twin Otter Dash 6 that can transport a maximum of 19 passengers.

To best meet requirements for transporting Project workers by air the existing airstrip will be upgraded to a Code 2 airstrip, which is a non-precision instrument runway, as per standard runway code categories. A Code 2 airstrip provides horizontal position guidance to aircraft on instrument approach to assist pilots and is the usual standard for small and medium-sized airports. At this stage, TEP PNG does not plan to have night flights to the airstrip and the airstrip will not be designed for night operations.

The runway will be extended to approximately 1,605 m by adding a section of new runway 455 m long and 30 m wide. The final design will be determined during FEED. The runway extension work will occupy approximately 71 ha, and approximately 33 ha of additional land will need to be cleared of vegetation for the visual approach to the runway during landing. The area cleared of vegetation will be 180 m wide at its largest point and will extend in a cone 125 m from both ends of the runway strip. The layout of the extended runway and associated vegetation clearance areas is shown in Figure 4.11.

The airstrip facilities to be constructed by the Project (Figure 4.12) comprise:

- A passenger building with a check-in area, security control area, boarding area and baggage offload area.
- Two aircraft stand areas, an ATR42 stand and a Twin Otter Dash 6 stand. Both stands will be able to be used at the same time.
- A fire station accommodating a firefighting vehicle, fire extinguishing agent and vehicle bay, with a storage area, restroom and watch room.
- A perimeter fence.
- A perimeter road, which will be unpaved and 4 m wide.
- A helipad for emergency use and to periodically support the Project.

4.9 Logistics and Transport

4.9.1 Material, Equipment, Fuel and Chemical Volumes to be Transported

4.9.1.1 Construction Phase

During construction, imported materials, fuel and chemicals, concrete, and equipment comprising CPF modules, pipes, and drilling equipment will be transported to the Project site over a 36-month period. The approximate quantities that are likely to be transported are summarized as follows:

- Early works: 860,000 tonnes.
- CPF construction: 78,000 tonnes.
- Export pipelines: 67,000 tonnes.
- Drilling: 7,000 tonnes.

These figures exclude approximately 600,000 m^3 of aggregates necessary for track construction.

EXISTING PURARI AIRSTRIP AND EXTENSION

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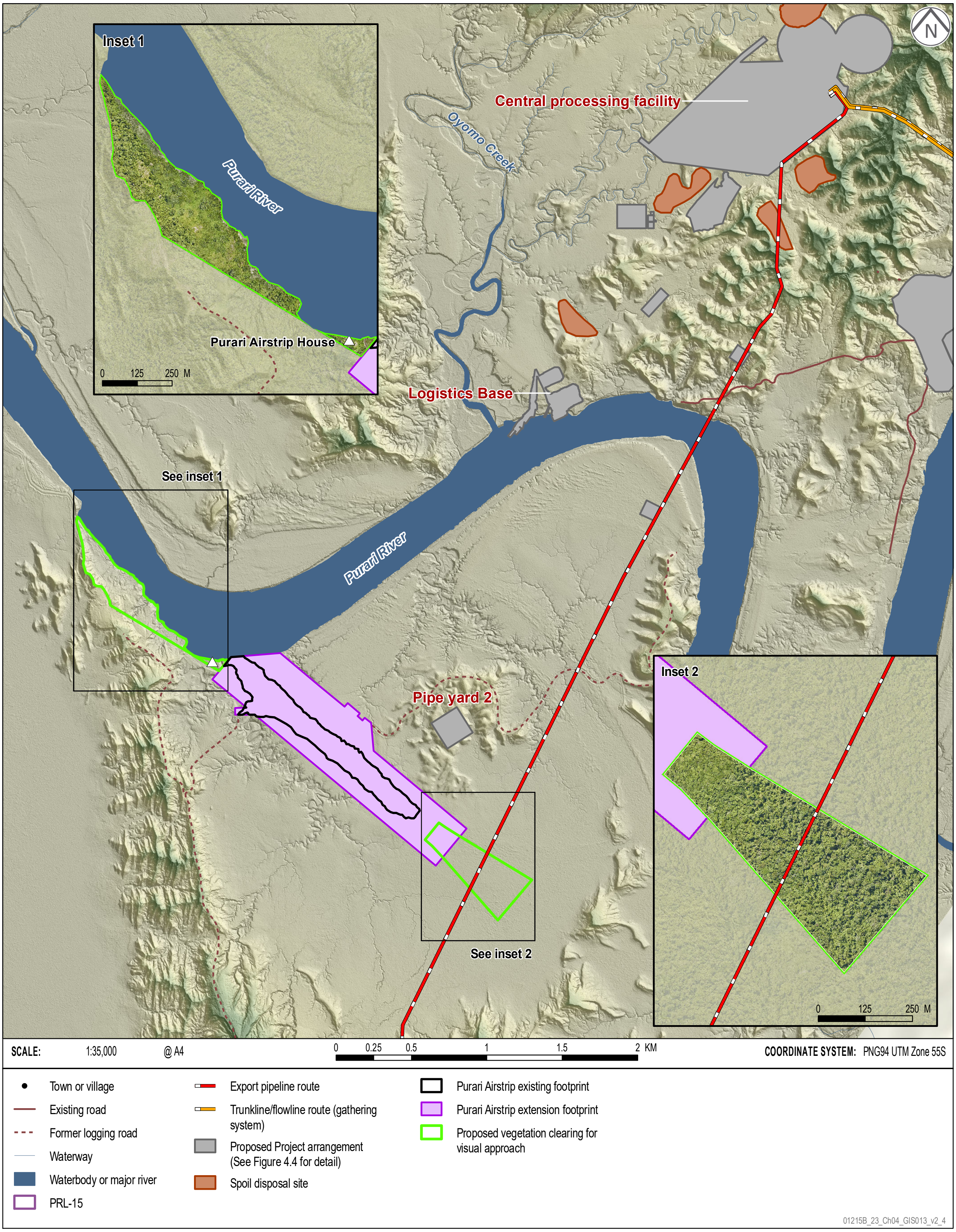
FIGURE 4.11



PURARI AIRSTRIP EXTENSION MASTERPLAN

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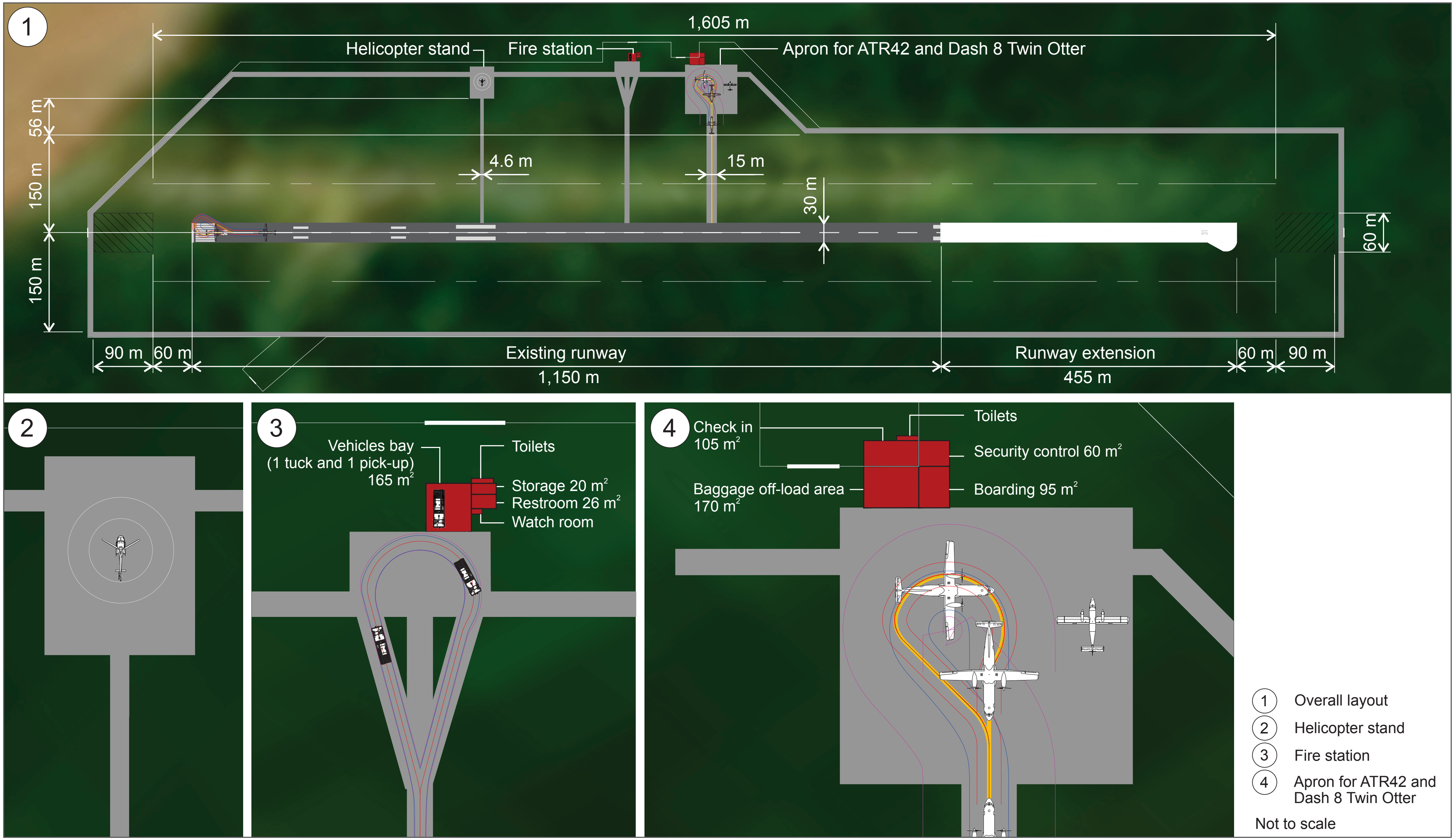
FIGURE 4.12



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Barges will transport fuel in fuel containers to the site along the Purari River. The existing fuel storage and refueling area at Herd Base will be used during the preparatory works and the beginning of the early works. Additional fuel storage and refueling facilities will be installed at the Logistics Base and the CPF construction area. The preliminary estimate of fuel requirements for the early works is 26,000 m^3 per month. The fuel will be stored in 100-m^3 tanks. Between two and four tanks are expected to be required.

Relatively small amounts of chemicals will be required during construction and are expected to comprise principally the non-toxic chemical additives used in preparing water-based drilling mud, and corrosion inhibitor, and biocides used in pipeline and processing equipment hydrotesting. The chemicals will be stored initially at Herd Base during construction then moved to the CPF when an appropriate facility is built (Section 4.11.1.2), and transported to the wellpads in drums or cubi-containers.

4.9.1.2 Operations Phase

Diverse types of materials and equipment will need to be transported to the CPF during the operations phase, mainly for maintenance purposes. The quantities will be significantly less than those needed in the construction phase.

Project facilities will be mostly electrically powered with power provided by gas turbines fueled by reservoir gas. Thus, fuel requirements will be significantly less than during the construction phase. Fuel will be also required for vehicles and diverse, small, diesel-fueled equipment items, such as small generators, compressors and lifting equipment. At this stage, the Project fuel requirements are estimated to be approximately 1,500 m^3 per year, and this will be further defined during FEED. Diesel tanks with a total capacity of 420 m^3 will be situated at the CPF (Section 4.11.1.2).

Key process chemicals used in operations (Section 4.11.1.2) will include the following:

- Monoethylene glycol, which is used as a hydrate inhibitor.
- Corrosion inhibitor.
- Biocides.
- Sodium hydroxide for the flue gas desulfurization process.
- Amines.

The chemicals are expected to be transported in drums or cubi-containers and the quantities required will be defined during FEED.

4.9.2 Transport Methods and Routes

The remoteness of PRL-15 and its lack of established land, water or air access has required TEP PNG to undertake a detailed analysis of logistics and transportation options, and these are summarized in Section 5.7. Sea and river water transport was determined to be the most feasible option for transporting bulk materials and equipment, and air transport was determined to be optimal for workers. These transport routes and methods are described in the following sections.

4.9.2.1 Transport by Water

Transport Routes

Most materials and equipment necessary for Project construction and operations will be transported by sea and river to the Project site from either Motukea Port or the Avenell Engineering Systems Ltd supply base near Port Moresby (see Section 4.8.1). From there it all will be transported by sea and river to the Logistics Base near the CPF or Herd Base while the Logistics Base is being constructed. From the Logistics Base, the equipment will be transported by road to the different worksites, except the materials and workers for construction of the Purari Airstrip extension, which will be barged across the river to that site.

The river transport routes the Project will use are shown in Figure 4.13, which includes the delta of the Purari River system as it approaches the Gulf of Papua. The transport routes comprise the following:

- Purari River.
- Urika-Ivo River (when the Purari River is impassable).

Some items, such as line pipe, may be shipped directly to the mouth of the Purari or Urika-Ivo rivers and offloaded onto smaller barges or landing craft–type vessels for transport upriver to the pipe yards.

Transshipment at the River Mouths

Wave conditions at the river mouths in the Purari River delta are favorable for transshipment operations during a six-month period of the northwest monsoon from November to April (see Section 7.3.2.2). During this period, large, high-value and motion-sensitive equipment and bulk aggregate transported by sea from Port Moresby will be transferred to smaller barges that are more suitable for river navigation and transported up the river to the Logistics Base.

During the six-month southeast monsoon (i.e., May to October), the prevailing wind and waves approach the river delta from the southeast creating unsettled sea state conditions in the nearshore zone and at the river mouths that are unsuitable for ships to anchor or for transshipment operations.

Types of Transport Vessels

Material and equipment transported by water will be carried on self-propelled barges, landing craft–type vessels or non-propelled barges, which are described briefly in the following sections. Plates 4.2 and 4.3 show typical examples of these types of vessels. The barges selected will be suitable for open sea passage, nearshore zone and shallow river mouth entrance maneuvers, and transits up and down-river.

Self-Propelled Barges

The term self-propelled barge covers a wide variety of vessel types from a conventional barge equipped with thruster units, to small river-sea ships. In general, these barges have a dead weight tonnage (DWT) in the order of 1,600 tonnes.

Landing Craft–type Vessels

Landing craft–type vessels typically have draughts of 2.5 m, and they are currently used on the Purari River to supply Herd Base. In general, these barges have a DWT in the order of 700 tonnes.

Non-Propelled Barges

Dry cargo, such as aggregate, is usually transported in a hold barge, which are equipped with features to keep the cargo dry, such as sideboards or watertight or waterproof hatches. Large items of processing equipment are probably transported on a deck barge, which are sometimes called a flat-top or pontoon barge. Non-propelled barges use a tug to provide propulsion. In general, the non-propelled barges have a DWT in the order of 2,300 tonnes.

ACCESS TO THE PROJECT BY RIVER

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FIGURE 4.13

Plate 4.2 – Examples of Barges

A. Examples of typical coastal aggregate barges with a single open hold. Photos: TOTAL

B. Examples of typical inland aggregate barges. Photos: TOTAL.

Plate 4.3 – Examples of Self-propelled River Transport Vessels

Photos: TOTAL.

Offloading

Barges will be offloaded at the Logistics Base at the barge ramp. The material and equipment will be loaded onto self-propelled modular transporter trailers and transported by road to the worksites.

Navigation Aids and Navigation Equipment

The following aids to navigation (river-based infrastructure) and navigation (vessel-based equipment) will be considered to improve river navigability and safety, and to assist safe passage during the Project:

Navigation Aids

- A control tower may be established at the mouth of the rivers to control entry and exit of barges to the rivers. The location of this tower will be determined during FEED.
- Marks (posts, pellet buoys) will mark problematic shallow water:
  - To be deployed during operations once problem areas have been identified.
  - Buoys (lit) marking access channel through river mouth(s).
  - Reflective strips will be used on marks.
- Chainage markers. These will provide visual confirmation of vessel position on the rivers. They will most likely be painted on trees (for security reasons).
- Search lights will be provided on Project vessels and tugs to help vessel crews to identify aids to navigation and river debris at night.

In addition, TEP PNG will consider providing reflectors for mounting on community canoes and boats so they are visible at night.

Navigation Equipment

- An e-chart of river navigation routes.
- GPS linked to ECDIS (electron chart display and information system) to identify the vessel’s position relative to the navigation channel and any nearby navigation hazards and to monitor the vessel’s speed and rate of turn around bends.
- AIS (automatic identification system) on all vessels. This system can be used to monitor the vessel’s position, course and speed. AIS can be used both by individual vessels to identify their position or course relative to other nearby Project vessels and as part of an overall Project vessel traffic management system.
- Echo sounders with data loggers linked to the GPS. The echo sounder will alert the vessel crew to shallow water and low under-keel clearance.
- VHF used to communicate with other Project vessels and Project river traffic control.

Dredging

The following two areas are likely to require dredging to facilitate navigability:

- Ivo and Upper Purari river junction. Required to reduce vessel downtime during low flow conditions and estimated to be approximately 70,000 m^3.
- Purari River mouth. Required to improve navigability during low tides and estimated to be approximately 500,000 m^3.

Dredging details, e.g., location, schedule, spoil character and disposal, will be finalized during FEED.

Number and Frequency of Barge Trips

Construction Phase

The estimated number of barge deliveries of equipment and material, including food supplies, from Port Moresby and the mouth of the Purari River over the 5-year construction period are shown in Table 4.9. During the peak period (i.e., Year 2), up to four to five barge deliveries are expected to be made per day to the Logistics Base, resulting in nine to ten barges on the river system at any given time. In other periods, the barge numbers will be lower. Small fuel volumes will be carried on the regular barges bringing supplies and equipment to site. A dedicated fuel barge will deliver a larger fuel volume approximately every two weeks, so an extra two return barge trips per month, in addition to those described in Table 4.9, is expected for fuel during peak construction.

Table 4.9 – Transport of Materials and Equipment by Barge

Year	Cargo	Port Moresby to Herd Base	Port Moresby to Logistics Base			Herd Base to Airstrip
		Landing Craft–type Barge (DWT = 700 t)*	Landing Craft–type Barge (DWT = 700 t)	Self-propelled Barge (DWT = 1,600 t)	Flat-top Barge (DWT = 2,300 t)	Landing Craft–type Barge (DWT = 700 t)
1	Material for earthworks	1 to 2 barges/day	-	1 barge/day	-	-
2	Materials for earthworks	1 to 2 barges/day	1 barge/week	1 barge/day	-	1 barge/day#
3	Equipment for pipeline, CPF construction and drilling	1 barge/week	1 barge/week	1 barge every 2 days	-	-
4	Equipment for CPF construction	1 barge/week	1 barge/week	1 barge every 2 days	1 barge/ week†	-
5	Equipment for CPF construction	1 barge/week	1 barge/week	1 barge every 4 days	-	-

* DWT= dead weight tonnage. # For four months. † Transports CPF modules.

If required, barge travel will occur at night with the support of navigational aids and in consultation with the community and National Maritime Safety Authority (NMSA) (see ‘Navigation Aids and Navigational Equipment’ under Section 4.9.2.1).

Operations Phase

During the operations phase, materials and equipment for maintenance plus fuel and chemicals will be transported by self-propelled barges. The frequency of these barges is expected to be approximately three to five barge deliveries per month (including the one per month to deliver the caustic soda (see ‘Acid Gas Management’ in Section 4.11.1.1).

4.9.2.2 Air Transport

Construction Phase

During construction, workers will be transported between Port Moresby and the Project site. During the peak construction period, 750 workers per week will be transported. The airplane will land at the Purari Airstrip, and workers will be ferried across the Purari River to the Logistics Base and transported to worksites by bus.

Three aircraft are planned to be used, the Twin Otter Dash 6 (as used currently on the airstrip), and the Dash 8 and ATR42 (Plate 4.4).

Plate 4.4 – Examples of Dash 8 and ATR42 Aircraft

Photo: Gerard van der Schaaf (2015)

Photo: Laurent Errera (2013)

Any of the planes will be used depending on the scheduling and logistics. The assessment is based on flights per day during the 6-month peak construction period being between five and seven flight landings per day at the Purari Airstrip. During the other periods of the construction phase, flights are expected to be less frequent, e.g., there will be approximately one flight per week during the initial period when the number of workers is lowest.

At this stage, it is not planned to have night flights to the airstrip, and the airstrip is not designed for night operations. In case of an accident, the patient will have to be stabilized on site until daylight before being evacuated.

Helicopters may be used during construction and they would be based at Herd Base, if flights are required. Helicopter use would be determined during FEED and in association with the construction contractors.

Operations Phase

Fixed-wing aircraft will transport operational workers between Jackson's International Airport and the Purari Airstrip, and by mini-bus (and ferry) to or from operational areas. One to two flights per week are expected.

At this stage, it is not planned to have night flights to the airstrip, and the airstrip is not designed for night operations. In case of an accident, the patient will have to be stabilized on site until daylight before being evacuated.

Regular helicopter use during operations is not planned at this stage of Project development but will be reviewed during FEED.

4.9.2.3 Road Transport

Road use by trucks is required to transport earthen quarried material and spoil; to transport heavy materials, machinery and equipment for drilling and facilities construction; and to transfer goods and wastes.

Trucks transporting earthen material from the quarries to the worksite are expected to be the main road users with up to 200 deliveries per month, which is approximately six trucks per day during the one-year peak construction period, and 10 to 200 during the rest of the construction period depending on the scale of the activities. Road use by trucks transporting other material will represent a maximum of 140 trucks per month (i.e., 4 to 5 trucks per day) for a three-month peak period, and 60 trucks per month (i.e., two trucks per day) for the rest of the construction period. These road movements will be in PRL-15 and distant from current settlements.

4.9.2.4 Other Transport

Project area workers will be transported to and from Project sites by dedicated contractors. The Project will provide suitable transport as appropriate to their locations.

4.9.3 Safety and Security

4.9.3.1 Occupational Health and Safety

Occupational health and safety (OHS) will be managed under the Project's health, safety and environment (HSE) management system which consists of a series of management policies, plans and procedures to address OHS risks and emergency situations. This includes provisions for OHS and HSE leadership; HSE induction and ongoing training requirements; specific HSE rules and procedures for undertaking different types of work tasks including risk assessment procedures, use of permits to work for hazardous activities, and the provision of personal protective equipment appropriate for various tasks and activities.

4.9.3.2 Risk Management

To include safety, environment and asset protection in the Project design, safety studies and reviews have been carried out and safety documents have been prepared. The principal techniques used at the pre-Project phase have been hazard identification (HAZID), hazards analysis (HAZAN) and Project reviews (PR). Hazard and operability (HAZOP) and other specific safety studies will be carried out during subsequent Project phases.

4.9.3.3 Site Layout

The key safety principles that have been adopted for the site layout are:

- Processing, utilities, services and flares are segregated into different fire zones.
- Separation distance between fire zones are sufficient to minimize the potential for escalation.
- As far as reasonably practicable, ignition sources are located upwind of or perpendicular to the flammable sources.
- As far as reasonably practicable, escape, evacuation and rescue routes and systems are located upwind of hazardous areas.

4.9.3.4 Seismic Hazards

The Project has undertaken probabilistic and deterministic seismic hazard assessments, and the design criteria include the seismic constraints. The facilities will be in a moderate to high seismic hazard zone (see Section 7.2) The CPF will be situated 6.4 km from a fault line. The CPF will be 38 km from the nearest deep seismic hazard source.

Trunklines

The trunklines will cross the following three, minor, fault lines, which are part of the Mena back-thrust tectonic domain (see Figure 7.3):

- Mena Upper Décollement.
- Kuku Fault.
- Herd Fault.

Seismic hazard assessments undertaken during the pre-Project stage have concluded that, in the event of seismic activity, only very small surface displacements of faults are anticipated; and so no specific design features are required.

Export Pipelines

The export pipelines will cross the Emergent Front fault line, which is part of the Aure Fold and Thrust Belt tectonic domain. Seismic hazard assessments undertaken during the pre-Project stage have predicted the 5,000-year maximum fault movement would be 98 cm and that a 475-year fault movement would be less than 10 cm. This potential movement is considered to be relatively minor, and TEP PNG has anticipated that this can be addressed through a specific trench design or above-ground crossing to be developed. The carbon-steel material used for the pipeline as a whole is also suitable for the fault crossing with potentially some strain-based design. Additional studies will be carried out during the FEED to estimate the strain on pipelines from the adverse impact of landslides triggered by seismic events.

4.9.3.5 Simultaneous Operations

Simultaneous operations (SIMOPS) are likely to be encountered during construction/ commissioning/operations when there are multiple activities occurring on site at the same time, e.g., maintenance overhauls in one unit with another unit in operation or during drilling. Particular attention is required for SIMOPs during the start-up phase when some parts of the plant may well be under construction without mechanical completion and or isolation in place. SIMOPS carry additional risks that must be evaluated and managed. Specific hazards associated with any SIMOPS will be identified and assessed using HAZID and SIMOPS risk assessment studies at a later stage in the Project design.

4.9.3.6 Toxic and Flammable Gas

The native gas is considered toxic, since the hydrogen sulfide concentration is higher than 100 ppm, which is the immediately dangerous to life and health (IDLH) threshold limit. Consequently, toxic gas detection systems will be installed at the CPF. Toxic gas detection systems will not be installed at the wellpads, as they are not permanently manned facilities. Personnel who visit the wellpad will be equipped with a protective mask and an individual portable toxic gas detector.

The presence of flammable gas will be detected by infra-red flammable gas detectors located at the wellpads and the CPF. The presence of flammable gas at a wellpad will trigger an alarm at the CPF control room and cause a manual emergency shutdown. The CPF will be equipped with fixed toxic gas detectors. Whenever the concentration of toxic gases temporarily exceeds the time weighted average, an alarm will be activated at the CPF, workers will put on escape masks and evacuate and there will be an emergency shutdown.

4.9.3.7 Fire-detection and Firewater Systems

The facilities will be equipped with flame, heat and smoke detectors in all locations where there is a fire risk and according to the most adapted detection method. Fire detection at the wellpads will trigger an alarm in the CPF control room and an emergency shutdown will be activated manually. Fire detection in the CPF processing area will automatically trigger an emergency shutdown, and activation of fire suppression systems and procedures.

4.9.3.8 Safety Shutdown Systems and Alarms

The facilities will be equipped with safety shutdown systems. At the CPF, emergency shutdown will be automatic in the event of fire, or toxic or flammable gas detection; however, activating the emergency depressurization will be performed manually. At the wellpad, fire or gas detection will trigger alarms at the CPF control room, and emergency shutdown will be initiated manually from the CPF control room.

4.9.3.9 Pipeline Protection

The flowlines, trunklines and onshore and offshore export pipelines are designed with cathodic protection and a fiber optic monitoring system that detects ground movement, any intrusion and leaks. The will to connect the upstream and the downstream facilities shall be determined during FEED. The pre-Project design is to install a fiber optic cable in the same trench for the trunkline and for both the onshore and marine export pipelines.

4.9.3.10 Site Security

Site security focuses on protecting the assets and workers. There will be no manned protection on the wellpads and pipeline infrastructure during normal operations, as no workers will be working on these sites.

So that workers are secure at the CPF, all work areas, accommodation areas and other related sites, where workers are required to work, will be in a single perimeter fence containing an area referred to as a global restricted area (GRA). The GRA will minimize the movement of workers and goods outside secure areas and; therefore, will reduce workers' exposure to security risks. If a security situation occurs, a lockdown procedure will be initiated.

The GRA will allow the site to maintain operations in a downgraded security environment. In case of lockdown for a high-risk security situation, the site will be able to continue operating for five days without the need for workers to move out of the GRA. For lower risk-level situations, the facility will be able to operate autonomously for up to one month.

Government security forces and a private security service provider residing in the operations camp will provide security. The private security guards will be responsible for guarding the GRA and controlling access. The government security force will also have a role in controlling access and will provide the security for Project worker movements s outside the GRA, which comprise:

- Logistics movement between the CPF, Logistics Base and Purari Airstrip. These movements will be monitored and, in the event of a security situation, the government security force, who are stationed at the operations camp, will intervene and take appropriate actions, as detailed in the Project's site security plan.
- Movements to the wellpads, and along the flowlines/trunklines and export pipeline operations easements. The government security force will regularly monitor the security situation along roads. Project workers will be provided with a government security escort during a security situation.
- Community affairs engagements with communities, as appropriate and in alignment with the Project's social management plan.

In the GRA, a security coordination room (SCR) will be installed close to the CPF operations control room, which will also be close to an emergency response room. The SCR will monitor the GRA perimeter, access gates, entry barrier , turnstiles and sensitive area doors, and will provide security workers with the capabilities to manage and control vehicle and worker access into the GRA. The SCR will monitor the wellpads and export pipeline protection and all movements outside the GRA.

Private security guards will be deployed to implement permanent access control procedures and to monitor any security situations in the GRA and at the Logistics Base. Herd Base and the

Logistics Base will be equipped with passive protection measures and a permanent access control process using private security guards.

The airstrip operator (e.g., TEP PNG or a third party) will provide security services to protect the Purari Airstrip; however, the Project's private security guards will be mobilized temporarily if necessary whenever there is a flight.

The government security shall protect the GRA and logistics bases, patrol along operation areas (e.g., wellpads and pipeline surface installations) and intervene in case of emergency situations.

4.10 Construction

4.10.1 Timing

Construction activities will take place over approximately 5 years and operations will continue for an estimated 25 years. The post-closure period will commence when operations cease. A notional development schedule is shown in Figure 4.14, noting that these timeframes are subject to obtaining regulatory approvals, achieving the final investment decision (FID), and completing the FEED and detailed engineering phases that may change some aspects of the Project design and schedule.

4.10.1.1 Preparatory Works and Early Works

The preparatory works and early works phases will be undertaken over 32 months. The works will comprise:

Preparatory Works

- Vegetation clearing for the roads R2 and R4, and access to the Purari Airstrip.
- Vegetation clearing for the Logistics Base.
- Vegetation clearing and site preparation, e.g., earthworks and gravel for the hard surfacing, for the Purari Airstrip runway extension.
- Using Herd Base Quarry A and possibly developing Herd Base quarries C and D (if needed).

After FID the following works will be undertaken:

Early Works

- Developing additional quarries if needed.
- Preparing the CPF and construction camp site.
- Constructing the Purari Airstrip runway extension.
- Vegetation clearing and constructing the R5 road from Herd Base to the ANT-10 wellpad.
- Vegetation clearing and construction of the R6 road from ANT-10 to ELK-11 wellpad.
- Vegetation clearing, earthworks and preparation of the ANT-10, ANT-11 and ELK-10 wellpads.

4.10.1.2 CPF Construction

The CPF construction is estimated to take 11 months. Construction activities will mainly take place during daylight hours for safety reasons.

4.10.1.3 Pipeline Construction

Onshore Pipelines

Construction of the flowlines, trunklines and onshore export pipelines will take 32 months. Pipe installation will progress at approximately 380 linear meters/day for the trunklines, 460 linear meters/day for flowlines and about 320 linear meters/day for the onshore export pipelines.

Offshore Pipelines

The offshore pipeline construction is estimated to take 12 months.

4.10.1.4 Drilling

Drilling at ANT-10, ANT-11 and ELK-10 is estimated to take 24 months.

4.10.2 Common Early Works Activities

The following construction activities will occur at all sites at which construction of new or upgraded facilities, infrastructure or drilling of wells will occur:

- Environmental and social preconstruction survey.
- Land survey.
- Archaeological clearance.
- Sediment and erosion control.
- Equipment mobilization.
- Vegetation clearing.
- Grading and excavation.
- Site clean-up and rehabilitation of temporarily disturbed areas.

Equipment required for these tasks will likely include:

- Excavators.
- Dump trucks.
- Graders.
- Dozers.
- Spreaders, pulvimixers and compactors.
- Gravel spreaders and water trucks.

4.10.2.1 Preconstruction Survey

All sites proposed for development as part of the Project will be subject to a preconstruction survey undertaken by environmental or social specialists, in association with Project engineers and surveyors. The purpose of the survey will be to identify any areas that may need to be avoided or protected (e.g., rare or protected plant or species, habitat for rare or protected animals, archaeological sites, burial sites, sites of religious importance, and watercourses) or requiring specific management and mitigation (e.g., weed or invasive species treatment, or active rehabilitation). The surveys will be conducted during FEED when sufficiently detailed information

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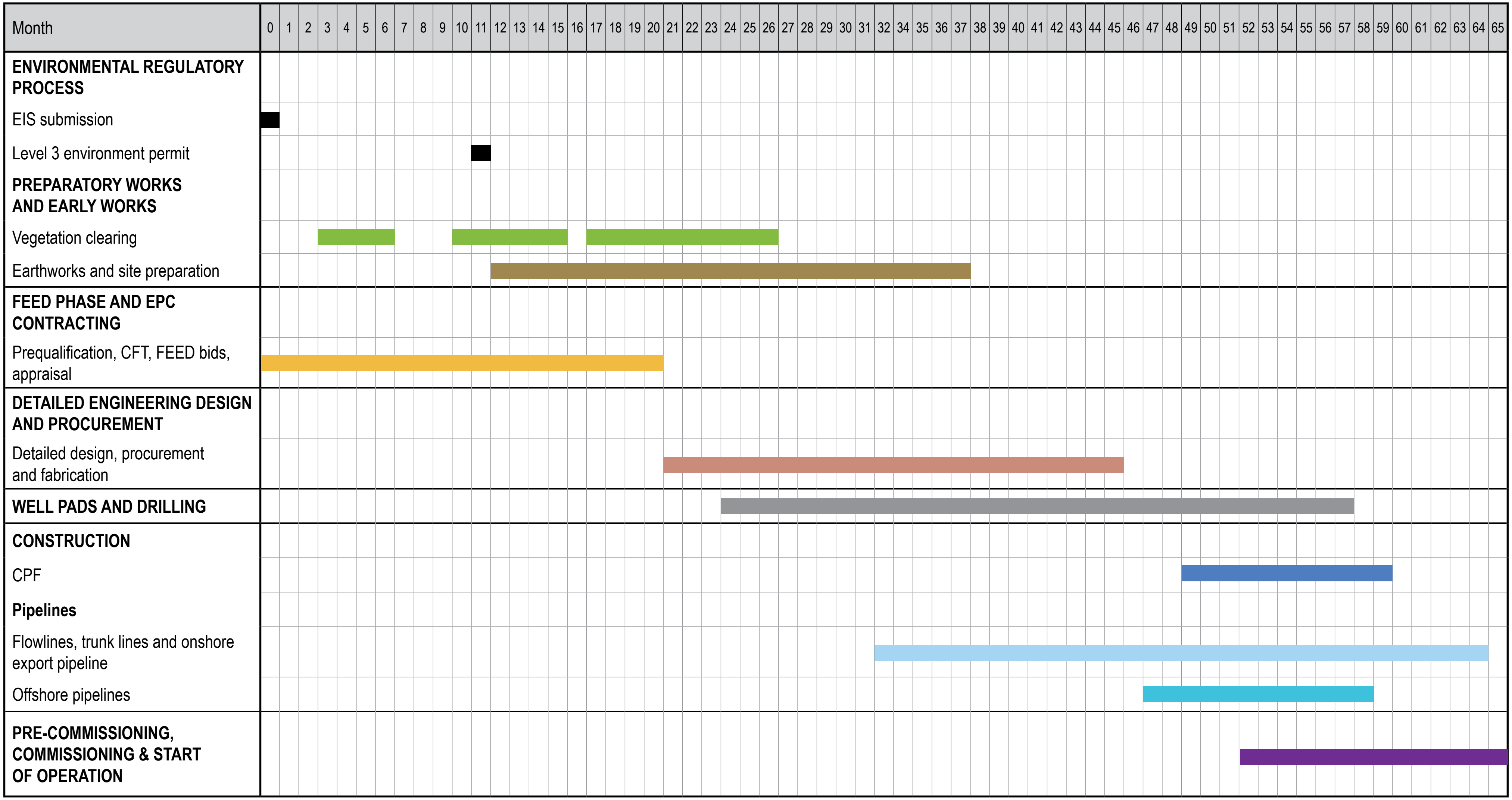
FIGURE 4.14



CFT	Call for tender
CPF	Central processing facility
EPC	Engineering, procurement, construction
FEED	Front-end engineering design

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on the near final proposed siting and alignment is available. The surveys will be conducted on foot, and the collected information will be recorded in the Project's geographic information system for use in preparing detailed site-scale designs and environmental and social management plans. Areas to be avoided or to be subject to specific mitigation measures will be demarcated in the field, where practicable.

4.10.2.2 Surveying

All sites proposed for infrastructure construction will be surveyed and demarcated to confirm they avoid, to the extent practicable, significant cultural and biodiversity areas and to reconcile other construction constraints encountered. Demarcating areas to be cleared and confining traffic to designated access ways and laydown areas will minimize the extent of site clearing and incidental site disturbance.

4.10.2.3 Archaeological Clearance

All areas disturbed by the Project will undergo a site archaeological clearance survey, and selective subsurface salvage and recording of artefact material where required. The survey and any salvage work will be conducted under a permit obtained from and in consultation with the PNG National Museum and Art Gallery, and will involve engaging with Project-affected communities on appropriate management and mitigation measures.

4.10.2.4 Sediment and Erosion Control

All facilities and non-linear infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. The drainage systems will divert clean surface water runoff away from areas to be disturbed and will collect sediment-laden water from disturbed areas in sediment traps, sediment retention ponds or similar structures prior to discharge.

Sediment retention ponds will be designed to accommodate the high rainfall and will be based on a 100-yr storm event. The size of each sediment settlement pond will be a function of the size of the catchment draining to that pond and will be designed to provide sufficient volume and residence time for sediment settling prior to the overflow discharging from the site. The sediment retention ponds will be inspected after major rain events and will be excavated or cleared regularly to maintain storage volumes at optimal capacity. Material removed from the sediment retention ponds is not expected to be contaminated and can be used on site as required or taken to a Project spoil area. Controlled release of water from sediment retention ponds will be in accordance with the requirements of the relevant environment permit. Erosion control structures will be installed, as required, along access ways and pipeline ROWs that are near streams and rivers.

4.10.2.5 Equipment Mobilization

Construction equipment will be transported to the Logistics Base and from there to the relevant worksite (see Section 4.9). It will then be moved to successive areas as the need arises.

4.10.2.6 Vegetation Clearing

After demarcating the site (see Section 4.10.2.1), the site will be cleared to the designed dimensions. This will involve:

- Clearing vegetation and grubbing stumps. Vegetation that is cut and not grubbed will be cut close to the ground without striking the earth, where practicable.

- Stockpiling timber and woody vegetation not used for construction purposes at the edge of the site or along the side of access ways.
- Clearing, where practicable, merchantable timber for potential sale.
- Pushing cut vegetation to the sides of the cleared areas. Some may be stockpiled for mulching, soil stabilization or rehabilitation works.

4.10.2.7 Grading and Excavation

Earthworks

Sites will be graded and excavated to the designed level and slope to provide a base for the infrastructure. Each wellpad will be a levelled area, covered with gravel and surrounded by a drainage ditch and a fence. Where necessary, concrete slabs will be located around the parts of the pad where drilling equipment will be temporarily located.

Grading activities will use front-end loaders, backhoes, bulldozers, motor graders, hydraulic excavators, rollers and dump trucks. Water trucks, water sprays or dust suppressants will be used as necessary to manage dust. Sites will be trimmed to final grade and compacted. During grading of the non-linear infrastructure sites, and where practicable for linear infrastructure, topsoil (i.e., the top layer of fertile soil, including all plant matter that has not been cleared) will be progressively stripped and either used immediately in rehabilitation works or stockpiled separately for subsequent use in rehabilitation works on the site. Topsoil will be respread over the final surfaces of areas designated for active rehabilitation and landscaping to support natural vegetation regrowth, i.e., regeneration. TEP PNG will avoid sidecasting excavated cut spoil material wherever practical. Excavated material will be used as fill where suitable; and any surplus spoil will be deposited in designated spoil areas in PRL-15. Despite maximizing the reuse of cut material, some imported and quarried material will be required.

The quantities of earthen excavated material, backfill material, spoil and quarried material requirements for the construction of the CPF and wellpads are provided in Table 4.10. Quantities for the flowlines, trunklines and onshore export pipelines are excluded as these will be confirmed during FEED. Preliminary studies for infield flowlines and the trunklines indicate that there will be 3 million m^3 of cut material and 2.3 million m^3 of fill material. Similarly, studies for the onshore export pipelines estimate that there will be 1.3 million m^3 of cut material and 2.5 million m^3 of fill for pipeline padding and fill (geotechnical testing will be undertaken to confirm the quality of the material required). In addition, 0.5 million m^3 of fill material will be required for construction platforms for the Purari River crossing horizontal directional drilling site, valve stations and pipe yards. The selected quarries are described in Section 4.8.4.

Table 4.10 – Quantities of Excavated and Fill Materials

Component	Total Volume of Cut (m^3)	Total Volume of Reuse Material (m^3)*	Total Volume of Spoil (Disposal) (m^3)*	Quarried (Fill) Material (m^3)		
				Herd Base Quarries	Local Quarry	Other Quarries#
ANT-10 wellpad	431,986	48,822	421,480	–	139,027	194
ANT-11 wellpad	14,806	962	15,228	–	31,265	92
ELK-10 wellpad	119,836	1,077	130,634	–	15,049	69
CPF accommodation area	226,883	26,728	220,170	–	–	3,393
CPF and Road R1	2,313,548	1,284,279	1,132,195	–	–	20,135
Road R2	96,951	31,787	71,680	–	–	5,652
Road R4	299,343	188,570	121,850	–	–	21,940
Road R5	984,006	530,067	499,333	91,113		131,915
Road R6	270,436	59,092	232,479	10,251	62,779	–
Road R7	1,212,001	25,548	1,305,098	32,760	28,651	179,362
Logistics Base	106,500	66,000	44,550	8,183	–	4,723
Purari Airstrip extension	100,620	–	110,682†	80,039	–	10,844
Total**	**6,176,916**	**2,262,932**	**4,194,697**	**222,346**	**276,771**	**378,319**

* Value multiplied by a bulk factor of 1.1 to account for expansion.
# Material imported from outside the Project area and transported to site by barge. The quarries to be used will be defined during FEED.
† A potential disposal site will be located on the south bank of the Purari River. Its location will be determined during FEED.
** The total volume of cut material equals the sum of the total volume of spoil, multiplied by 0.9 to account for the bulk factor, and the total volume of reuse material. Quarried material is required to cover the needs that are not provided for by the cut material.

Activities Involving Explosives

Explosives may be used during construction activities such as blasting for quarrying and clearing rocky areas for infrastructure development, and seismic surveys. Explosive requirements and potential locations where blasting may be necessary will be determined during FEED and following detailed geotechnical assessments of specific development sites. Explosives management, including authorization, type, procurement, transportation, use, storage, disposal, recording, safety and security, will be undertaken according to PNG laws and regulations, and following TOTAL's general specifications.

Spoil Disposal

The reuse of excavated material will be maximized (see Table 4.10); however, some spoil will be generated that needs to be disposed of. TEP PNG has identified locations, considering seismic hazards, where excess material will be disposed of along roads in shallow areas for stability, while limiting haulage to an average of 3.8 km. These disposal sites are listed in Table 4.11.

The disposal areas will allow excess spoil to be disposed of in a controlled manner. Each disposal site will have sediment controls and drainage to manage water and erosion. Excavated material will be treated with a binding agent to improve its handling ability and to minimize sediment loss during haulage and placement activities.

Table 4.11 – Spoil Disposal Sites

Component	Disposal Site	Area (ha)	Volume to be Disposed of (m^3)	Maximum Capacity of Disposal Site (m^3)
CPF, operations camp and Road R1	CPF-01	10.2	1,017,939	1,073,383*
	CPF-02	3.3	334,426	515,100
Road R2 and Logistics Base	R02-01	1.2	116,230	325,740
Road R4	R04-01	1.7	121,850	404,136*
Road R5	R05-01 to 05-16	7.0 (18.4)	499,333 (1,331,685)	1,000,000 (4,904,037*)
ANT-10	R05-16	4.4	421,480	564,710
ANT-11 and Road R6	R06-01/02	3.5	247,707	257,789
Road R7	R07-01 to R07-08	18.6 (30.2)	1,305,098 (2,113,064)	1,700,000 (2,773,310#)
ELK-10	R07-09	1.7	130,634	171,010
Total		**72.9**	**5,713,165**	**10,585,079**

Notes: Numbers in brackets reflect initial volume calculations used for the impact assessment undertaken in Chapters 11 to 17 and which have been subsequently optimized in pre-Project design. * Volume is from 3D modeling. # Of which 84,610 m^3 of the volume is from 3D modeling.

4.10.2.8 Site Clean-up and Rehabilitation

Following construction, all sites will be cleaned up and rehabilitated where required. Site clean-up activities feature:

- Removing and disposing of all hazardous waste from the site and documenting the process in accordance with local laws and the Project waste management plan.
- Removing surplus material and scrap, unless otherwise identified for retention, for recycling in accordance with the Project waste management plan.
- Removing any temporary buildings from the site.
- Removing all construction equipment, including all equipment owned, leased or rented by contractors.
- Undertaking site restoration, which will involve all or any of the following:
  - Site clean-up. The site will be cleaned of all residual debris. Pits for septic systems will be emptied, neutralized with lime, covered with dirt and compacted.
  - Soil remediation and rehabilitation. Any soil found to be contaminated by hydrocarbons will be managed in accordance with the Project's soil contamination plan.
  - Revegetation. Where soil has been compacted by Project activities, the surface will be ripped to alleviate compaction and assist vegetation regeneration. After ripping, any topsoil and vegetation saved during grading will be spread to reduce the risk of erosion and to promote natural regeneration. Areas will be allowed to naturally regenerate except where active revegetation has been specifically identified during preconstruction surveys and FEED as being required.

4.10.3 Drilling

4.10.3.1 Drilling Program

Drilling will be carried out during one campaign from three wellpads as follows:

- ELK-10 wellpad: one producer well (which will be used later as an acid gas injection well).
- ANT-10 wellpad: seven gas producer wells.
- ANT-11 wellpad: one produced water/acid gas liquid effluent injection well.

Drilling of each well is estimated to take approximately 70 days.

4.10.3.2 Wellpad Preparation

ANT-10 will be a new wellpad, but ELK-10 and ANT-11 wellpads will be established on the existing Elk-1 and ANT-1 wellpads, respectively, which were developed during the exploration and appraisal phases (see Figure 1.3). Accordingly, new ground disturbance for site preparation works will be less than that needed to create three new wellpads. The site preparation for the new ANT-10 wellpad will comprise vegetation clearing, leveling and grading as described in Section 4.10.2. The wellpad will occupy approximately 5 ha. Some site preparation will be required to reuse the Elk-1 and ANT-1 wellpads, and this will comprise some vegetation clearing and earthworks; however, as each wellpad accommodates only one well, as for the original wellpad, the wellpad areas will not need to extend beyond the current boundaries. Once the access roads to the wellpads have been constructed (see Section 4.8.3), the wellpad production equipment will be transported to the site by road and installed. The drill rig will then be transported to the wellpad and drilling will commence.

4.10.3.3 Drilling Method

A general sequence for drilling the gas producer wells and the water injection well is as follows:

- A hole with a 27-inch diameter will be drilled to a depth of 100 m, and a 24-inch diameter casing will be inserted into the hole and cemented in place.
- This process will be repeated using progressively smaller diameter holes and casings as the well deepens. The casings line the hole as it is drilled through the formations. They prevent upper or unstable formations from caving in and either isolate different pressure zones or seal off high pressure zones from the surface, thereby minimizing the potential for a blowout. Casings also prevent fluid loss into or contamination of surrounding freshwater zones.
- When the well is drilled through the hydrocarbon-bearing strata, a pre-perforated production liner will be positioned in the hole to allow reservoir fluids (i.e., gas and condensate) to flow into the well.
- The process of drilling and installing casings and liners will be continued until the well reaches a depth of approximately 2,000 m for both Elk and Antelope wells.
- Tubing will then be lowered vertically into the well. The topmost tubing will be attached to a wellhead installed at the surface.

The drilling will use drilling mud, which will be continuously pumped into the well and back to the surface, as the well is drilled. The drilling mud will act as a lubricant and help keep the drill bit cool and clean. Drilling will generate shards of rock and sand, referred to as cuttings, which will become suspended in the mud and carried to the surface. The drilling will be performed using water-based mud. Oil-based muds and non-aqueous–based muds are favored at this stage, as they have less adverse environmental impact.

The Elk well will be vertical, and the upper 700 m of the Antelope wells will be vertical while the lower parts will have deviated trajectories. The well architecture is illustrated in Figure 4.15, and the diameters and depths of hole, casings and liners are indicated.

When drilling is completed, each well will be cleaned-up and a production test will be carried out. Well clean-up flushes out any debris in the well by allowing the reservoir fluids to flow in a controlled manner from the well. The production test will also allow the reservoir fluids to flow in a controlled manner, and the flow rates and pressure of the reservoir fluids will be monitored. The current plan is that the clean-up/production test will be performed by routing the reservoir fluids to the CPF as soon as they are available. This is considered feasible because earlier well tests carried out during the appraisal phase have found very low quantities of water in the reservoir fluids. Portable well test packages may be considered if the CPF has not been commissioned and is not ready to receive reservoir fluids.

4.10.3.4 Management of Cuttings

Shale shakers will be used to separate the drilling cuttings from the mud at the surface so the clean mud can be reused. The cuttings are then dewatered and mixed with cement to produce a stabilized product that will be disposed at the general waste landfill. Only small volumes of residual waste water are expected and this will be transported to the CPF for treatment, if required, prior to release in accordance with the environment permit. Reusing cuttings for surface grading will be considered if feasible. Cuttings will be managed within the wellpad footprint.

4.10.3.5 Drilling Camp

Key personnel in the drilling crew that must remain on site 24 hr/day are likely to be accommodated at a temporary drilling field camp at the existing ANT-5 wellpad, which was developed during the exploration and appraisal phases, while the balance of the drilling crew will commute form Herd Base.

Drilling field camps typically are designed to accommodate approximately 100 workers and occupy approximately 0.4 ha. They are equipped with portable accommodation units, food storage and preparation areas, a dining hall, recreational facilities, offices, a laundry and self-contained sanitary facilities. A portable diesel generator supplies power. The water source will most likely be that used for supplying water for the drilling operations. Potable water may be bottled or trucked in, eliminating the need for a water treatment plant at the remote location.

4.10.3.6 Water Supply

Water will be required to prepare the water-based mud used for drilling. Based on experience, approximately 200 m^3/day of water will be required to drill the appraisal wells, with occasional peaks of up to 1,300 m^3/day. Water is also needed to pressurize the drilling mud for well control purposes, and a flow rate of 100 m^3/day will be required. The total water demand during drilling will consequently be between 300 and 1,400 m^3/day.

Control of well pressure could be accidentally lost during the drilling; this is known as a blowout and could cause an uncontrolled flow of reservoir fluids from the well into the surrounding environment. The likelihood of this type of event occurring is very low; but if it was to occur, additional water would be needed to control any fire ignited by the blowout. For the ANT-10 wellpad, the nearby Boa Creek watercourse is expected to be able to provide enough water most of the time. So that sufficient water would be available during periods of low river flow, a temporary dam structure 5 m high, which will store 2,000 m^3 of water, will be constructed on the creek. In addition, a 1,000-m^3 water pit will be constructed adjacent to the wellpad. Both water storage sources will supply water for drilling and are being considered for controlling a well

GENERAL WELL ARCHITECTURE SCHEMATIC

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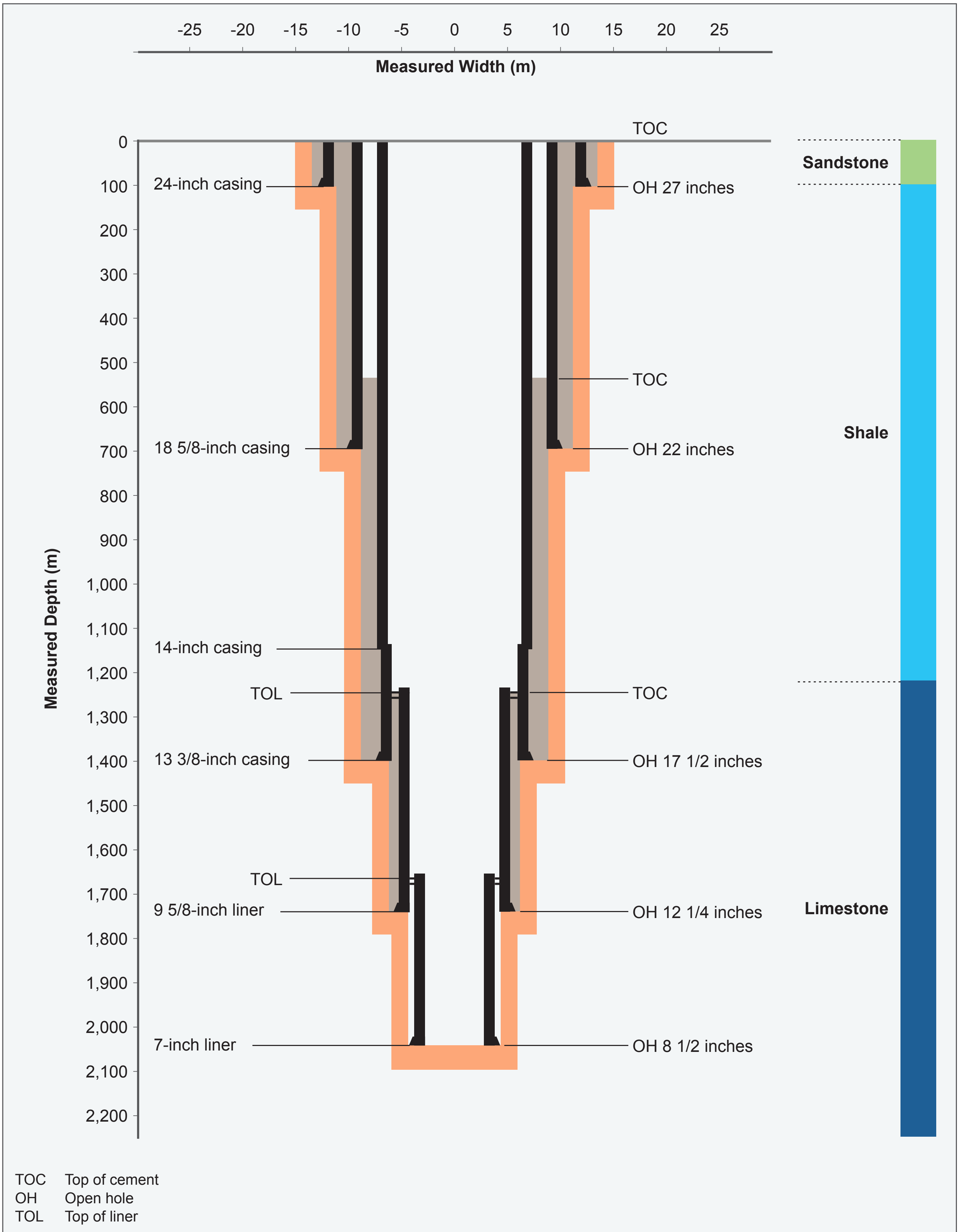
FIGURE 4.15



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blowout. The future use of the dams and their removal will be finalized during FEED. For the ELK-10 wellpad, the closest watercourse is not expected to be able to provide enough water; therefore a temporary dam structure, similar in size to that on Boa Creek, will be constructed on another watercourse approximately 1,500 m northeast of the pad, on the headwaters of Hou Creek (known locally as Woh Creek). Pipes and pumps will convey the water to the pad.

The final water extraction points and dam structure locations will be defined during FEED.

4.10.3.7 Equipment

The drilling rig site (Plate 4.5) will typically accommodate a main derrick and substructure, power supply system (i.e., generators), flare area, drilling fluids and cuttings management area, which will also cater for equipment discharges, water storage areas, fuel storage, drilling pipe racks, suction pit, circulatory system (i.e., pumps, drilling fluid tanks and shale shakers), tanks for bulk mud products, cement and extra water, storage and truck equipment movement area, well control system (e.g., blowout preventer), and well monitoring system.

Plate 4.5 – Example of a Project Wellpad and Drill Rig

Photo: TOTAL.

4.10.4 Constructing the Central Processing Facility and Associated Infrastructure

4.10.4.1 Constructing the CPF

Early Works

In addition to the common early works activities of vegetation clearing and some earthworks described in Section 4.10.2, the early works activities associated with the CPF will include:

- Establishing the temporary facilities that will be required for the earthworks, which include vehicle washdown facilities, diesel fuel storage and refueling station, waste management area, and water supply headworks.
- Developing other quarries (possibly off site) to provide the rocky material that cannot be provided by reusing cut material or from the Herd Base quarries (see Table 4.10 and Section 4.8.4).

Site Preparation

Site preparation involves constructing platforms to provide a level and solid base on which the infrastructure can be erected, constructing internal site access ways and installing the site perimeter fence. Standard earthmoving machinery will be used to prepare the site for the non-linear infrastructure. The amount of excavated and backfill material is identified in Table 4.10. Relatively small quantities of additional backfill material (e.g., 20,000 m^3), comprising granular fill that is unavailable in the excavated material or at the Herd Base quarries, will be barged to the site from outside the region. The worksite will be equipped with sediment control features, including retention ponds to accommodate the high rainfall at the site and to allow sediment particles to settle. These features will be designed during the detailed design phase (see Section 4.10.2.4).

Construction

The CPF will be constructed using modules that can be assembled off site and by modules that will have to be assembled on site. This approach is dictated by the navigability of the Purari River and by the module dimensions, which are limited to a maximum length of 50 m, width of 20 m and weight of 2,000 tonnes. The pre-assembled modules will be barged to the Logistics Base along the Purari River and then trucked by road to the site for installation. The unassembled modules will be assembled at the site. The CPF construction sequence will be based on the construction contractor’s construction execution plan. A possible construction execution plan would include the following elements:

- Civil works (e.g., concrete foundations).
- Steel, pipe and electrical installation.
- Equipment setting.
- Welding and radiography.
- Electrical and instrumentation installation.
- Insulation and application of coating materials.

4.10.4.2 Constructing the Logistics Base

The early works activities associated with the Logistics Base will include:

- Clearing vegetation.

- Installing a temporary ramp to allow the offloading of barges.
- Bulk earthworks requiring material from the Herd Base quarries and material from other quarries, (see Table 4.10 and Section 4.8.4) and spoil disposal.
- Constructing a quay and ramps for offloading modules. Dredging requirements will be determined during FEED; however, it is anticipated that dredging of approximately 6,000 m^3 of sand and sediment from the Purari River adjacent to the Logistics Base will be needed. Periodic maintenance dredging is considered unnecessary but may be undertaken if required. The dredged material disposal area will be defined during FEED and subjected to a pre-construction survey. Constructing the quay will involve sheet piling using 12-m long piles; piling will take approximately two months.

Site preparatory and construction activities are described in Section 4.10.2.

The Logistics Base structures will be constructed using a stick-build approach, i.e., it will be constructed using materials and equipment transported to the site and then installed. Equipment and materials will be barged to Herd Base via the Purari River.

4.10.4.3 Constructing the Purari Airstrip Extension

The pre-early works activities associated with the Purari Airstrip extension and new apron areas include clearing vegetation and earthworks, as described in Section 4.11.2. The total area of clearing will be 71 ha. In addition to vegetation clearing associated with the extension, vegetation clearing to achieve the requirements of the Code 2 visual approach will be undertaken. This will require clearing vegetation in the area of approach to minimize the obstacle limitation surfaces. This equates to approximately 33 ha (see Figure 4.11).

Cut and fill requirements are described in Table 4.10. The hard surfacing (e.g., gravel) for the runway and new apron areas will be laid down and the new passenger and firefighting buildings (see Section 4.8.7) constructed. Any flown-in materials and workers will be transported across the Purari River by barge (see Section 4.9.2.1).

4.10.5 Constructing the Onshore Pipelines

4.10.5.1 Right of Way and Trench Characteristics

Right of Way

A construction easement, commonly referred to as a right of way (ROW), will be required for pipeline construction. Common early works activities for the onshore pipelines are described in Section 4.10.2.

Flowlines and trunklines will be installed in trenches in a corridor cleared of vegetation between ELK-10 (start of flowline) and ANT-10 (trunklines) and the CPF. The onshore sections of the export pipelines will be installed between the CPF and Orokolo Bay, where the pipeline enters the sea. The gas and condensate pipelines will be laid in the same trench. The pipelines’ ROW will be cleared of vegetation, and a running track will be constructed that follows the pipelines in the ROW. The running track will be used as an access road for maintenance during operations (Section 4.11.3.2). The running track/access road construction will occur concurrently with the pipeline installation. The pipeline construction contractor will design the running track/access road. Key characteristics of the ROWs are shown in Table 4.12.

Table 4.12 – Key Characteristics of the Pipeline ROWs

ROW	Start to End	Length (km)	ROW Width (m)	Number of Trenches	Pipe Arrangement
Elk flowline	ANT-10 to ELK-10	8.0	32	1	1 flowline (14" diameter)
Trunkline	ANT-10 to CPF	28.0	40	2	One trench with 1 trunkline (22" diameter) 14" diameter (Elk) flowline One trench with 1 trunkline (22" diameter) and a 4" diameter (water) flowline
Water injection flowline	CPF to ANT-11	3.1	32	1	1 flowline (4" diameter)
Onshore export pipelines	CPF to Orokolo Bay	60	35*	1	1 gas pipeline (40" diameter) and 1 condensate pipeline (10" diameter)

Notes: " : inches. * The width may need to be reduced to 16.1 m at some points due to spatial constraints and these locations will be defined during FEED.

Trench Characteristics

Typical trench characteristics are provided in Table 4.13.

Table 4.13 – Key Characteristics of Trenches in the ROW for Trunklines and Flowlines

ROW	Pipes in Trench*	Trench Depth (m)	Trench Width (m)	Distance Between Trenches (m)	Distance Between Pipes in Same Trench (m)	Depth of Pipe Below Surface (m)
Elk flowline	14" diameter	1.4	2.2	N/A	N/A	1.0
Trunkline	22" and 14" diameter	1.7	3.1	5	0.4	1.0
	22" and 4" diameter	1.7	3.0	5	0.4	1.0
Water injection flowline	4" diameter	1.4	2.2	N/A	N/A	1.0
Onshore export pipelines	40" and 10" diameter	2.3	4.1	N/A	0.4	1.0

Notes: * Each pipe is fitted with a fiber optic cable. An electric power cable is installed with one of the trunklines and with each flowline. N/A: Not applicable. " : inches.

Pipe Yards

Four pipe yards are planned to facilitate construction of the onshore export pipelines. These areas will be located along the export pipelines' route and will be used for pipe storage (Plate 4.6), workshops, and, for two of them (i.e., pipe yards 1 and 4), temporary construction camps. The selection of the pipe yard locations has considered topography, existing disturbance, proximity to the river and existing access tracks.

Pipe yard 1 is within Herd Base and will be used for the construction of the flowlines and trunklines between the wellpads and the CPF. The three other pipe yards (2, 3 and 4) are situated along the Purari River at strategic positions along the onshore export pipeline route, close to the river and accessible from both the river and from the export pipeline ROW (via the existing road or track network left behind from previous logging activities in the area). Temporary wharfing facilities will be constructed on the Purari River capable of accepting 1,500- to 2,000-tonne loads. Land requirements and associated vegetation clearing will be kept to a minimum. Sheet piling may be required to stabilize the river banks, but the design will be finalized during FEED. The wharfs will not be maintained after construction; however, there is potential for the infrastructure to be handed over to the community if there was interest. Pipe yard 4, which is the closest to the Purari River mouth, will include the main accommodation area (i.e., in a temporary construction camp) and the project management office for the construction of the onshore sections of the pipelines. The pipe yard locations and the pipeline construction camp are shown in Figure 4.6. Each pipe yard will occupy approximately 3 ha.

Plate 4.6 – Typical Pipe Yard Laydown Area

Photo: TOTAL.

4.10.5.2 General Onshore Pipeline Construction Activities

Construction Sequence

The onshore pipeline construction activities described in the following subsections are typically performed in the following sequence (Plate 4.7):

- ROW survey, environmental and social clearance surveys.
- Clearing and grading of the ROW and construction of the running track/access road, which is in the pipeline ROW.
- ROW trench excavation.
- Pipe transport, stringing, welding, bending and non-destructive examination.
- Pipeline joint coating and inspection.
- Pipe lowering-in and tie-in, backfilling and hydrostatic testing.
- Reinstating the ROW and installing cathodic protection.

Plate 4.7 – Typical Pipeline Installation Activities

A. Grading. Photo: TOTAL.

B. Pipeline laying spread. Photo: TOTAL.

C. Stringing. Photo: TOTAL.

D. Bending. Photo: TOTAL.

E. Tie in. Photo: ERIAS Group.

F. ROW reinstatement. Photo: TOTAL.

Vegetation clearing will take 11 months followed by 9 months of ROW preparation and pipeline installation. Each ROW will be open for approximately 9 to 11 months, i.e., the time between topsoil clearing and respreading. The two trenches between ANT-10 and the CPF will be installed at the same time involving two pipeline spreads. Due to space constraints and ensuring that the newly-installed pipeline is not worked over, there will be a delay of approximately two to three days between each pipeline spread. The onshore export pipeline installation will involve one pipeline spread.

ROW Survey, Environmental Preconstruction Surveys, Clearing and Grading

Typical ROW and trench profiles are provided in Figures 4.16 and 4.17.

Early works construction activities will be undertaken as described in Section 4.10.2.

Clearing will include removing above-ground vegetation and rock from the pipeline ROW. Any trees and large shrubs requiring removal will be felled and stockpiled adjacent to the ROW. South of the Purari River, the volume of tall trees is not expected to be large as the area has been previously logged. Stockpiled vegetation will be conserved where practicable for reuse after construction to assist with erosion control, serve as mulch and provide a seed source for natural regeneration. Vegetation clearing will be in two stages; firstly a 5-m wide track will be manually cleared, and then the full width of the ROW will be cleared using machinery, with cut trees reused to reinforce the working tracks.

Grading of the ROWs will be carried out where practicable and will comprise the progressive clearing of topsoil from the ROW. The removed topsoil will be either used immediately as fill or stockpiled in spoil areas along the ROWs with appropriate stabilization and erosion control measures. During ROW rehabilitation, topsoil that has been set aside will be respread over areas designated for rehabilitation to support vegetation regrowth.

ROW Stripping and Trench Excavation

The pipeline trench will be excavated using mechanical shovels and other earthmoving equipment. The pre-FEED design is for a trench that is 4.1 m wide and 2.3 m deep; the pipes will be laid in the trench at a depth of 1 m (see Figure 4.17). The detailed trench design will be prepared during FEED, and depth and width may be modified slightly.

Trench depth will be sufficient to give a minimum depth of cover above the pipe in accordance with relevant industry standards. The depth of cover will be increased under roadways and watercourse crossings as appropriate.

In rocky areas, the bottom of the trench may be padded with granular material to provide a uniform bearing surface for the pipe, or a suitable mechanical pipe protection system may be applied.

Preliminary estimates of cut and fill material are provided in Section 4.10.2.7. Detailed estimates will be prepared during FEED, including determination of the quantities of cut material that can be reused as fill, and quantities of material to be supplied from quarries. Any excess spoil will be disposed of at spoil disposal sites which have additional capacity along roads R5, R6 and R7, which follow the ROWs for the flowlines and trunklines.

Pipe Transport, Stringing, Bending, Welding and Radiography

Tractor-trailer trucks will transport the line pipe to work sites from the pipe yards. The pipe will be unloaded and strung end-to-end alongside the trench (see Plate 4.7, photograph C). A hydraulic pipe-bending machine will be used to bend the pipe (see Plate 4.7, photograph D) to conform with the topography or to facilitate lateral changes in direction. Welding crews will clean and align the pipe ends, clamp them into place and weld them into sections of pipeline (called strings) up to 1 km long. Each weld will be inspected visually and by nondestructive testing methods (such as X-ray for a selection) for faults. Unsatisfactory welds will be repaired or cut out and rewelded.

Pipeline Lowering-in, Tie-in and Backfilling

Pipeline strings will be lowered into the trench using side-boom tractors, which will move progressively along the ROW. The pipeline strings will then be welded together, and the pipe

CROSS-SECTION OF TYPICAL TRUNKLINE AND FLOWLINE RIGHT OF WAY

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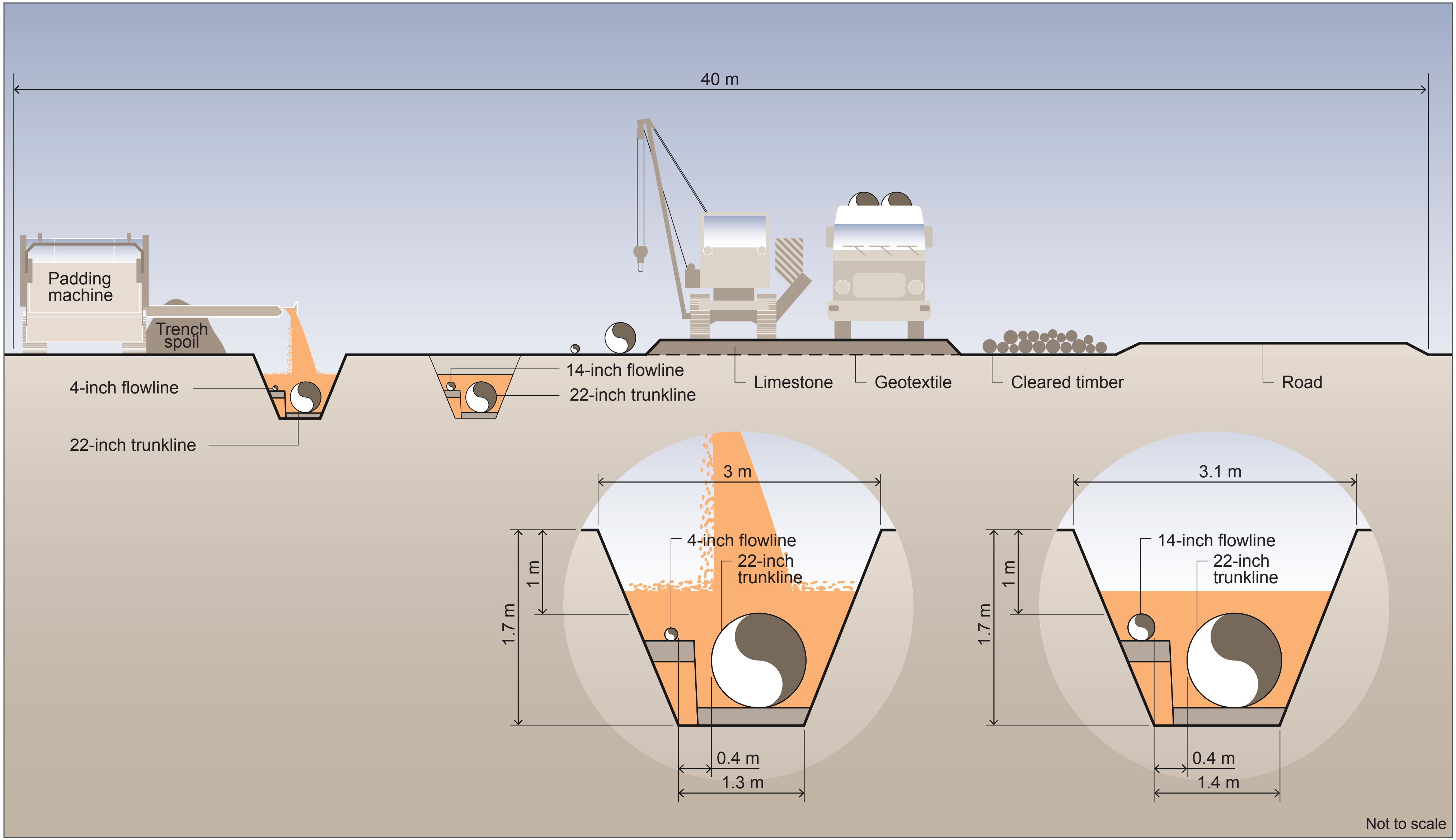
FIGURE 4.16



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CROSS-SECTION OF TYPICAL EXPORT PIPELINE RIGHT OF WAY

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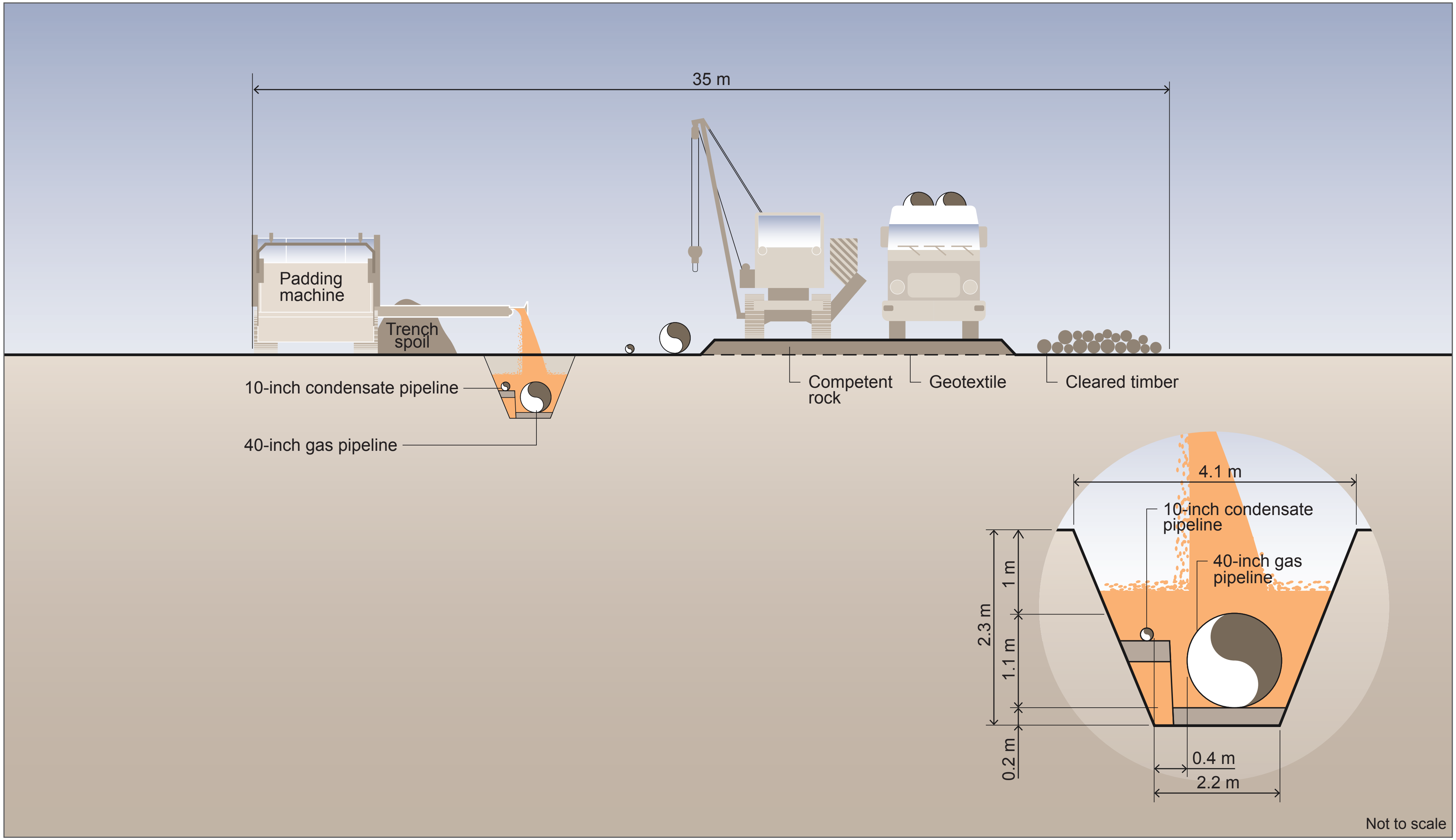
FIGURE 4.17



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padded with sand or soil where necessary. It may be necessary to dewater the trench prior to lowering the pipeline string into the trench. Any such water will be pumped out of the trench and discharged to the surroundings in accordance with relevant conditions of the Project's environment permit, including measures to prevent erosion and sediment discharge. Spoil excavated during trenching will be backfilled into the trench.

ROW Reinstatement and Rehabilitation

ROW clean-up and rehabilitation will be undertaken progressively, as soon as practicable after backfilling. Clean-up will involve removing all temporary infrastructure and machinery, while rehabilitation will reinstate a stable land surface, suitable for regeneration of natural vegetation. The ROW will be returned to its natural contour and grade to the extent practicable. Stockpiled topsoil will be respread over areas designated for rehabilitation and salvaged vegetation will be spread over the surface to control erosion and assist in natural vegetation regeneration.

While a 35-m construction ROW is planned for the onshore export pipeline route, a narrower ROW is foreseen for the operations phase (Section 4.11.3). The access road will be maintained but not fenced, and vegetation will be allowed to grow back within the narrower operations ROW. Broader cleared areas will be maintained around the valve stations. Erosion and sediment control measures, such as diversion berms and sediment traps, will be put in place as appropriate.

Pipeline Cleaning, Gauging and Hydrotesting

Once buried, the pipeline will be cleaned, gauged, hydrotested, dewatered and dried.

The Project will determine the method for cleaning the pipeline. Typically, a series of pipeline scrapers each equipped with a brush would be introduced into the pipeline, propelled by a flow of water or compressed air. The cleaning action can be enhanced using water-based biodegradable cleaning gels.

Gauging checks the pipeline for deformation of the cross-section (ovality) and dents. It normally occurs concurrently with cleaning, with the penultimate scraper fitted with one or two aluminum gauging plates.

Hydrotesting involves pressurizing the pipeline to confirm weld integrity. The treated water used for cleaning is reused for the hydrotest process but will require topping up. The pipelines will be tested in sections, generally between valve sites. The preferred course of action is to recycle hydrotest water from one section of the pipe to another. If this is not feasible, hydrotest water will be discharged (see Hydrotest Waste Disposal).

Water will be used for cleaning and hydrotesting, and a small amount of an oxygen scavenger and biocide will be added to the water to prevent the pipeline corroding. Oxygen-scavenger chemicals, such as sodium sulfite, sodium bisulfite and ammonium bisulfite solutions, will be used to reduce the dissolved oxygen in the water to prevent pipe corrosion. A biocide will be used to prevent the development of bacteria that can produce hydrogen sulfide in anaerobic conditions. Water for hydrotesting the onshore pipelines is expected to be drawn from the Purari River at the Logistics Base, and will be filtered/treated as necessary to meet Project requirements for hydrotesting. The quantity of water required for hydrotesting is expected to be approximately equivalent to the total volume of the onshore pipelines as follows:

- Elk flowline: 3,800 m^3.
- Antelope trunkline 1: 7,200 m^3.
- Antelope trunkline 2: 7,200 m^3.
- Water injection flowline: 264 m^3.

- Condensate export pipeline: 3,500 m^3.
- Gas export pipeline: 47,000 m^3.

The total volume of hydrotesting water to be abstracted from the river is therefore approximately 69,000 m^3. Following hydrotesting, the pipeline is dewatered and dried.

Hydrotest Waste Disposal

Pipeline cleaning and testing will require disposal of solid matter removed from the pipeline and used hydrotest water. The former will comprise small volumes of rust and dirt, and will be disposed of as per the Project's waste management strategy (see Section 4.8.5). Hydrotest water will contain traces of corrosion inhibitors and biocides and will typically be safe to discharge to the environment. Once hydrotest water is no longer required, all hydrotest water will be tested to check compliance with the Project's environment permit and IFC Environmental, Health and Safety Guidelines, General and Onshore Oil and Gas Development (IFC, 2012) and then discharged at a controlled rate to a site in accordance with the Project's environment permit. The discharge locations and discharge rates will be defined during the FEED. Hydrotest water will be discharged over protective riprap or a similar energy dissipater to reduce the potential for erosion at the discharge point. The hydrotest water volumes required are indicated in the previous section (i.e., Pipeline Cleaning, Gauging and Hydrotesting).

Gas and Condensate Introduction

Gas and condensate will be introduced into the pipelines after testing has been completed and all equipment is operational. When gas or condensate is introduced at one end of the pipeline, the other end of the pipeline will be vented to the atmosphere and monitored until all the air in the pipeline has been displaced.

4.10.5.3 Special Onshore Construction

Specialist crews will be used to handle complex, difficult or restricted-width areas where construction with standard equipment is not feasible.

Steep Terrain

Pipeline installation in steep areas (i.e., grades of 20 to 50%) typically requires single- or double-joint sections of pipe. These circumstances will require a specific study of slope stability. On steep or unstable slopes, heavy machinery will be secured by a cable and winch system to prevent rollovers and runaways.

Watercourse Crossings

Watercourses will be crossed by the pipeline using trenching (open-cut method), except for the Purari River, which will be crossed by horizontal directional drilling (HDD) described below. The open trench method for watercourse crossings will involve temporarily damming the watercourse and diverting water past the work area (Figure 4.18). At crossings the ROW width may be widened as necessary when approaching the crossing; however, this will be defined during the FEED. The additional ROW width, if necessary, will allow for storing the additional depth of material required to be excavated from the river bed and banks. Clearing at watercourse crossings will be determined by the watercourse size, but will typically be 1 ha for minor watercourses. Environmental management aspects during construction and rehabilitation include:

- Construction, to the extent practicable, when water levels are low.

TYPICAL PIPELINE WATERCOURSE CROSSING (OPEN TRENCH, FLUME PIPE METHOD)

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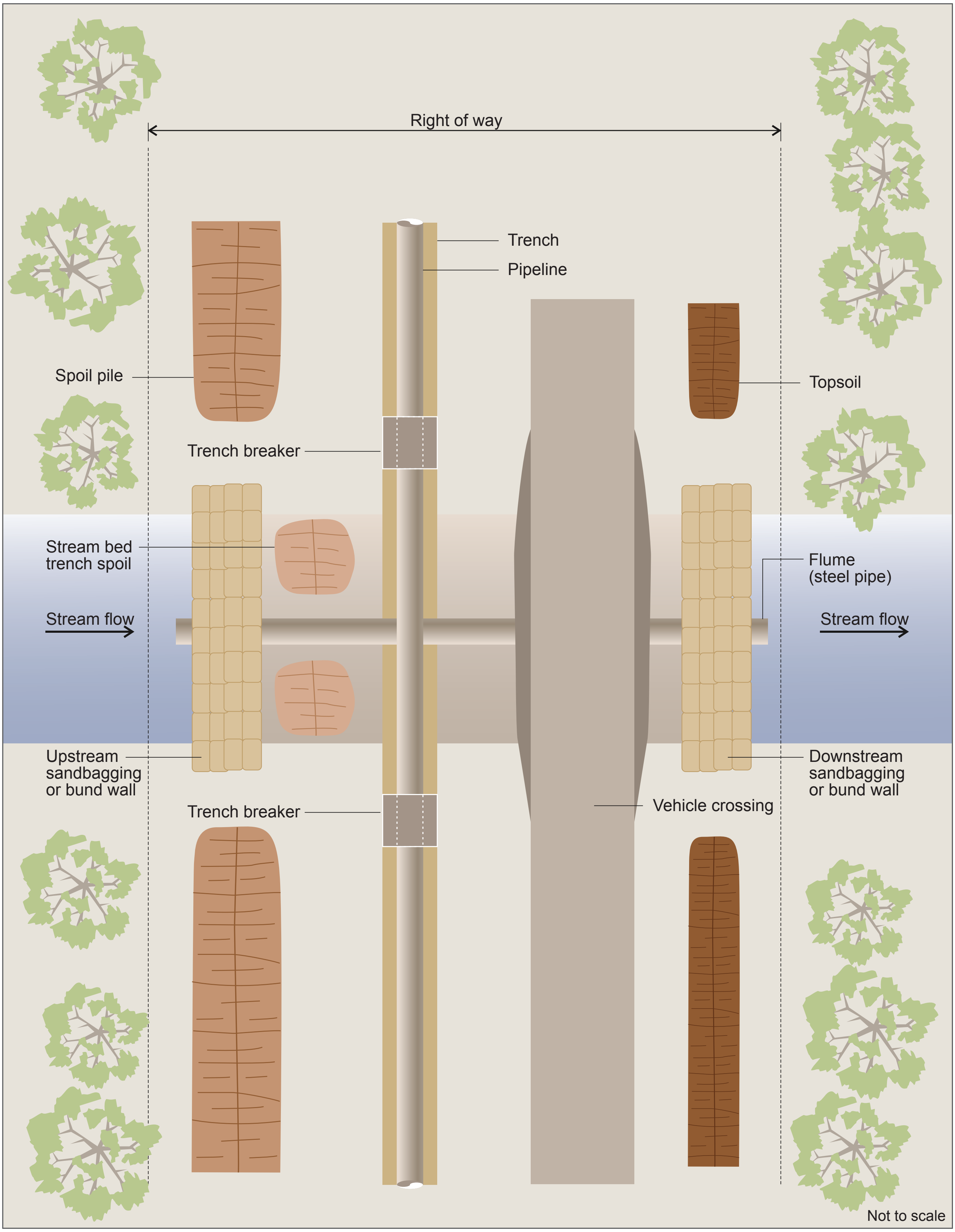
FIGURE 4.18



Source: CNS (2009)

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- Maintaining a vegetation buffer or reducing the width of the crossing disturbance.
- Pipe to be strung, welded, coated and tested ready for installation prior to watercourse trenching, to minimize the disturbance timeframe.
- A temporary vehicle crossing will be constructed across the river for construction traffic, with a flume pipe to allow continued watercourse flow.
- Erosion and sediment control measures will be installed as required (Figure 4.19).
- The trench through the watercourse will retain hard plugs at each bank until just prior to pipe installation.
- The pipe will be lowered in and backfilled immediately, perhaps with additional rock armoring if required.
- The original riverbed material replaced on the river bed to a depth equivalent to the original conditions.
- Immediately after backfill and prior to dismantling any flow diversion measures, watercourse banks will be reinstated and rehabilitated.

Horizontal Directional Drilling

Horizontal directional drilling (HDD) will be used for the pipeline crossing of the Purari River, as this river is too wide and the flow too fast for conventional trenching to be used. This is the only watercourse that is proposed to be crossed using this technique.

Areas, approximately 150 m by 75 m and 100 m by 50 m, will be cleared and graded on the rig and pipe side of the river, respectively (Figure 4.20; however, the temporary construction areas adjacent to the ROW will be rehabilitated after construction. The crossing will be established by first drilling a pilot hole approximately 24 to 25 m deep, which will be then progressively expanded to obtain the final diameter using different sized rotary cutting tools that are passed successively through the hole. The pipestring will then be pulled through the hole. If ground conditions are poor, a pre-welded casing may be first pulled into the hole prior to the pipestring. Figure 4.21 shows the typical stages of a HDD river crossing with tunneling.

At the HDD rig side, drilling muds and cuttings will be contained in a closed system that recirculates the drilling fluid through a holding tank (slurry mixing tank), while a series of shakers will be used to separate the drill cuttings before recirculating drilling fluid down the hole. Slurry containment pits will contain the drilling mud, and the HDD drill cuttings will be managed as for the cuttings generated during producer well drilling (see Section 4.10.3).

4.10.5.4 Constructing the Onshore Pipeline Infrastructure

Site preparation and rehabilitation associated with constructing the onshore pipeline infrastructure described in the previous sections, such as cathodic protection stations, valve stations, pipe yards and temporary accommodation camps for the construction workers, will be as described in Section 4.10.2. The use of pipeline markers will be defined during FEED.

PIPELINE WATERCOURSE CROSSING EROSION AND SEDIMENT CONTROL

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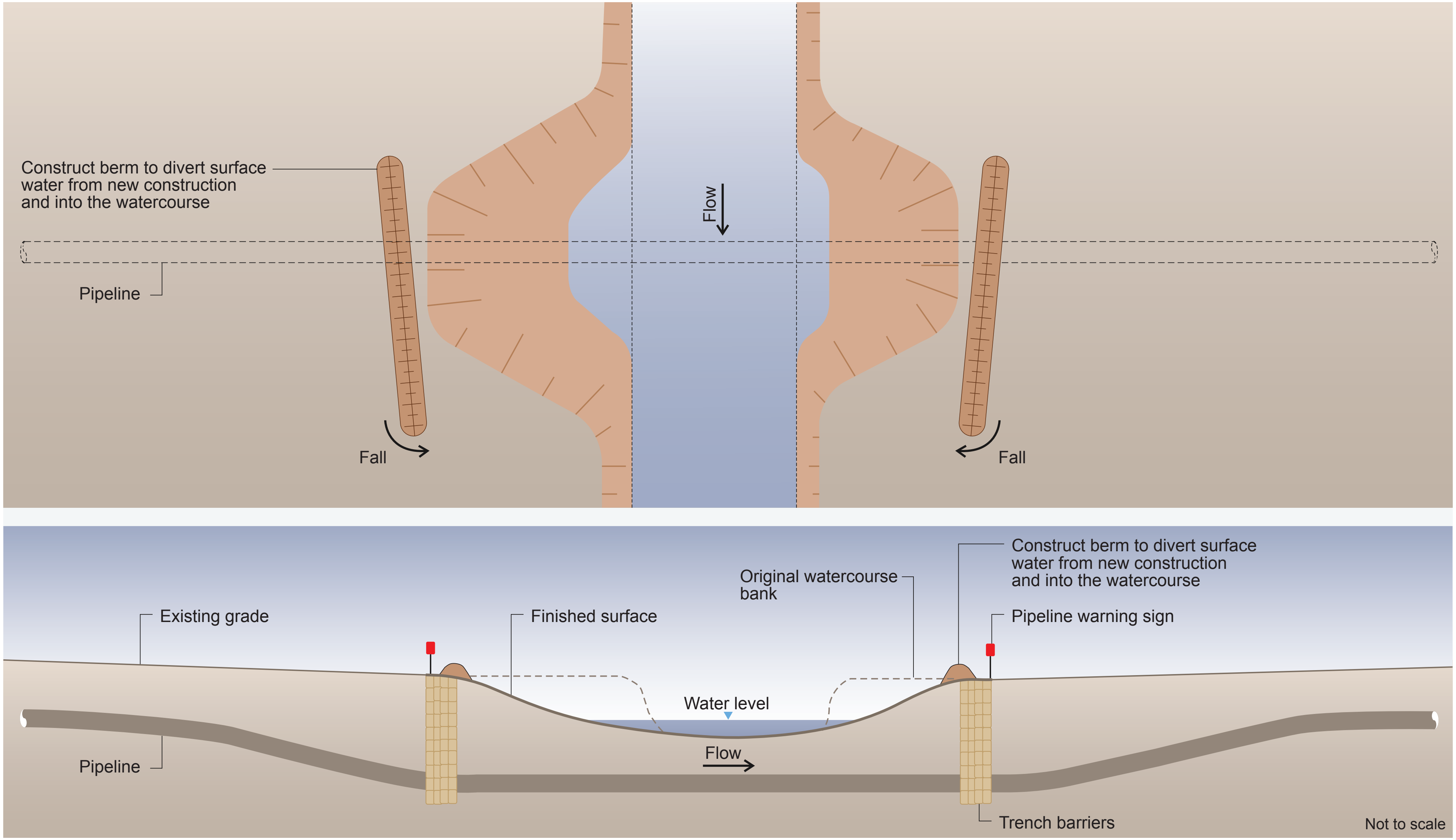
FIGURE 4.19



Source: CNS (2009)

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TYPICAL HORIZONTAL DIRECTIONAL DRILLING CONSTRUCTION SITE

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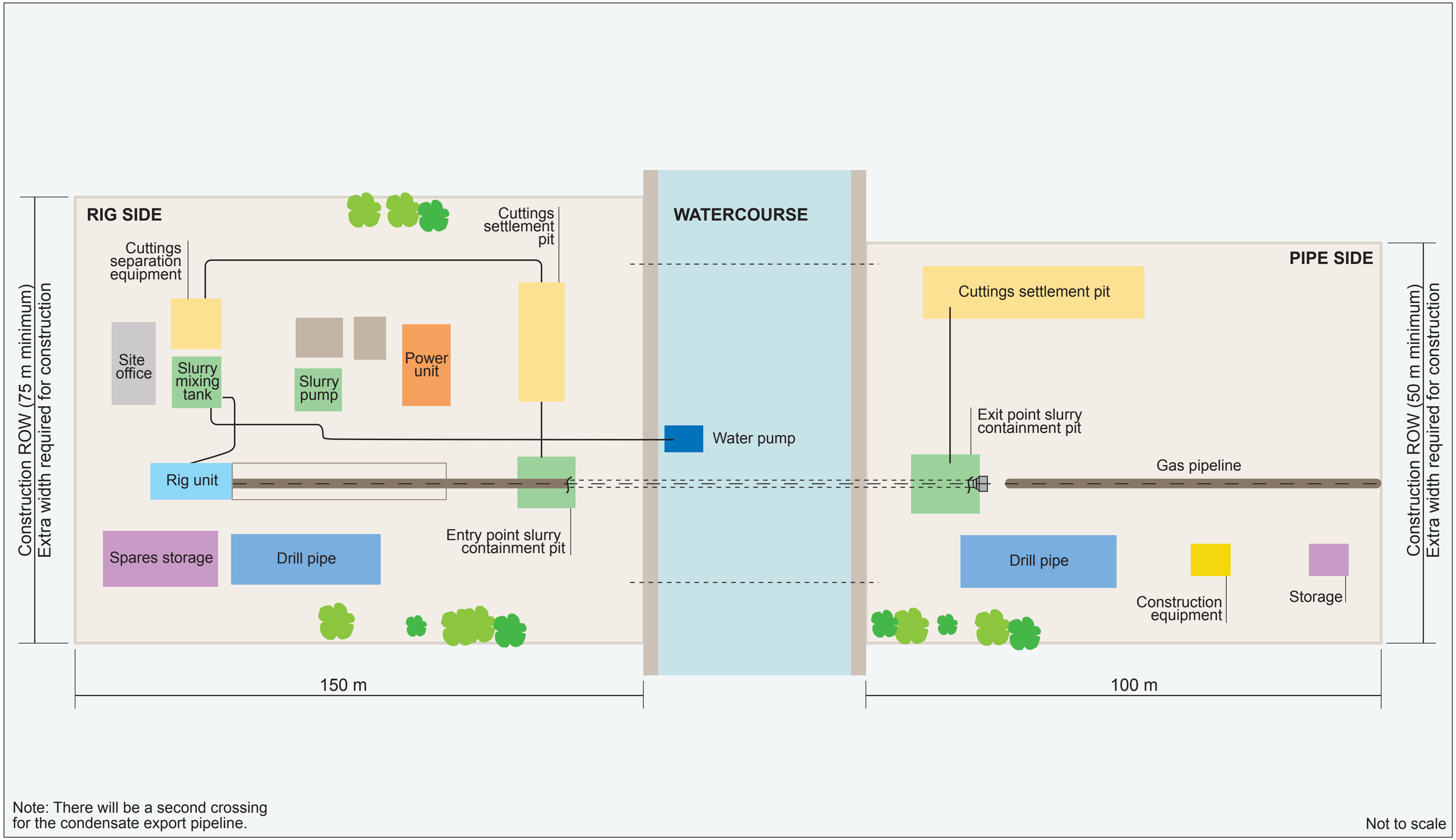
FIGURE 4.20



Source: CNS (2009)

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TYPICAL STAGES OF HORIZONTAL DIRECTIONAL DRILLING CONSTRUCTION

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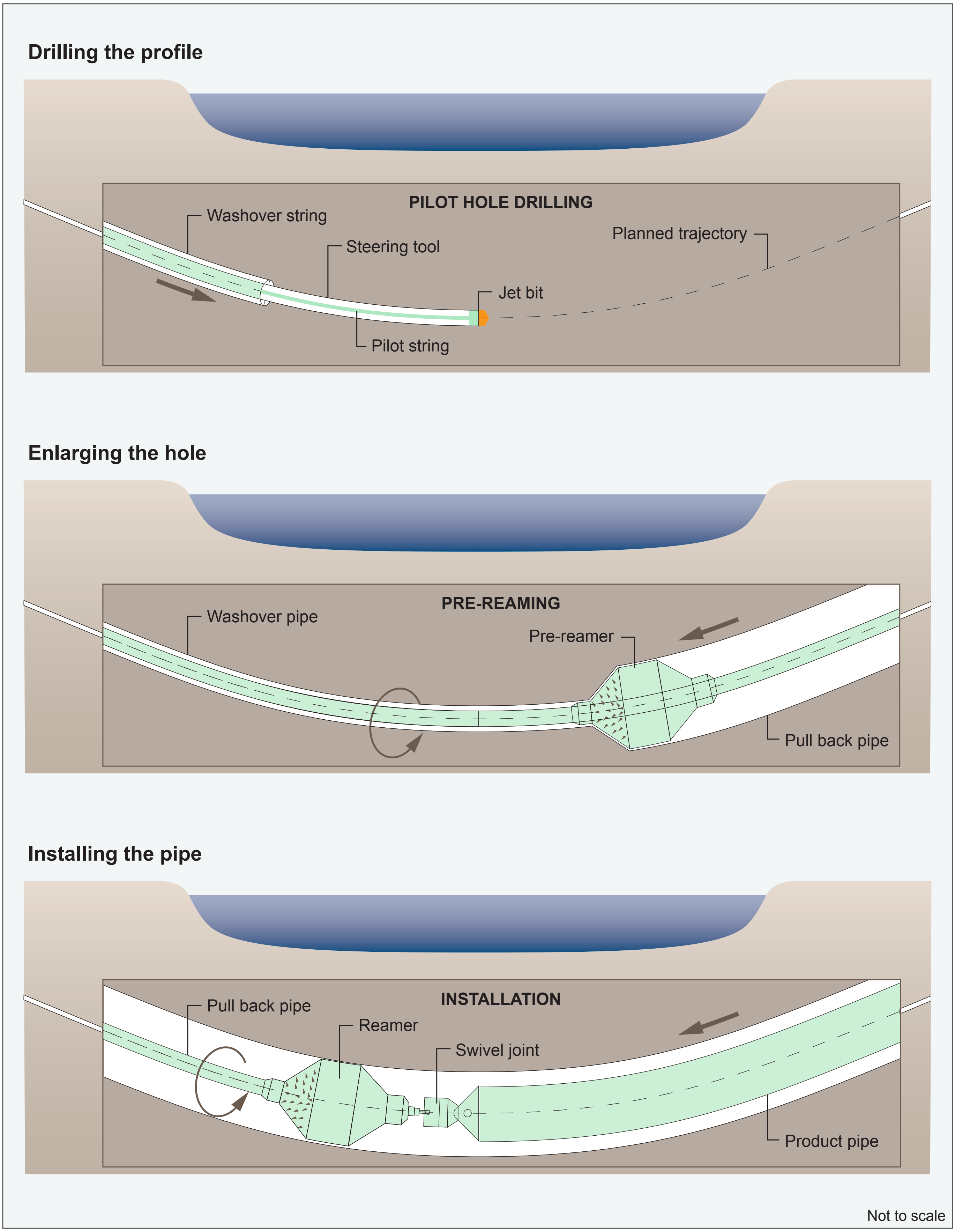
FIGURE 4.21



Source: CNS (2009)

4.10.6 Constructing the Offshore Pipelines

4.10.6.1 Shore Crossing Construction

Pipeline shore crossings at Orokolo Bay and Caution Bay will be constructed using an open trench method. The installation method and the definition of facilities and equipment necessary are yet to be defined; however, the pipelines will probably be installed using a shore-pull technique, whereby a winch situated onshore is used to pull the pipestring towards the shore from a laybarge anchored offshore. The laybarge will be anchored in water approximately 10 to 15 m deep and will be situated approximately 5 km offshore in Orokolo Bay and between 4 and 5 km offshore in Caution Bay, depending on the approach route adopted (Figure 4.22). This method will require that the trench be excavated prior to pipeline installation. It is likely that sheet piling would be used to keep the trench open during construction (Plate 4.8, photo A), with the piles cut to approximately 1 m below the seabed and backfilling to cover the trench following pipeline installation. Temporary construction areas adjacent to the ROW at the coast are likely to be required to accommodate the winch area, offices, space for truck circulation (Plate 4.8, photo B). The section of land-based pipeline will be welded to the offshore pipeline on the surface. The pipelay vessel will winch the end of the offshore pipeline and the land-based pipelines to the surface, weld them together and lower them back to the seabed.

Plate 4.8 – Examples of Shore Crossing

A. Typical shore crossing using sheet piling.
Photo: Jan De Nul Group.

B. Example of a wider right of way at a shore crossing.
Photo: Gorgon.

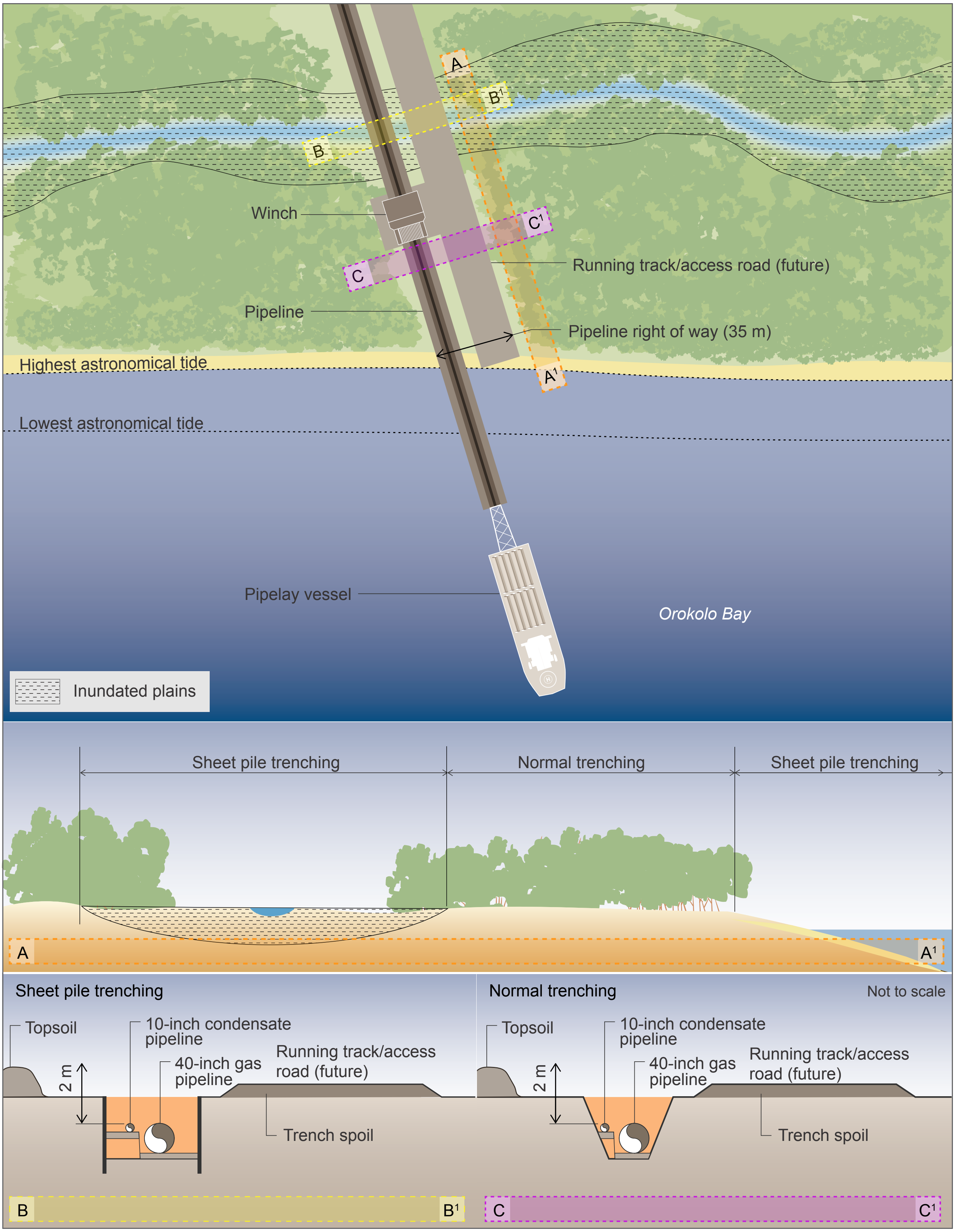
The pipe pull phase will be a 24-hr operation that will only last several days, during which time there will be additional lighting requirements.

The shore approach routes at Orokolo Bay and Caution Bay are shown in Figure 4.7. The approach at Caution Bay has been designed to avoid congested use areas, fishing zones and sensitive marine ecosystems (e.g., coral reefs, seagrass and mangroves), as much as possible while also addressing the potential for unexploded ordinance and the presence of the PNG LNG Gas Pipeline.

4.10.6.2 Offshore Pipeline Installation

The offshore condensate and gas pipelines will each be 260 km long and follow the same route. The distance between the gas and condensate pipelines may vary between 10 and 50 m, and an exclusion zone of typically 500 m shall be maintained around the pipelay vessel.

FIGURE 4.22



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Pipelaying

The pipeline will be installed on the seabed using a dedicated pipelaying vessel. Typically, the pipelaying process is as follows:

- Sections of pipe with anticorrosion material and concrete coating, for sections where this is necessary, are stacked on the pipelaying vessel.
- Pipe ends are prepared for welding.
- Successive joints of pipe are aligned and welded together.
- Welds are subject to non-destructive testing and repaired as necessary.
- Anti-corrosion material and a field joint infill are applied to the welded joints.
- The pipeline is lowered to the seafloor.

A constant tension will be applied to the pipeline as it is progressively lowered from the vessel to the seabed, to prevent the pipeline from bending excessively. Offshore pipelaying will be a continuous process. Barges, either towed by tugs or self-propelled, will bring the pipe and other supplies to the pipelaying vessel. An offshore pipelay spread typically comprises:

- A pipelaying vessel.
- A general supply vessel.
- Pipe supply vessels that continuously supply the pipelaying vessel.
- Bulk carriers that transport pipe to a location from which it can be loaded onto the pipe supply vessels.
- A dedicated survey vessel.
- An accommodation vessel.
- Crew boats to transfer workers to and from shore bases.

These vessel types and their roles in pipeline installation are described in the following sections.

Pipelaying Vessel

The pipeline will be installed using a heavy lift dynamic positioning vessel, which is also referred to as a laybarge. The pipeline contractor and laybarge will be defined during FEED. The laybarge will move forward along the pipelaying route using a dynamic positioning system, which will also avoid the need to use anchors. Plate 4.9 shows an example of a pipeline installation vessel.

Plate 4.9 – Typical Offshore Pipeline Installation Vessel

Photo: Saipem.

Support Vessels

General Supply Vessel

A general supply vessel will move continuously between the pipelaying vessel and the onshore support base to:

- Deliver general stores (e.g., food, water, fuel) and supplies (e.g., field joint-coating material, welding materials).
- Return waste that cannot be disposed of offshore or treated onboard will be managed, in compliance with national and international regulations.

A supply base, comprising facilities such as a wharf, crane, laydown area, ablutions and office facilities, may be required for the offshore pipeline construction activities. If so, existing facilities or facilities built for other Project purposes will be used and this will be defined during FEED.

Pipe Supply Vessel

Pipe will arrive with anti-corrosion coating on it and will be shipped to offshore holding locations as close as possible to the pipelaying vessel. Pipe supply vessels will then bring the pipe to the pipelaying vessel.

Survey Vessel

A dedicated survey vessel will accompany the pipelaying spread to conduct the pre-lay survey ahead of pipelaying, and subsequently survey the as-installed position of the pipeline.

Pipeline Stabilization and Protection

Stabilization

The pipeline will have a concrete coat for sections where this is needed for stability. The concrete coat stabilizes the pipeline on the seabed under all design environmental conditions. Additionally, the weight coating will provide protection against adverse natural or third-party impact. Due to the prevalence of soft deltaic sediments in the Gulf of Papua, the pipeline is expected to partially settle in these sediments. Where the seabed is hard or the sediments thin, the pipeline may remain largely on the seabed surface. Localized sections of the pipeline may become unsupported (i.e., freespan) if lateral currents are sufficiently strong to scour the seabed underneath the pipeline. TEP PNG has undertaken a freespan analysis considering seabed depressions. The proposed pipeline route has been modified to avoid areas where there is a freespan risk.

Protection from Vessels and Anchors

The offshore pipeline will be buried with a 1-m cover depth to the top of the pipe when located in water shallower than 20 m for protection against impacts from vessels and anchors.

For the shipping channel crossing offshore from the PNG LNG Facilities in Caution Bay, the pipeline will be trenched and buried with a 2.5 m cover depth from top of pipe. Rocks will also be placed over the seabed in the shipping lane in this area for 700 m. The cover depth to the top of the pipeline in other trenched sections in Orokolo Bay and Caution Bay will be defined during FEED.

Methods of Protection

Pipeline protection methods depend on seabed conditions and will be selected during FEED. Trenching in harder substrates using techniques such as dredging and cutting is typically undertaken before the pipe is laid, with the pipe laid directly into the trench. Trenching in softer substrates using techniques such as ploughing and jetting is typically undertaken almost simultaneously with pipelaying, with the soft sediment pushed back over the laid pipe and trench.

Dredging

Dredging may be required in shallow water and at the shore crossings. If dredging is necessary, one or both of the following dredging techniques may be used depending on seabed conditions:

- Suction dredging, which suits very fine muds and silts. The suction head operates close to the seabed and disturbed sediments tend to remain close to the suction head, with minimal amounts becoming suspended in the water. There are two methods of suction dredging:
  - Cutter suction: this method can effectively dredge most seabed types, including rocky material in water up to 30 m deep.
  - Trailing suction: this method is most effective for softer seabeds and water up to 80 m deep.
- Dipper or backhoe dredging, which uses an excavator attached to a barge. This method suits hard seabeds but is slow and best suited to short trenches in shallow water up to 15 m deep.

Cutting

Mechanical cutters use a series of chains or rotating disks to cut a trench and remove the excavated material. Cutters are usually self-propelled and produce trenches with steep sidewalls into which the pipestring can be laid. This method only suits hard seabeds, such as very stiff clays or rock. It may be used in Caution Bay.

Ploughing

This technique buries pipelines that have already been laid and is like conventional agricultural ploughing. A surface vessel pulls a plough to create a vee-shaped trench under the pipeline, into which the laid pipestring drops progressively. This method works in most seabeds, including sand, clay and low-strength rock. Ploughed trenches will typically backfill naturally.

Jetting

Jetting is suitable for sand and soft-to-medium clays but will not work in hard clay or rocky seabeds. High-pressure water jets dislodge sediment around the pipeline and deposit the sediment adjacent to the pipeline while the pipestring falls under its own weight through the liquefied sediments. Trenches excavated by jetting will normally backfill naturally.

Grout-bag Support

Grout bags are used to support a span that is greater than the design criteria allow. The bags are placed in position by divers and filled with a cement-grout slurry, which then sets.

Spoil

Trenching spoil disposal will be addressed during FEED and in association with the construction contractors when the construction method is determined.

Protection from Prawn Trawls

Partial self-burial of the pipeline in the soft sediments will reduce the risk of contact with trawl gear in the prawn trawling grounds of the Gulf of Papua. Moreover, the pipeline’s concrete coating, for the sections where it is used, will protect the pipeline from the adverse impact of the equipment typically used by prawn trawlers operating in the Gulf of Papua. There are no protrusions on the pipeline that could cause trawl gear to become snagged. Pipeline freespans (see Pipeline Stabilization and Protection above) can represent a snagging risk; however, the Project has undertaken a freespan analysis and modified the pipeline route to minimize this risk.

Pre-commissioning Activities

Post-installation Survey

A post-installation survey will confirm that the pipeline's installation conforms with design specifications. This may be achieved using video or bathymetric surveys, as permitted by environmental conditions. Pipeline freespans in excess of specification criteria will be rectified.

Navigation charts will be updated in consultation with the NMSA once the pipeline installation is finalized.

Cleaning, Gauging and Hydrotesting

Once installed, the pipeline will be cleaned, gauged, hydrotested, dewatered and dried before gas or condensate are introduced. Pipeline cleaning will follow the approach described for onshore pipelines (see Section 4.10.5.2) and will use either a freshwater- or seawater-based gel that is non-hazardous and biodegradable.

Water will be required for both the cleaning and hydrotest procedures. The water supply will be defined during FEED but will probably be drawn from the Purari River or from the sea at either the Orokolo Bay or Caution Bay shore crossing. The total volume of the offshore pipelines is 220,000 m^3. The volume discharged after cleaning may be two to three times this volume and the hydrotest water volume will be similar to the pipeline volume.

The hydrotest water discharge rate will depend on the capacity of the dewatering train, but would typically be 15 to 23 m^3/minute. Consequently, discharge could take six to ten days from one or more discharge lines. Discharge will be in accordance with the Project's environment permit and options may include the Purari River, Orokolo Bay or Caution Bay. Following removal of hydrotest water, the pipeline will be dried with compressed air until a specified dewpoint is reached at the outlet.

Clean-up and Regeneration of Shore Crossing Sites

The shore crossing sites will be cleared of construction equipment and unused construction materials. Materials that are unable to be recycled will be disposed of in accordance with the Project's waste management strategy.

Offshore Construction Crew and Accommodation

The offshore pipeline construction crews will be mainly accommodated offshore (i.e., on specific accommodation vessels). The specialized construction crew for the Orokolo Bay shore crossing may be partially accommodated at pipe yard 4 camp and this will be defined during FEED.

4.10.6.3 Special Offshore Construction

The Project pipelines will cross the PNG LNG Gas Pipeline approximately midway between Orokolo and Caution bays (see Figure 4.7). The crossing point has been identified:

- After conducting specific route selection studies driven by the need for the pipeline to be more than 5 km from the coastline.
- For the angle of crossing to be between 60 and 90°.
- For the overall Project pipeline length to be minimized and for potential seabed abnormalities and geohazards to be avoided.

At the crossing point, the Project pipelines will be raised 150 cm above the seabed and supported by several prefabricated mattresses or concrete engineered blocks that will be positioned on the seabed prior to pipeline installation. This will enable the Project pipelines to pass over the PNG LNG Gas Pipeline with a gap of 30 cm between the pipelines, avoiding direct contact, and without excessive bending.

Mattresses/blocks will be installed, leading up to and over, each side of the PNG LNG Gas Pipeline and will be installed at 15-m and 10-m intervals for the gas and condensate pipelines, respectively (Figure 4.23). The crossing of the Project gas pipeline will have a total span of 180 m and the crossing of the condensate pipeline will have a span of 64 m and no support will be within 2 m of the existing PNG LNG Gas Pipeline. This pipeline support system will also carry the fiber optic cable that will be installed in parallel with the gas and condensate pipelines. The PNG LNG Project fiber optic cable is buried parallel to the PNG LNG Gas Pipeline and consequently this system of crossing the latter should also prevent direct contact between the Project pipelines and the fiber optic cable.

4.11 Operations

4.11.1 Operating and Maintaining the Processing Facilities

4.11.1.1 Gas Processing Systems

A simplified description of the gas processing systems is provided in the following paragraphs and illustrated in Figure 4.24.

Gas-condensate Separation and Export

Receiving Facilities

Flowlines and trunklines will transport reservoir fluids comprising a gas-condensate mixture from the Elk and Antelope wellheads to the CPF. At the CPF, the reservoir fluids will flow into receiving facilities where the fluids from the two reservoirs will be commingled after Elk gas goes through a dedicated compression. The receiving facilities will comprise an inlet separator (i.e., a vapor-liquid separator), which separates the gas from the non-stabilized condensate. The gas will be routed through the gas processing units and the liquid routed to the condensate stabilization unit, where the produced water is separated from the condensate.

Gas Processing

The raw gas from the Elk and Antelope fields is expected to have slightly different compositions (see Section 4.2.2) but will be commingled at the receiving facilities and processed together after the Elk fluid goes through a dedicated compression. The raw gas contains carbon dioxide (CO_2) and hydrogen sulfide (H_2S), which are referred to as ‘acid gas’; however, the Elk gas contains lower concentrations of H_2S than the Antelope gas. The export gas specification requires an H_2S concentration of less than 3 ppm and a CO_2 concentration of less than 45 ppm. To achieve this, gas processing will remove the acid gas. The gas leaving the inlet separator will; therefore, be routed to an acid gas removal unit (AGRU; see Acid Gas Management). The processed gas leaving the AGRU will pass through a dewpoint unit[2] and will then be ready for export.

2 The dewpoint unit condenses part of the natural gas to a liquid state by cooling the gas below the dewpoint in a propane refrigeration loop.

SCHEMATIC OF THE PNG LNG PIPELINE CROSSING

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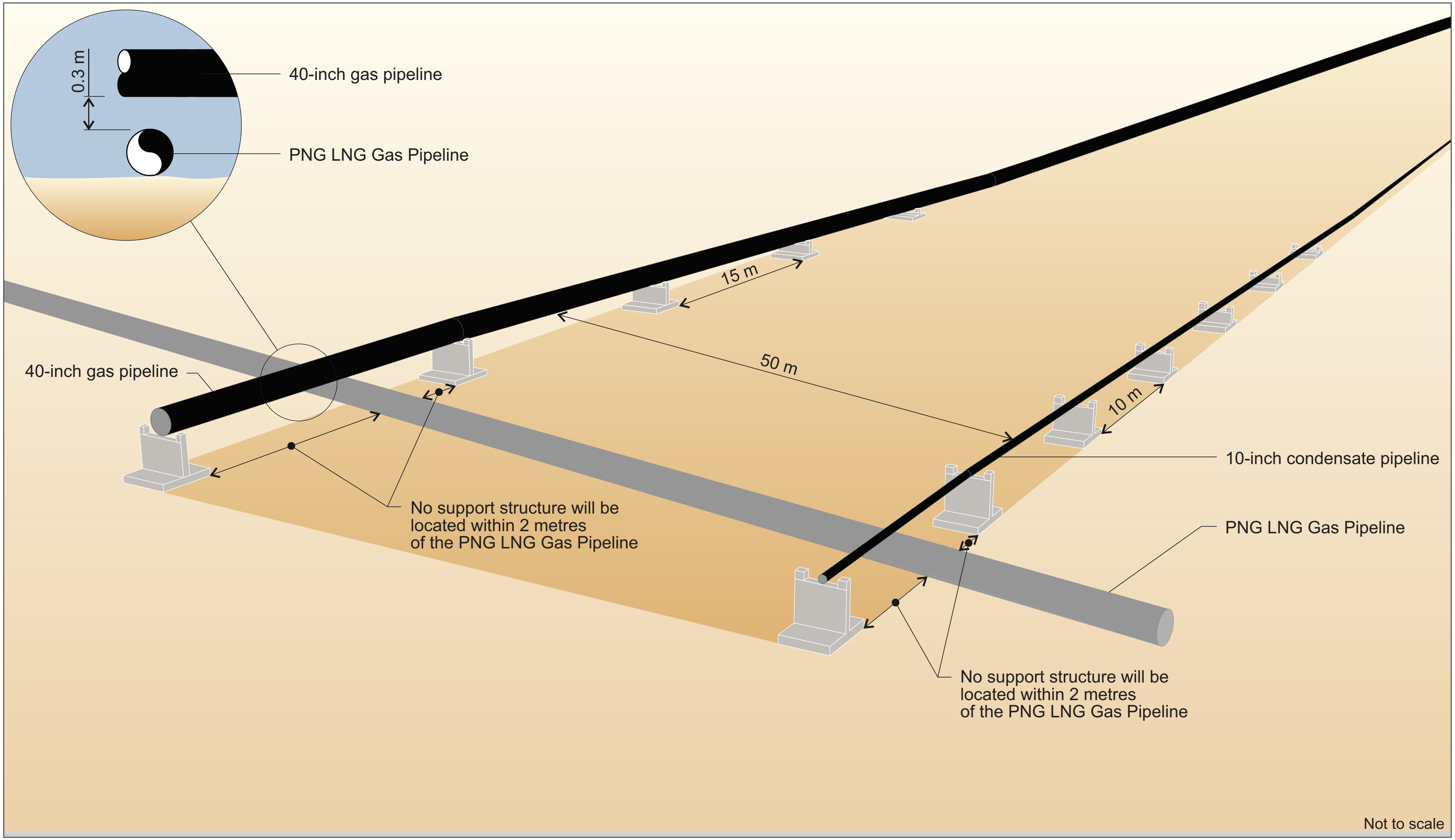
FIGURE 4.23



Note: Design of support structures will be finalised during front-end engineering design and will likely be concrete engineered supports (as pictured) or prefabricated mattresses. The support type will depend on the substrate present at the site.

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GAS PROCESSING SCHEMATIC

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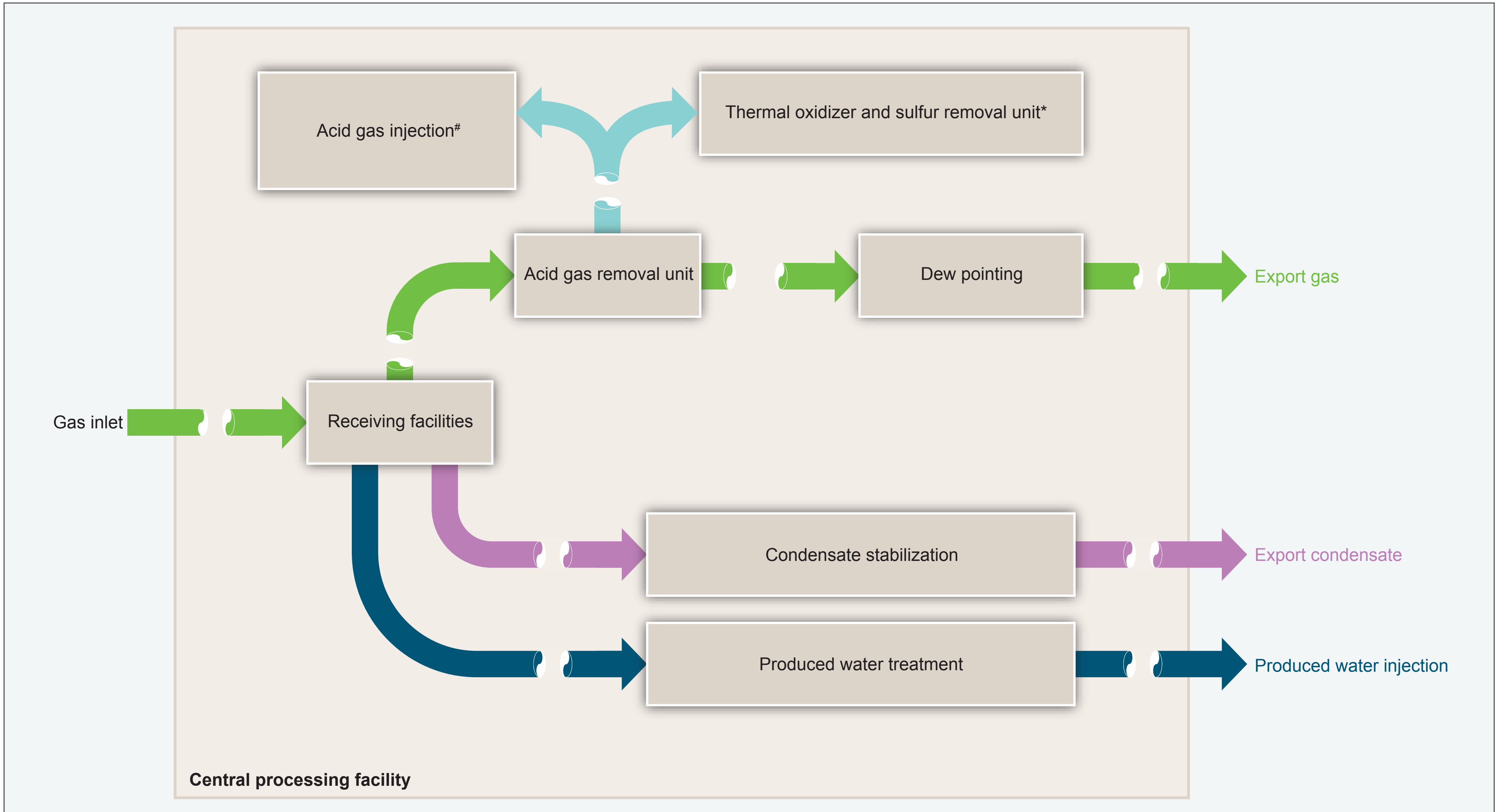
FIGURE 4.24



* Only until the Elk reservoir is depleted
\# After the Elk reservoir is depleted

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Gas Export

The processed gas leaving the dewpoint unit will be warmed using heat exchangers, it will pass through a gas export metering unit and will be conveyed to the export pipeline which will transport the gas to the LNG plant in Caution Bay.

Compression

For the first 10-year production period, the natural reservoir pressure will convey the gas from the Antelope reservoir to the CPF and from commingled gas to the LNG plant at Caution Bay, without the need for gas compression. Dedicated compression is required for the Elk flowline until the Elk reservoir is depleted so the pressure matches that of the Antelope reservoir. In subsequent years the Antelope reservoir pressure will decrease because of depleting reservoir fluids, thus requiring additional gas compression to boost the pressure of the gas that flows into the CPF. Consequently, the CPF facilities have been designed with areas for installing the additional compression units.

Condensate Stabilization and Export

Non-stabilized condensate that is separated from the gas in the inlet separator will be conveyed to the condensate stabilization unit. The unit will include a degassing drum and a stabilization column. Water separated from the condensate in the degassing drum will be routed to the produced water treatment unit. The stabilized condensate will be routed to the export pumps that will pump the condensate to the LNG plant at Caution Bay via the condensate export pipeline.

Acid Gas Management

Several acid gas management concepts were, and still are, being assessed that variously consider acid gas removal; these are described in more detail in Section 5.5.1. The concept presented in this section is representative of various concepts under investigation and is used to address air quality and GHG requirements (Chapter 15).

Acid Gas Removal

Gas processing would include removing H_2S and CO_2 from the raw gas using an AGRU (see Gas-condensate Separation and Export). The AGRU will consist principally of an amine absorption unit and an amine regeneration unit. The raw gas that leaves the receiving facilities will be contacted with an amine solution, which will absorb the H_2S and CO_2 gases. The gas from which the acid gases have been removed will be routed to the export facilities. The amine solution, now rich in H_2S and CO_2, will be routed to a regeneration unit where the solution will be heated using boiler-generated steam. This process will require 72 m^3/day of demineralized water that would be sourced from the Purari River. The acid gas will be released from the amine solution in the form of vapor, which would be routed to an acid gas injection unit. The regenerated amine would be reused in the amine absorption unit and wastewater generated by the condensation of the steam would be routed to a wastewater treatment plant.

Acid Gas Injection

Once the Elk reservoir has been depleted, it may be possible for acid gas removed from the raw gas using the AGRU to be disposed of by injecting it into the reservoir. The injection equipment will comprise two electric gas compressors, a low pressure unit and a high pressure unit (Section 4.11.1.2, Fuel Gas System). The compressed gas will be transported to the ELK-10 wellpad via the Elk trunkline where it will be injected into the reservoir using the ELK-10 well, which will be converted to a gas injection well. Mixing of the gas injected into the depleted Elk reservoir with the Antelope reservoir gas is unlikely to occur (see Section 4.2.2), as the two reservoirs are geologically segregated.

Thermal Oxidizer and Flue Gas Desulfurization

During at least the first four years of production when it may not be possible to dispose of acid gas by injection, acid gas from the AGRU will be treated using a thermal oxidizer and flue gas desulfurization process. This treatment will allow CO_2, separated from the export gas, to be discharged without releasing sulfur as H_2S. The flue gas desulfurization process uses a caustic soda wash to remove sulfide from the acid gas. The efficiency of this sulfur recovery process will be approximately 80 to 95%. The treatment process was selected following assessment of various sulfur recovery technologies and disposal options, which are still being optimized (see Chapter 5).

The treatment process involves incineration of acid gas in the thermal oxidizer to convert sulfur compounds, including H_2S, into sulfur dioxide (SO_2). Incineration will take place in a closed chamber.

A flue gas desulfurization process then remove the SO_2 from the flue gas using liquid caustic soda (NaOH) that is injected directly into the flue gas stream, which converts SO_2 to sulfite salts. This desulfurization process will be based on a pH control system, maintained between pH 6 and 7, which selectively removes SO_2 from the flue gas but leaves CO_2. The treated flue gas will be released to the atmosphere via a conventional stack. The liquid effluent containing the dissolved sulfite salts will be injected into the ANT-11 well, along with produced water from the condensate stabilization unit.

Approximately 16 m^3/day of NaOH will be required for the flue gas desulfurization. NaOH will be imported in liquid form from Australia to the AES base at Port Moresby. The liquid will be transported in offshore cargo carrying tanks (approximate capacity of 20 m^3) approved for the transport of hazardous liquids, i.e., compliant with International Organization for Standardization (ISO), International Maritime Organization (IMO) and International Maritime Dangerous Goods (IMDG) standards. The process will also require approximately 100 m^3/hr (2,400 m^3/day) of water for the AGRU and diluting the NaOH, which will be sourced from the Purari River. Most of this water is vaporized in the desulfurization process and reports in the treated flue gas. The volume of liquid effluent from the desulfurization process that will be injected into the ANT-11 well is expected be approximately 45 to 65 m^3/hr. This represents approximately 60 to 70% of the liquid volume injected into the reservoir, with the remaining 30 to 40% being treated produced water.

The liquid effluent from the desulfurization process will have near neutral pH (pH 6 to 7) and be at a temperature of about 80ºC prior to mixing with the produced water. It will mostly comprise water (90%), with the remaining volume comprising dissolved sodium bisulfite ($NaHSO_3$) (6.4%) and sodium sulfite (Na_2SO_3) (3.6%).

The treated flue gas from the desulfurization process will mainly comprise water, oxygen, nitrogen, CO_2, with traces of oxides of nitrogen, volatile organic compounds and SO_2.

Once the Elk reservoir has been depleted and acid gas injection commences, the thermal oxidizer and flue gas desulfurization processes would remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible.

Produced Water Management

No reservoir water is expected. Relatively small quantities (e.g., 3,000 barrels of water per day) of condensation water, produced during condensate stabilization, are expected. The selected management approach for the produced water is to inject it into the Antelope reservoir. Consequently, produced water separated from the condensate in the condensate stabilization process will be routed to a produced water treatment unit and the treated produced water piped to the ANT-11 wellpad. The produced water unit comprises a degassing drum and a flotation unit.

The oil concentration in the injected produced water will be less than 50 mg/L and total suspended solids will be less than 100 mg/L.

4.11.1.2 Utilities

Fuel Gas System

Part of the processed gas (e.g., 26.2 MMscfd) will be used as fuel to provide power at the CPF. High pressure (HP) fuel gas will be taken from the gas processing train downstream from the AGRU, while low pressure (LP) fuel gas will be taken from the condensate stabilization degassing drum. HP fuel gas will have hydrogen sulfide concentrations of less than 3 ppm. The main consumers of the HP fuel gas will be the power generation gas turbines and the amine regeneration boilers. The main consumer of LP fuel gas is likely to be the amine regeneration boilers and the thermal oxidizer.

Power Generation

The power demand for the CPF, wellheads and Logistics Base will be 38 MW. Gas turbines burning fuel gas will generate the required power at the CPF. Four turbines will be installed with one being in reserve and placed on standby. The main power consumers will comprise the various electrically-driven pumps and compressors at the CPF. A power cable laid in the trunkline/flowline ROW between the CPF and the wellpads will supply power to the wellpads from the CPF. The wellpad power demand is negligible compared to that of the CPF.

Permanent lighting is planned for facilities that will be constantly manned in the CPF and the Logistics Base.

Nitrogen Systems

Nitrogen will be required at the CPF for instruments and will be used as inert gas for purging equipment and maintaining an inert atmosphere in vessels and pipes for safety reasons. The nitrogen will be generated on site using a typical nitrogen generation unit.

Firewater System

The CPF will be equipped with fixed firewater systems to protect processing and storage facilities. The main system components will comprise ‘deluge’ systems, fire monitors and hydrants, firewater distribution network including pumps, and firewater storage tanks. The system will be designed to provide 845 m^3/hour of firewater for three hours and foam at a rate of 21 m^3/hour for one hour. The firewater storage capacity will be 3,000 m^3 and foam storage capacity will be 21 m^3.

Water Systems

Freshwater will be supplied to the CPF, accommodation buildings and utilities from the pumping station at the Logistics Base. The water will be pumped from the Purari River to the CPF through a PVC pipeline that will be laid in association with R2. The maximum water abstraction rate may be at least 2,500 m^3/day (additional requirements for pipeline hydrotesting are described in Section 4.10.5.2), which includes potable water (approximately 100 m^3/day) and process water (approximately 2,400 m^3/day). The water to be used as potable water will be filtered and treated. The remainder will be used as utility water, part of which will be demineralized water for the AGRU, dilution of the caustic soda and for condensate stabilization. The demineralized water system will comprise two 700-m^3 storage tanks and distribution pumps.

Utility and Instrument Air System

Typical industry utility and industrial air systems will be used, including air compressors, air drier and distribution networks. Valve operation will consume the majority of the instrument air. The main utility air consumer will be the purge gas rate on the power gas turbines, compressors and pumps.

Diesel Systems

The principle use of diesel will be during start-up of the processing facilities when no fuel gas is available to provide power. Some small temporary and mobile items of equipment will also be fueled with diesel during normal operation.

Heating Systems

Three boilers and waste heat recovery units installed in the power gas turbines will generate hot water from 145 to 170°C. This will be used as a heating medium for the amine regeneration reboilers (part of the AGRU) and the condensate stabilization unit.

Chemical Systems

Chemicals will be selected according to TOTAL's General Specification: Environmental Requirements for Project Design and E&P Activities (GS EP ENV 001) considering the following criteria:

- Lowest toxicity.
- Lowest bioaccumulation potential.
- Highest biodegradation.
- Chemicals subject to bans or phase-outs.

The chemicals necessary in the CPF include hydrate inhibitor, corrosion inhibitor, biocide, caustic soda and oxygen scavenger. Storage areas will have an impervious slab with a slope towards a gutter and drainage system. Appropriate secondary containment will also be installed and rainwater infiltration will be prevented from entering hazardous materials storage areas. Table 4.14 summarizes the key chemicals and other hazardous materials to be stored at the CPF, and their uses.

No hydrocarbon will be stored within 50 m of any well, unless it is stored in an appropriate operational storage tank with facilities in place to prevent any leakage or spillage from contacting the ground. Any spills or leaks will be directed away from the well.

Table 4.14 – Key Chemicals and Hazardous Materials Use

<table>
<tr><th>Chemical</th><th>Use</th><th>Type of Storage</th><th>Total Capacity (m^3)</th></tr>
<tr><td>Corrosion inhibitor</td><td>Prevents corrosion. Injected into the production manifold at the production wellpads. Transported in drums or cubi-containers by road to the wellheads where a remote injection system is installed.</td><td>Tank</td><td>34</td></tr>
<tr><td>Monoethylene glycol (MEG)</td><td rowspan="2">Hydrate inhibitor. Injected into the processing flow stream where there is a risk of hydrates being formed, which can cause blockages. The MEG is stored at the CPF and transported by road in drums or cubi-containers to the wellheads where a remote injection system is installed. The MEG injected into the dew pointing unit is recovered from the stabilized condensate and reused.</td><td>Tank</td><td>300</td></tr>
<tr><td>Tri-ethylene glycol (TEG)</td><td>Tank</td><td>300</td></tr>
</table>

Table 4.14 – Key Chemicals and Hazardous Materials Use (cont'd)

Chemical	Use	Type of Storage	Total Capacity (m^3)
Biocides	Prevents bacteria developing in water from the open drain network that is recycled back to the process and in the produced water that is disposed of by injection into the Antelope reservoir. Biocide is injected in small quantities into these process streams.	Drums/ cubi-containers	TBD
Oxygen scavenger	Blanketing of equipment is required to limit oxygen entrance. Some oxygen can come from open drain effluent recycled in production. As soon as oxygen is measured above 30 ppb, oxygen scavenger must be injected (then potentially continuously).	Drums/ cubi-containers	TBD
Antiscale	Prevents scaling of pipework and vessels.	Drums/ cubi-containers	TBD
Amine	Used in the acid gas process to absorb hydrogen sulfide. The amine is regenerated.	Tank	1,400
Sodium hydroxide	Used in the acid gas process to absorb sulfur dioxide during the desulfurization process.	Tank	TBD
Propane	Used as a refrigerant in the condensate processing. Two bullets normally empty to be able to drain the full propane loop and the third one large enough to refill the loop.	Bullets	150
Diesel	Fuel for diverse small equipment items that are not electrically driven.	Tank	420
	Emergency fuel supply at the operations camp.	Tank	10

TBD: To be defined during FEED. The number and volume of tanks will also be defined during FEED.

Flares

In 2014, TOTAL officially endorsed the World Bank Zero Routine Flaring by 2030 initiative, which is reported in the company's 2014 Sustainable Growth Report, and is committed to develop the Project without routine flaring; however, the CPF will be equipped with high pressure (HP) and low pressure (LP) flares for safety reasons. The HP and LP flares will be situated on the same stack, as there are no operational or safety related constraints that require separate stacks. The HP flare has been designed for an emergency relief rate of 1,850 MMscfd of gas and has a height of 104 m. The LP flare is designed for 58 MMscfd and has a height of 30 m.

The flares will be used only for safety flaring in alignment with the no routine flaring policy, as follows:

- During start-up after a shutdown, flaring will be tolerated for six hours, which is the time necessary for the processing systems to stabilize.
- In the event of upset conditions, such as the unavailability of acid gas treatment or unavailability of gas export, the CPF production will immediately be reduced and flaring of gas at the minimum turndown capacity of the plant will be tolerated for six hours. After six hours, if the problem is not resolved, wellheads will be remotely shutdown.
- Flaring of gas from depressurizing the processing equipment for safety reasons prior to planned preventive maintenance.
- Emergency depressurization of the facilities in the event of a safety situation. Emergency depressurization will occur infrequently, and the flaring duration will be less than 20 minutes.

Open Drain Systems

The CPF will be equipped with three open drain networks to manage and control surface water in the facility. Two drains will discharge to the Purari River and one to the surrounding environment by percolation and evaporation:

- Open drain network 1 (OD1) will collect rainwater runoff from areas where there is a permanent risk of hydrocarbon contamination. The drained water will be routed to a 18-m^3 hydrocarbon-water separator. The treated water will be then directed to a 2,340-m^3 observation basin. If the water quality complies with the Project's environmental permit discharge values, the water will then be discharged to the Purari River.
- Open drain network 2 (OD2) will collect rainwater runoff from areas where there is a risk of accidental contamination from hydrocarbons in the area. The drained water will be routed directly to the observation basin (without passing through the separator) and if the water quality complies with discharge values it will be discharged to the Purari River.
- Open drain network 3 (OD3) will collect rainwater runoff from areas where there is no processing equipment, and it will be disposed of to the surrounding environment by natural percolation and evaporation.

The hydrocarbon-water separator has been designed with a retention time of 30 minutes based on the flow for a washdown of the processing areas. The observation basin is sized to contain site runoff from 20 minutes of rain and three hours of firewater.

4.11.1.3 Water Storage

The water storage facilities comprise the following:

- Produced water holding tank with a capacity for five days of produced water in case of a temporary upset of the produced water system.
- Various water tanks to store utilities potable water, accommodation potable water, utility water, demineralized water and fire water.

4.11.1.4 Process Control

The CPF, Project pipelines, gathering systems and wells will be monitored and controlled 24 hours per day from the CPF control center under the Project's supervisory control and data acquisition system. The integrated control and safety system will be designed to monitor, control and protect Project facilities. Pressure, temperature, level, flow rate and position instrumentation and control systems will be monitored. Process and safety control systems will provide surveillance to safely shutdown the process if a safety situation occurs (see Section 4.9.3.7). Upstream operations will collaborate with the downstream operations to facilitate process control and maintenance schedules.

4.11.1.5 Maintenance

Planned maintenance shutdowns are to be scheduled and coordinated to achieve an operations availability of 93% over the design life of 25 years. Piping, valving and equipment will be designed so that sections of the plant can be isolated for maintenance work. Vents and drains will allow for safe and effective depressurizing, draining and purging of equipment. Where possible, common equipment will be considered across the facilities (e.g., gas turbines, valves, instrumentation) to minimize spares holdings and workers' competency requirements.

Plant data and equipment performance monitoring systems collects and plots data, monitors critical rotating equipment and processes data so it can be accessed locally and remotely for troubleshooting and predictive maintenance.

The Project is not expecting naturally occurring radioactive material (NORM) to be generated; however, contingency plans will be prepared for the unlikely event NORM occurs.

4.11.2 Operating and Maintaining the Wells and Gathering Systems

The Antelope wellpad layout during production is shown in Figure 4.25. The Elk wellpad will have a similar layout, but for only one wellhead. The wellpads will be unmanned and therefore, no permanent lighting is planned. Each wellpad will be equipped with pressure relief and venting systems and a power cable will supply electricity from the CPF. The gathering system and wells will be routinely inspected and maintained. Later in their life, some wells are expected to require the following interventions:

- Well stimulation to restore the permeability and yield of the wellbore.
- Mechanical repair of surface or down-hole equipment.
- Potential water shutoffs to restrict inflow into the wellbore and eliminate produced water in the wellstream.

The open drain system described in Section 4.11.1.2 will apply at the wellpads. OD1 water will be drained to a dedicated sump for collection and transport to the CPF where it will be treated with other OD1 wastewater. Process control will be automated as much as practicable. All the wells will be capable of being remotely started and shutdown from the CPF control center.

4.11.3 Operating the Pipelines

During operations, the Project will require a narrower ROW than during construction to be used for surface and aerial inspection, maintenance and possibly emergency response. The width of the pipeline operations ROW will be minimized, but may fluctuate depending on the topography and operational requirements. No permanent structures will be allowed in the ROW. Vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow. All of the remaining construction ROW will be allowed to regenerate or to return to its former use after construction activities cease.

A small team will operate the pipelines using standard systems and procedures so that pipeline integrity is maintained.

4.11.3.1 Monitoring and Control

The CPF will have a control room that can monitor and control the overall pipeline system, so that there will be an operable, reliable backup system in an emergency situation. Pipeline, processing and well flowrate adjustments will be made so that daily nominations are met. An online analyzer with read-out in the CPF control room will be used to monitor and control gas quality, and pipeline shutdown will occur automatically should the gas quality specifications be exceeded.

4.11.3.2 Inspection and Maintenance

Pipeline inspection and maintenance will be performed in alignment with an inspection and maintenance program that will be developed during FEED. Routine ground or aerial patrols will be undertaken to monitor and manage tree regrowth and soil erosion. Routine visual inspection from helicopters or fixed-wing aircraft will be used to monitor for threats to pipeline integrity, which could include slope instability or vandalism. Pipeline valve stations will be visited for routine inspections.

ANTELOPE PRODUCTION WELLPAD LAYOUT

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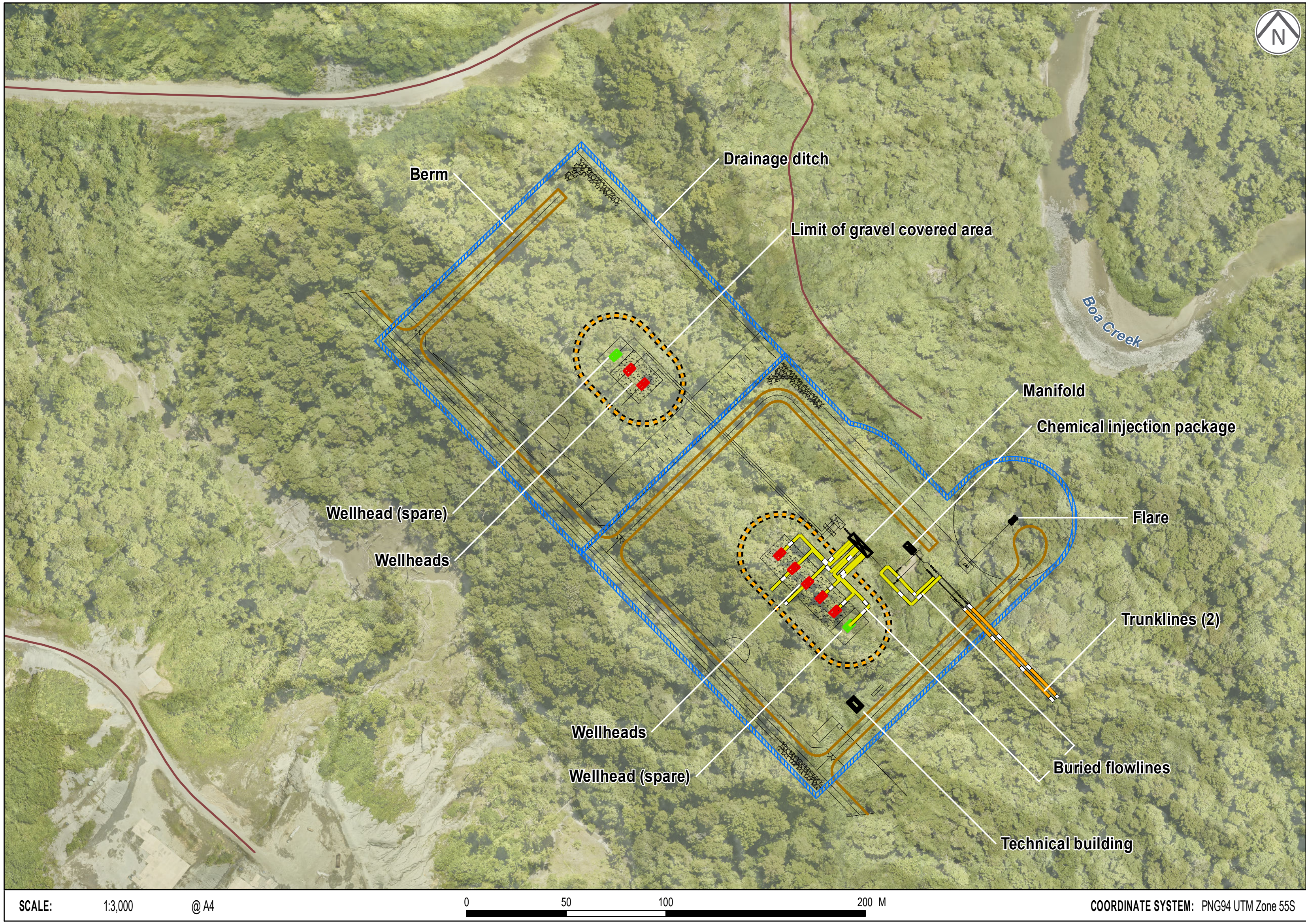
FIGURE 4.25



Existing road

Refer to Figure 4.4 for location of ANT-10 Production pad.

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Ground and aerial markers with distance indicators will be installed along the pipeline route to aid in maintenance and possible emergency response. Pigs will be passed through the pipelines at programed intervals to internally test the pipeline wall integrity. All pipelines will be equipped with pig launchers and receivers to enable such tests. A pig is a pipeline inspection and gauging device that is introduced into a pipeline periodically to inspect the pipeline wall condition. The pig is introduced into the pipeline using a pig launcher, an oversized section of pipe that can be shut off from the rest of the pipe. The pig is introduced into the launcher, the launcher is closed, and the pig propelled along the pipeline by the fluid or gas transported by the pipeline. The pig receiver is a similar device to the pig launcher and is used to extract the pig. Pigs can be used to clean pipelines by scraping the inside of the pipeline. The pigs used for the Project are essentially only for inspection and are not expected to be required for cleaning. Pipeline scrapping is not expected to be required and if it is, it will be infrequent.

Full-time workers or contractors based at the CPF will be trained in, and will have responsibility for, pipeline inspection and maintenance, including vegetation maintenance and erosion control.

The offshore pipeline will be subject to routine external surveys to confirm a stable position on the seabed. The initial and pre-lay surveys will identify any seabed processes that could pose a risk to the pipeline, which in turn, will determine the appropriate long-term inspection frequency.

4.11.4 Operating and Maintaining the Camps

Camps will be maintained and operated to meet safety, hygiene, public amenity, hazardous materials, environmental and pollution control requirements. Solid and liquid waste will be managed as part of the waste management plan (see Section 4.8.5).

4.11.5 Cleaner Production and Energy Balance

The greatest Project energy demand is estimated to be from the various electrically-driven pumps and compressors at the CPF that will provide power to the CPF, the wellpads and the Logistics Base. Raw gas will fuel the gas turbines to generate power rather than importing another fuel, or engaging an independent or third-party provider.

Several measures have been considered in the design to maximize energy efficiency:

- Hot water has been selected as the most appropriate heating medium.
- Waste-heat recovery units will be installed on the power gas turbines to supply part of the amine reboiler heating requirements.
- A free-flow gas export scheme has been selected for the initial production phase to reduce energy use (versus compression).
- Heat from hot processes or exhaust streams will be recovered to reduce system loads.
- Buildings will be insulated, where practicable.
- Energy-efficient glass and shade windows from the sun will be installed, where practicable.

TOTAL’s General Specification, Sustainable Development: Environmental Requirements for Project Design and E&P Activities (GS EP ENV 001) requires ‘Minimization of GHG emissions and optimization of energy efficiency shall be considered in the selection of the development scheme and main equipment.’. Energy efficiency opportunities will be under continual review during Project design, construction and operations, e.g., opportunities to pre-cool using heat recovery to a process stream requiring heating.

4.12 Decommissioning

Decommissioning requirements (see Chapter 19) will be further developed during FEED and shall address:

- Decommissioning and disposal options for all equipment and materials, including products used and wastes generated on site.
- Removing condensate from pipelines, and removing surface equipment and facilities.
- Decommissioning wells, flowlines, trunklines, and land-based and marine export pipelines.
- Reinstating land.

Decommissioning details will be developed as operations progress and finalized before the completion of field life. They will be based on standards and technology that exist at that time and will include details on decommissioning activities and arrangements for post-decommissioning monitoring.

Project decommissioning activities will comply with regulatory requirements that are in force at the time of decommissioning, and good industry practice.

4.12.1 Decommissioning the Wellpads and CPF

Individual equipment items may be decommissioned when they have no further foreseeable use. Each production facility will be decommissioned when its operation is no longer economically viable. Reuse and recycling alternatives will be considered where feasible, for example:

- Removal for use by another operator or for sale to a third party.
- Rerouting hydrocarbons to a future development.
- Access to the plant and equipment by new production fields.

If none of the above options is feasible, the facilities or parts thereof and associated infrastructure will be decommissioned. Larger equipment may require a life-cycle analysis of the energy, safety, resource and environmental implications of recovery and recycling alternatives.

The overall aim is to leave Project land, and any equipment and infrastructure that remains, in a condition that allows it to be transferred with minimal residual liabilities or risk to public safety and the environment.

The nominal life of the proposed facilities is approximately 25 years (and so it is reasonable to expect that the decommissioning procedures and regulatory requirements of the day will reflect advances in technology, new information, different monetary and other values for land and materials, and the PNG Government’s decision on whether and if so how to exercise its rights to take over or transfer facilities and licenses. Commitments to specific procedures now cannot anticipate future circumstances. For present purposes, therefore, the Project will follow the regulatory requirements and good industry practice at the time of decommissioning.

Project decommissioning, when it ultimately occurs, is expected to entail the following:

- Plugging of development wells.
- Dismantling above-ground facilities, including production equipment and wellheads.
- Removing dismantled equipment.
- Site clearance, cleanup and rehabilitation.

The hydrocarbon product to be processed will be predominantly gaseous, therefore soil contamination is not expected to be an issue; however, in addition to regular liquid hydrocarbon management (e.g., clean-up following diesel fuel spills), a soil contamination survey will be conducted to determine if there has been any inadvertent and unobserved contamination. If any contamination is discovered, a soil remediation program will be instigated, consistent with good industry practice environmental management, as it stands at the time of decommissioning.

Decommissioning plans will be prepared for facilities before decommissioning work starts and will be documented in the Project's environmental and social management plan (see Chapter 19, Environmental Management, Monitoring and Reporting).

4.12.2 Decommissioning the Pipelines

Decommissioning the pipelines includes decommissioning flowlines, trunklines and the export pipelines. The nominal life of the proposed pipelines is approximately 25 years for the trunklines, water injection line and Elk flowline, and 40 years for the export pipelines.

4.12.2.1 Decommissioning the Flowlines, Trunklines and Onshore Export Pipelines

Pipeline decommissioning requires the flowlines, trunklines and onshore export pipelines to be made safe by:

- Purging and flaring gas or condensate from within the flowlines, trunklines and onshore export pipelines, which will then be filled with water and capped.
- Removing all above-ground components of mainline valves.

The flowlines, trunklines and onshore export pipelines will remain buried, because recovering the pipe would be extensive and create unnecessary environmental disturbance. If the pipelines were still in an operable condition, their cathodic protection facilities would be retained to prevent corrosion and to leave open the option of recommissioning at some future date should additional gas reserves in the region become economic in the future.

4.12.2.2 Decommissioning the Offshore Export Pipelines

Current standard international industry practice for decommissioning offshore pipelines is to:

- Flush the pipeline of hydrocarbon liquids and vapor.
- Flood the pipeline with seawater.
- Seal the pipeline openings with mechanical plugs.
- Abandon all offshore sections of pipeline in place to minimize the disturbance of removal.
- Update navigation charts for offshore areas to show what remains, in consultation with the NMSA.

It is possible that these current practices will have changed by the time the pipeline comes to the end of its service life and, if so, decommissioning will follow industry practice of the day.

4.12.3 Decommissioning the Infrastructure

All logistical infrastructure not required for operational purposes may be dismantled and removed for sale, recycling or disposal, or may be retained by the State or provincial governments as public assets. Infrastructure retained for operation will be decommissioned, and sites stabilized and rehabilitated as for the production facilities described in Section 4.12.1. This is expected to include the Logistics Base, Purari Airstrip, roads, and pumping stations (for water abstraction).

Quarries and spoil disposal areas will be rendered safe, stabilized and rehabilitated to a self-sustaining state.

4.13 Project Summary

4.13.1 Project Activities

A summary of the Project phases and the activities or drivers of change that are likely to cause impacts are provided in Table 4.15. These are the phases and activities upon which the impact assessment presented in Chapters 11 to 18 are based.

Table 4.15 – Summary of Project Activities

Project Activity	Project Phase			
	EW*	C#	O†	D**
Land acquisition.	✓	✓		
Logistics and transport including equipment, plant, construction materials, supplies and workforce (barging, Purari Airstrip and Project roads).	✓	✓	✓	✓
Vegetation clearing.	✓	✓		
Earthworks (including sidecasting, if required).	✓	✓		
Quarries.	✓	✓	✓	
Construction and operation of temporary construction camps (CPF, Herd Base, Ant-3 and pipe yard 4).	✓	✓		
Construction and operation of accommodation camps (CPF, Herd Base).		✓	✓	✓
Construction works (construction camps, wellpads, CPF, roads, Logistics Base).		✓		
Jetty construction (Logistics Base, access to pipe yards).		✓		
Drilling.		✓		
Dredging at the Logistics Base.		✓	✓	
Water extraction from the Purari River for water supply (including for hydrotesting).	✓	✓	✓	✓
Construction of water supply dams on Hou and Boa creeks.		✓		
Operation of fixed and mobile plant and equipment.	✓	✓	✓	✓
Fuel and energy consumption (including power generation).	✓	✓	✓	✓
Onshore pipeline construction (including associated infrastructure).		✓		
Offshore pipeline construction.		✓		
Disposal of pipeline hydrotest water.		✓		
Construction of pipeline watercourse crossings.		✓		
Construction, including trenching, of the Orokolo Bay export pipeline shore crossing.		✓		
Waste generation, storage and disposal.	✓	✓	✓	✓

Table 4.15 – Summary of Project Activities (cont'd)

Project Activity	Project Phase			
	EW*	C#	O†	D**
Construction and operation of landfills.		✓	✓	✓
Spoil disposal.		✓		
Waste incineration.		✓	✓	✓
Operation of wellpads.			✓	
CPF operations (gas processing).			✓	
Gas flaring.			✓	✓
Produced water and flue gas desulfurization liquid effluent disposal.			✓	
Acid gas injection.			✓	
Project facilities and camps lighting emissions.	✓	✓	✓	✓
Use of hazardous materials.	✓	✓	✓	✓
Discharge of surface runoff (roads, wellpads, CPF, pipeline ROWs).	✓	✓	✓	
Pipeline operations.			✓	
Pipeline maintenance (including maintenance of access roads).			✓	
Rehabilitation works.	✓	✓	✓	✓
Project employment and procurement.	✓	✓	✓	✓

Notes: * Preparatory works and early works. # Construction. † Operations. ** Decommissioning and closure. Activities will be dependent upon the decommissioning plan that will be developed; however, it is expected that there will some similarity with the activities identified for the other Project phases.

4.13.2 Disturbance Footprint

Table 4.16 and Figures 4.26 to 4.30 summarizes the estimated direct disturbance areas associated with Project facilities from north to south. The disturbance footprint area, due predominantly to vegetation clearance, is much smaller than the land requirements presented in Chapter 13, Table 13.6, as land requirements need to accommodate additional land uses such as safety/security exclusion zones and buffer areas around Project infrastructure, and contingencies for Project infrastructure location changes. The land required in addition to the disturbance footprint shall not have the forest cleared or be otherwise disturbed.

The Project design will be refined during FEED and detailed design, and the footprint may change, e.g., since the assessment was completed for the EIS, the ROW for the trunklines has been reduced from 49 to 40 m and spoil disposal areas for roads R5 and R7 have been reduced from 18.4 ha and 30.2 ha to 7 ha and 18.6 ha, respectively. The estimated direct disturbance areas and associated impact assessment are based on the larger values.

Table 4.16 – Project Facilities and Associated Direct Disturbance Areas

Project Facility	Estimated Total Area of Direct Disturbance (ha)	Does Project Facility Coincide with Existing Disturbance?
Wellpads		
ELK-10	2	Yes
ANT-10	5	No
ANT-11	2	Yes

Table 4.16 – Project Facilities and Associated Direct Disturbance Areas (cont'd)

Project Facility	Estimated Total Area of Direct Disturbance (ha)	Does Project Facility Coincide with Existing Disturbance?
Flowlines and Trunklines Construction ROW		
Elk flowline to ANT-10	24	Yes (for approximately 1.6 km)
Water injection/acid gas liquid effluent line ANT-10 to ANT-11	10	No
Flowlines and trunklines ROW from ANT-10 to CPF	136	No
Dam for water supply ELK-10, ANT-10	2	No
CPF		
CPF, including construction and operations accommodation camp	100	No
Export Pipeline Construction ROW		
Export onshore pipeline including HDD sites and valve stations	217	Yes
Infrastructure		
Herd Base quarries A, C and D, KM6 quarry and associated access	52	Quarry A - yes KM6, quarries C and D - no
Roads (R1, R2, R4, R5, R6, R7)	132	R1, R2 – no R4 (Herd Base to Quarry A), R5, R6, R7 (for approximately 1.6 km) – yes
Pipe yards (3)*, pipeline construction camps	19	Pipe yards 1, 4 – yes Pipe yards 2, 3 – no Pipeline construction camp - no
Logistics Base	7	No
Purari Airstrip extension and vegetation clearing for visual approach	103	Yes
Spoil disposal areas (25) and associated access	120	No
General landfills	5	No
TOTAL	**936**	

Note: * Pipe yard 1 and its associated accommodation camp are located within Herd Base.

Of the estimated direct disturbance area, approximately 190 ha (20%) uses existing disturbed areas and the onshore export pipeline route traverses 217 ha of degraded vegetation.

PROJECT DIRECT DISTURBANCE AREAS - 1

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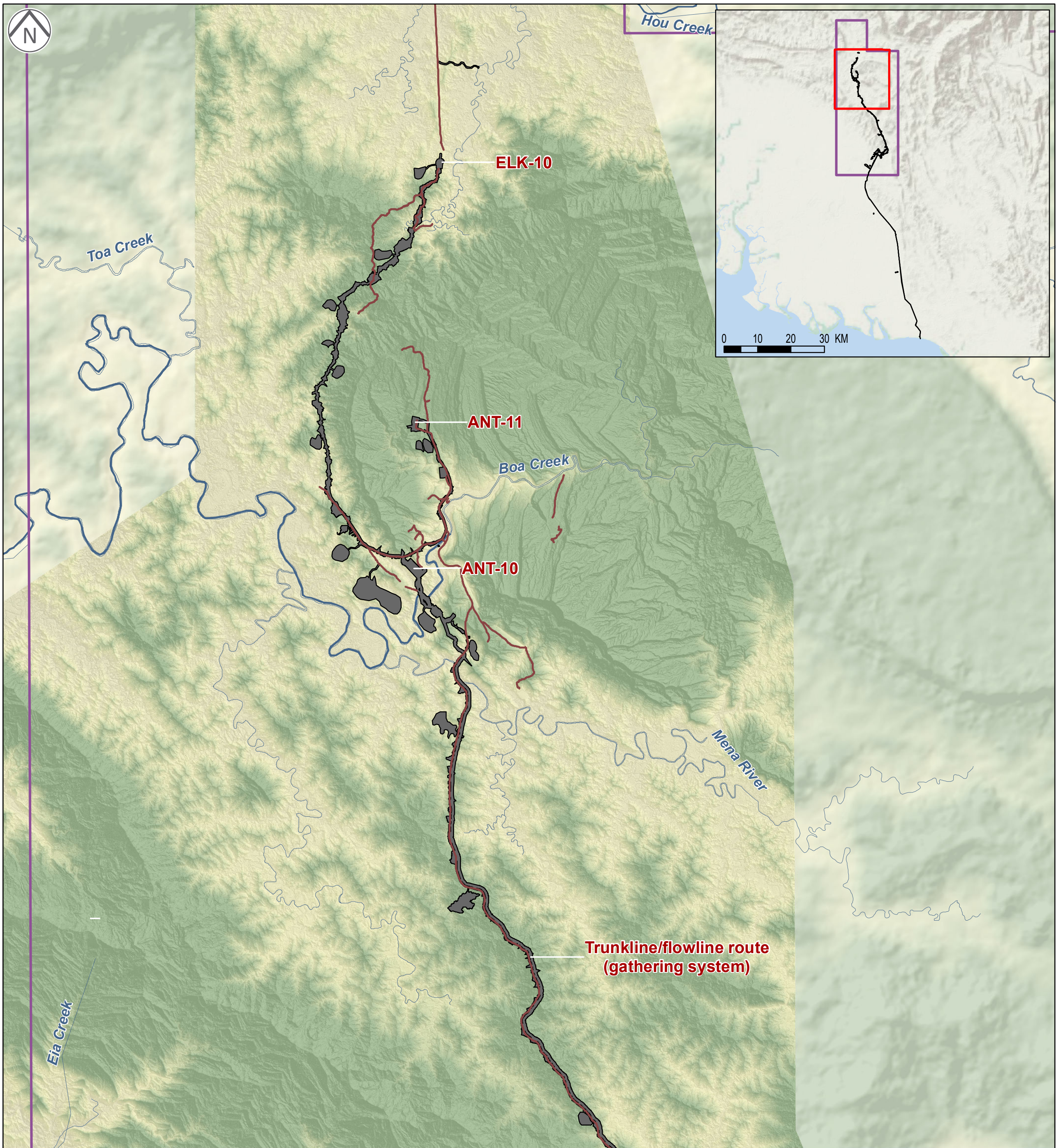
FIGURE 4.26



SCALE: 1:90,000 @ A4

0 0.5 1 2 3 4 5 KM

COORDINATE SYSTEM: GCS WGS 1984

- Existing road
- Waterway
- Waterbody or major river
- PRL-15
- Project direct disturbance area

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PROJECT DIRECT DISTURBANCE AREAS - 2

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FIGURE 4.27

PROJECT DIRECT DISTURBANCE AREAS - 3

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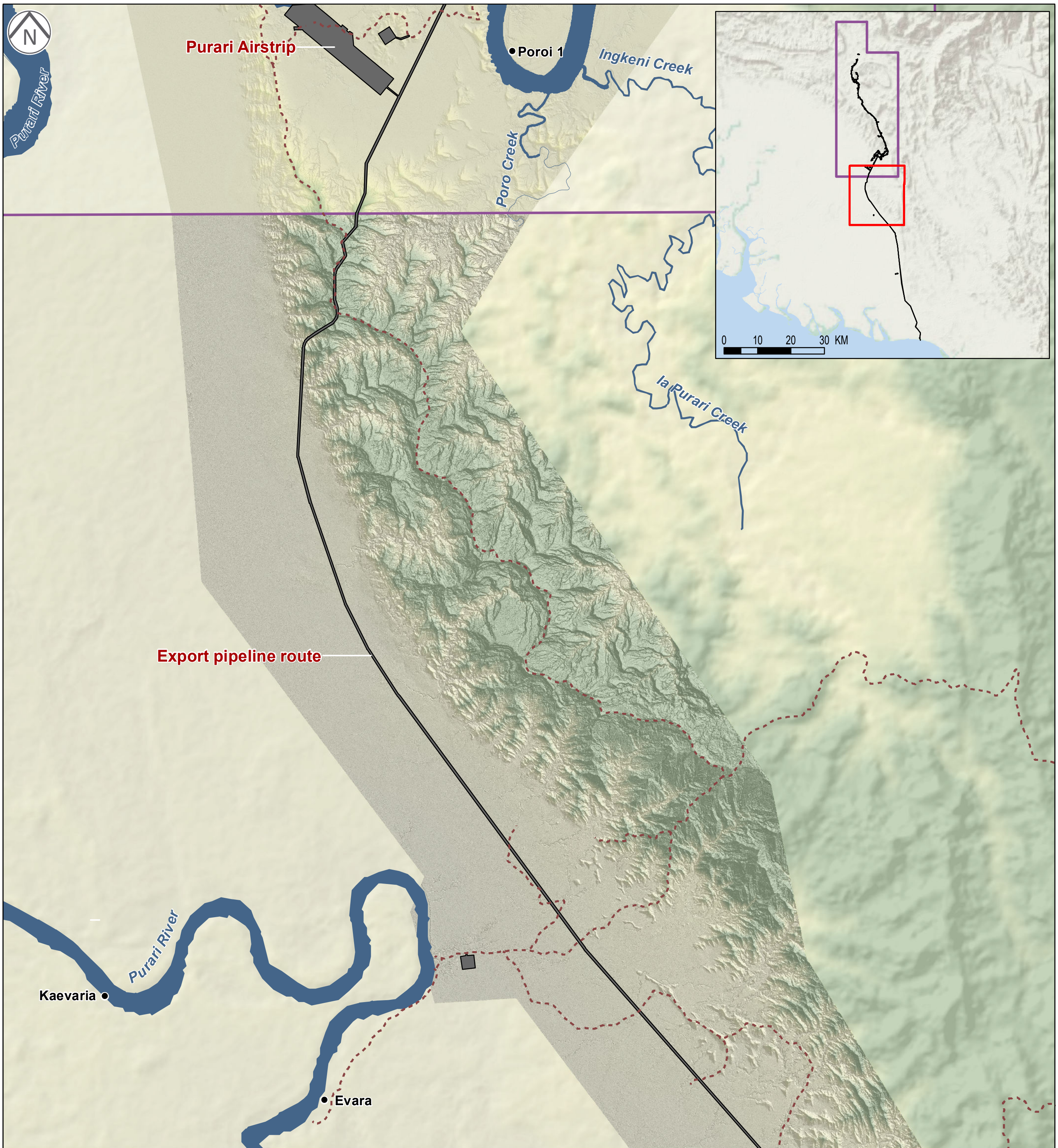
FIGURE 4.28



SCALE: 1:90,000 @ A4 0 0.5 1 2 3 4 5 KM COORDINATE SYSTEM: GCS WGS 1984

- Town or village
- Former logging road
- Waterway
- Waterbody or major river
- PRL-15
- Project direct disturbance area

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PROJECT DIRECT DISTURBANCE AREAS - 4

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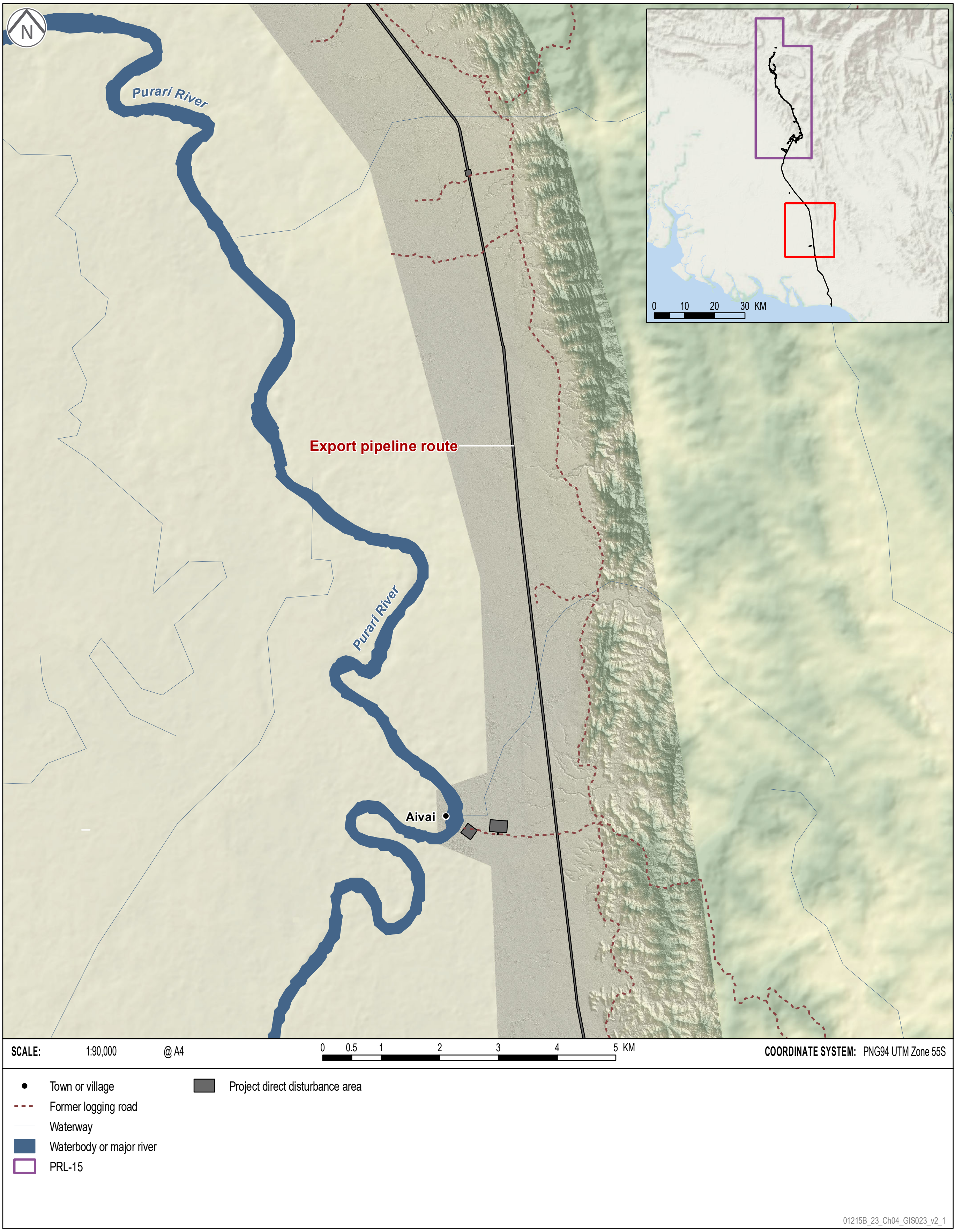
FIGURE 4.29



PROJECT DIRECT DISTURBANCE AREAS - 5

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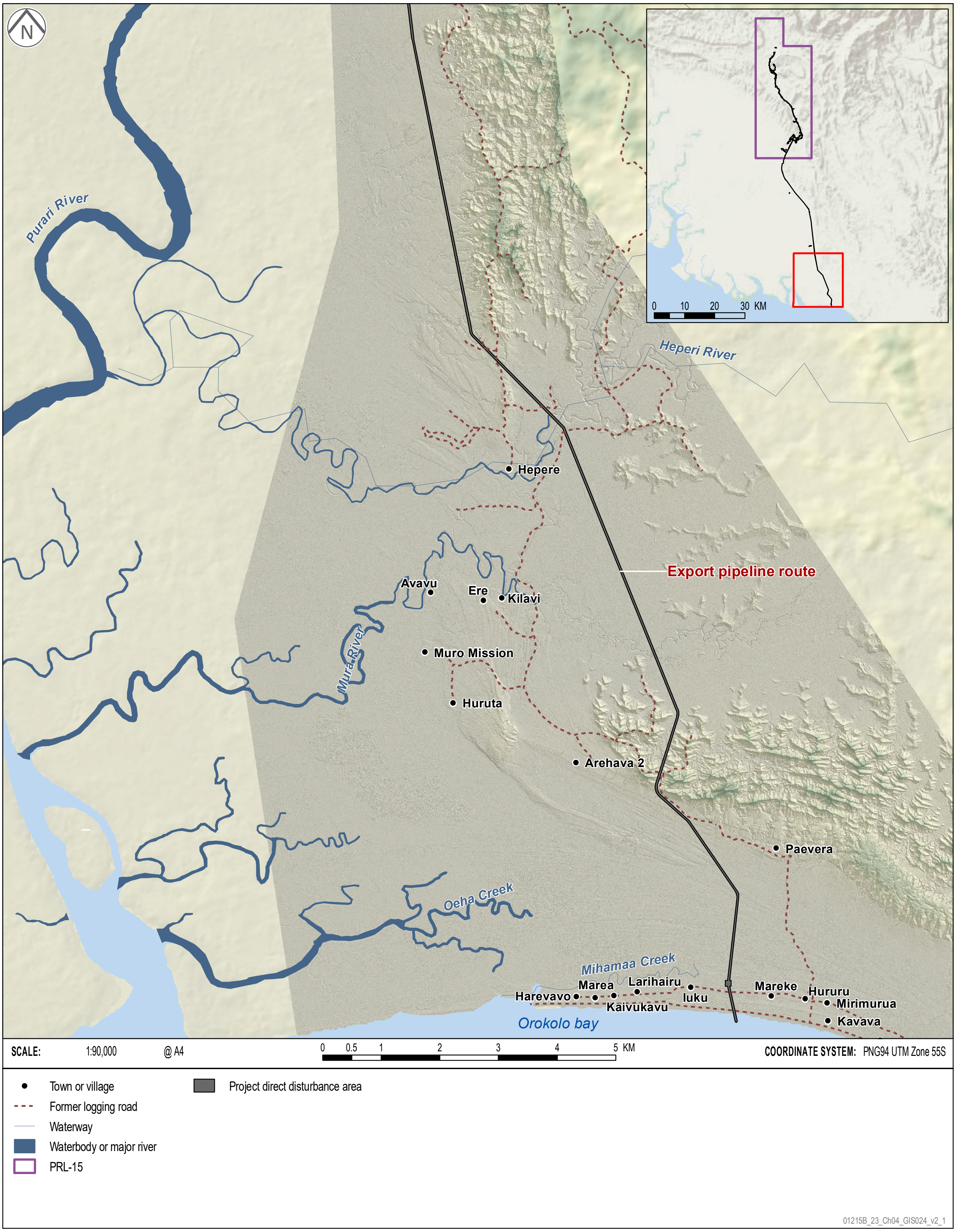
FIGURE 4.30



4.13.3 Embedded Design Controls

Pre-Project design has followed the first two steps of the mitigation hierarchy (see Section 3.1.4.3) to anticipate and avoid, or where avoidance is impossible, to minimize adverse impacts through prudent infrastructure location and design.

Positioning Project infrastructure has included ‘micro-siting’ of wellpads and other facilities, and prudent routing of access roads and pipelines to avoid sensitive features, and physical and economic displacement where possible. In addition to the actual siting of facilities, the construction and design details have considered possible receptors, e.g., the footprint of individual facilities has been reduced as far as practicable and drainage systems have been designed to minimize the effects of runoff.

Table 4.17 summarizes the major embedded design controls already incorporated in the current pre-Project base case design, which are based on good international industry practice. Embedded design optimization will continue during FEED.

Additional mitigation for impacts remaining after embedded design and management measures have been applied but is insufficient to reduce an impact to an acceptable level has been identified and is presented in impact assessment Chapters 11 to 16.

Table 4.17 – Embedded Design Controls

No.	Discipline	Embedded Design Controls
ED001	Air quality	Vessels will comply with applicable International Maritime Organization requirements related to fuel to minimize related atmospheric emissions.
ED002	Air quality	The Project will design its plant to meet the applicable emission standards and relevant ambient air quality criteria beyond the proposed facility boundary.
ED003	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; marine water quality; marine biodiversity; ecosystem services	Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as: ♦ Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan. ♦ Building infrastructure on impervious surfaces where required. ♦ Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials. ♦ Installing interceptor pits or similar to collect contaminated surface water runoff and to treat it when required. ♦ Installing tanks above ground with impermeable liners and bunds around tanks. ♦ Regularly inspecting and maintaining containers, and storage and transfer infrastructure to prevent/control spills or leaks. ♦ Installing readily accessible spill kits and training personnel in their use. ♦ Appropriately treating and disposing of any accidentally contaminated soils.
ED004	Landform and soils; groundwater; surface water quality; ecosystem services	The drilling will be performed using water-based mud.
ED005	Landform and soils; groundwater; climate change; ecosystem services	Landfills will be designed to comply with TOTAL’s general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED006	Landform and soils; freshwater and estuarine biodiversity; surface water; marine water quality; marine biodiversity; ecosystem services	Minimize chemical use and select chemicals considering the following criteria: ♦ Lowest toxicity, lowest bioaccumulation potential and highest biodegradation; ♦ Chemicals subject to bans or phase-outs.
ED007	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; ecosystem services	Use low-pressure detection alarms to detect pipeline leaks.
ED008	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; ecosystem services	Use fiber optic cable laid in the same trench to monitor pipelines. This cable will detect intrusions and ground movements.
ED009	Landform and soils; groundwater; freshwater and estuarine biodiversity; ecosystem services	Locate valve stations along the onshore pipeline route to isolate pipeline sections if a leak occurs.
ED010	Groundwater; ecosystem services	Wells are to be cased and cemented to insulate and protect any aquifers.
ED011	Groundwater; ecosystem services	The gathering and reinjection system, and wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational control (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring).
ED012	Groundwater; ecosystem services	Hydrotesting will be undertaken to confirm weld integrity.
ED013	All disciplines	Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges).
ED014	Hydrology, fluvial geomorphology and sediment processes; ecosystem services	All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is: ♦ To account for local rainfall conditions and catchment size of works areas. ♦ To allow avoiding unseasonal waterlogging ♦ To allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED015	Surface water quality; ecosystem services	The CPF will have an open drain system to manage rainwater; the system will have three separate networks: OD1 = permanently hydrocarbon-contaminated drains. OD2 = accidentally hydrocarbon-contaminated drains. OD3 = hydrocarbon-free drains. Water from each system will be treated separately and discharged to the environment according to applicable limits.
ED016	Surface water quality; freshwater and estuarine biodiversity	All OD1 waters will undergo water treatment by a hydrocarbon/water separation system prior to discharge to the Purari River according to applicable standards. All OD2 waters and water from primary treatment will be sent to an observation basin and treated by the hydrocarbon/water separation system prior to release if required. Clean OD2 water will be discharged to the Purari River. Non-contaminated stormwater (OD3) will be disposed of by natural percolation and evaporation.
ED017	Surface Water Quality	All OD1 water from wellpads will be collected in a dedicated closed tank and transported to the CPF for treatment prior to being discharged.
ED018	Surface water quality	The produced water generated at the CPF will be injected back into the reservoir. Produced water will be retained in a tank with a capacity to contain five days of water production, as a backup if injection is unavailable.
ED019	Surface water quality; air quality; noise	All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired.
ED020	Surface water quality; ecosystem services	Rainwater infiltration into hazardous materials storage areas will be prevented.
ED021	Surface water quality; freshwater and estuarine biodiversity	Requirements for hazardous material transfer, overfill protection, and alarms will be implemented, e.g.: ♦ Using dedicated fittings, pipes, and hoses specific to materials in tanks. ♦ Providing secondary containment, drip trays, etc. at connection points or other possible overflow points. ♦ Using dripless hose connections for vehicle tank and fixed connections with storage tanks. ♦ Providing automatic fill shutoff valves on storage tanks to prevent overfilling. ♦ Using piping connections with automatic overfill protection (float valve). ♦ Fitting tanks with high-level alarms with both audible and visible annunciation.
ED022	Marine water quality; marine biodiversity; ecosystem services	Ballast waters, liquid effluents and waste from vessels will be managed in accordance with the MARPOL 73/78 requirements.
ED023	Air quality, GHG	The flares will be used only for safety flaring in alignment with the TOTAL no routine flaring policy
ED024	Air quality	During the first years of production when it is not possible to dispose of acid gas by injection, a sulfur recovery unit will be installed and operated at the CPF to remove sulfur-containing compounds from the acid gas after it has passed through a thermal oxidizer.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED025	Air quality, GHG	Once the Elk reservoir has been depleted, acid gas removed from the raw gas using the AGRU will be disposed of by injecting it into the reservoir.
ED026	Air quality	The sulfur recovery unit will remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible.
ED027	GHG	The Project will generate its own electricity during the operations phase, which will minimize the use of diesel and related emissions.
ED028	GHG	Waste-heat recovery units will be installed on the power gas turbines.
ED029	GHG	Buildings will be insulated, where practicable.
ED030	Noise; air quality; terrestrial biodiversity	Fixed or mobile equipment will be used and/or located considering people and other sensitive receptors.
ED031	Noise	Minimize noise from machinery, plant and equipment, as far as practicable.
ED032	Noise	The Project will design its plant and undertake activities to comply with the applicable noise criteria.
ED033	All disciplines	The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent.
ED034	Community health and safety	Continue pre-employment and ongoing health and fitness to work screening and annual medical checks for all workers working for the Project in the Project area.
ED035	Community health and safety	Design Project infrastructure (including workforce accommodation) to minimize vector harborage (e.g., minimize pooling water, proper waste disposal) and human exposure (e.g., screening of doors and windows) to minimize spread of disease
ED036	Governance and leadership	Transparency and ethics: ♦ The Project operator will pay taxes and royalties in an accurate and timely manner during construction and operations phases. ♦ The Project operator reports within the PNG Extractive Industry Transparency Initiative (EITI) framework, the amounts of taxes and royalties paid within its operated perimeter.
ED037	Governance and leadership	Continue the employment and, when possible, the recruitment of women in community relations positions (community liaison officer, village liaison officer) to conduct specific engagements with women and ensure that women's views and interests are identified.
ED038	Conflict, law and order	The Project has been and will continue to work with security forces in alignment with Voluntary Principles on Security and Human Rights.
ED039	Landscape and visual amenity	Waste will be managed to reduce, reuse and recycle/ recover the waste where practicable. Waste management requirements (e.g., waste inventory, segregation, storage, disposal, tracking, recording) will be detailed during FEED.
ED040	Landform and soils; hydrology, fluvial geomorphology and sediment processes; surface water quality; freshwater and estuarine biodiversity	Hydrotest water discharges will be managed according to applicable requirements.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED041	Marine biodiversity	The offshore pipelines will be buried with 1-m cover depth to the top when located in water shallower than 20 m.
ED042	Commercial traffic and transport	Liaise with NMSA to establish a safety exclusion zone around offshore export pipeline construction activities.
ED043	Commercial traffic and transport	Continue to work with relevant commercial operators to: ♦ Coordinate barge movements along the Purari River. ♦ Notify them, as required, of in river Project activities and the associated hazards.
ED044	Commercial traffic and transport	Inform NFA and commercial fishing fleets who operate in the vicinity of the offshore export pipeline route of construction activities, including timing of construction activities and the safety exclusion zone.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 5: Project Options and Analysis

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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Chapter

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5. Project Options and Analysis

5.1 Introduction

This chapter describes the commercial, facility siting, design, technology, construction and transportation alternatives considered for the Project. Avoiding and or minimizing social and environmental impacts has been integral when considering alternatives during the Project's conceptual and pre-Project design phases. Further optimization of the Project 'base case' design will continue through the Project's front-end engineering design (FEED) and detailed design phases.

5.1.1 Options Analysis Approach

Resource projects of this size and nature undergo assessment so that they are both viable physically, technically and commercially, and acceptable socially and environmentally. TEP PNG has rigorously and continuously assessed options at successive stages during the conceptual and pre-Project design phases and has adopted a risk-management approach through the hierarchical application of:

- Avoidance.
- Minimization.
- Rehabilitation or restoration.
- Offset or compensation.

Analysis of options and alternatives for the Project began in 2014, with a preliminary study that assessed gas and condensate commercialization and export options (Section 5.2). The next stages of assessment comprised a conceptual phase (April 2014 to July 2015) and a pre-Project phase (September 2015 to December 2018):

- The conceptual phase focused on selecting the optimum development concept based on a comprehensive screening of scenarios. This involved:
  - A screening study (April to September 2014), which assessed various options and locations for the key process and infrastructure components (e.g., liquefied natural gas (LNG) plant, central processing facility (CPF) and export pipeline corridor).
  - An additional screening study (October 2014 to February 2015) to reduce the number of scenarios.
  - A detailed conceptual phase (March to July 2015) to further compare the options from the screening studies and review potential social and environmental constraints (Section 5.3).
- The pre-Project phase considered pipeline alignment and gas transportation (Section 5.4), Project process and technological design such as acid gas management (Section 5.5), construction techniques (Section 5.6) and logistics routes (Section 5.7).

Finally, TEP PNG considered the no-project option (Section 5.8) in terms of avoiding adverse environmental and social impacts, and potential lost economic and social development opportunities for Papua New Guinea.

Stakeholder input (Chapter 6), baseline surveys (Chapters 7 to 10), technical studies and risk workshops helped filter options to arrive at the Project 'base case' design description presented in Chapter 4.

Alternatives to the base case were assessed for their potential to impact on environmental and social sensitivities and on their physical, technical and commercial feasibility. Different Project components were assessed using different methods. In this chapter, qualitative criteria aligned with International Finance Corporation requirements have been used to communicate the outcomes of these assessments in a cohesive format.

Table 5.1 outlines the main criteria that informed the alternatives analyses, and the tables that follow throughout the chapter provide a summary of how each has informed the assessment of multiple options.

Table 5.1 – Qualitative Criteria for Assessing Options

Ranking	Technical or Logistical Difficulty	Environmental Sensitivity	Social Sensitivity
High	Constructability (e.g., risk of flooding or landslides) geohazards, gas processing technology, gas transport parameters, logistical constraints, infrastructure requirements and commercial viability.	Potential impacts on sensitive species and ecosystems, topography, landforms and soils, and water resources.	Proximity to population centers, potential impacts on livelihoods and on access to resources and services, cultural heritage, community resilience, in-migration, and health and safety risks.
Medium			
Low			

5.1.2 Alternatives Considered

An overview of all the alternatives considered for each Project component is provided in Table 5.2 and those taken forward for assessment are described further in the following sections.

Table 5.2 – Summary of Alternatives Considered During the Conceptual and Pre-Project Phases

Item	Summary of Alternatives Considered
Commercialization and Export Options	
Gas commercialization	♦ Initial screening of 14 locations for the LNG plant location. ♦ Construct a greenfield plant or extend existing LNG facilities.
Gas and condensate export	♦ Use existing condensate export terminals at Kutubu. ♦ Construct a greenfield terminal closer to PRL-15. ♦ Use a single pipeline for gas and condensate. ♦ Barge condensate export down the Purari River. ♦ Export gas and condensate through onshore pipelines rather than a combination of onshore and offshore pipelines.
Location and Layout	
Central processing facility (CPF) location	♦ Six site locations initially screened. ♦ Two site locations assessed in detail.
Wellpads and gathering station layout and location	♦ Re-use existing wellpads and wells. ♦ Group wells on each wellpad. ♦ Collocate wellpads and gathering station.
Logistic facilities	♦ Develop a new logistics base. ♦ Upgrade and use Herd Base as the logistics base throughout the Project life. ♦ Upgrade and use Herd Base for early works, and develop and use a new logistics base for construction and operations.

Table 5.2 – Summary of Alternatives Considered During the Conceptual and Pre-Project Phases (cont'd)

Item	Summary of Alternatives Considered
Routing	
Gathering network (flowlines and trunklines) routing	♦ Initial screening of several alignment options for both flowlines and trunklines. ♦ Re-use existing tracks or roads. ♦ Optimize the pipeline trench through collocation of pipelines (e.g., production, water injection).
Onshore export pipeline routing	♦ Full onshore alignment from the CPF to Caution Bay. ♦ Purari River route from the CPF to Orokolo Bay. ♦ CPF to shore crossing route options. ♦ Several alignment options at the Orokolo Bay shore crossing. ♦ Alignment options for the Purari River crossing.
Offshore export pipeline routing	♦ Several alignment options from Orokolo Bay to Caution Bay.
Process and Technology	
Acid gas management	♦ Acid gas injection into the Antelope and/or Elk reservoirs. ♦ Acid gas incineration. ♦ SO_2 venting to the atmosphere. ♦ Solid sulfur landfill disposal. ♦ Conversion of sulfur in liquid form for injection with water.
Produced water management	♦ Use reed bed technology. ♦ Discharge to soils/irrigation after treatment. ♦ Use solar and/or mechanical evaporation. ♦ Dilution during upset conditions prior to discharge. ♦ Discharge to the sea at Orokolo or Caution Bay. ♦ Discharge to the Purari River. ♦ Reinjection into the Antelope reservoir.
Construction	
Aggregate sourcing and quarry locations	♦ Transport aggregates by road and barge from Port Moresby. ♦ Re-use materials from onsite excavations (e.g., for the CPF, roads). ♦ Establish/use quarries (various options).
Pipeline construction techniques (river crossings and shore crossing)	♦ Horizontal directional drilling (HDD). ♦ Micro-tunneling. ♦ Direct Pipe. ♦ Bridge. ♦ Open trenching.
Transport and Logistics	
Airfield design and location	♦ Upgrade the existing Purari airstrip to Code 2. ♦ Develop a new (Code 2) airstrip north of the Purari River. ♦ Develop a smaller new (Code 1) airstrip north of the Purari River and use the existing airstrip during construction.
Water transport routes	♦ Wame-Varoi River. ♦ Uriko-Ivo River. ♦ Purari River.

5.1.3 Consideration of Alternatives During the FEED Phase

Additional technological and process alternatives will be evaluated as part of the FEED phase in alignment with the hierarchy outlined in Section 5.1.1 and with good international industry practice.

5.2 Commercialization and Export Options

5.2.1 Gas Commercialization

During the early Project phases, screening studies to identify a recommended LNG plant location considered fourteen locations. Six were selected for further analysis, and environmental and social screening was undertaken on these sites (Table 5.3). This process progressed concurrently with a similar screening process for the CPF locations (Section 5.3.1).

Table 5.3 – LNG Plant Location Social and Environmental Screening Results

	Aspect	Caution Bay	Ala-Ala	Obu Plantation	Cape Possession	Oiapu	Cape Cupola
Social Assessment	Resettlement	Low	Med	High	High	Med	Low
	Land ownership	Low	High	Med	Low	Low	Med
	In-migration	Med	Med	Med	Med	Low	High
	Cultural heritage	High	High	Low	Low	Med	Low
	Livelihood	Low	Low	High	High	Low	Low
	Community resilience	Med	High	Med	High	Med	High
	Community sensitivity	Low	High	High	High	High	High
Environmental Assessment	Landform and soils	Low	Med	Low	High	Med	High
	Water resources	Med	Low	Low	Low	Med	Med
	Terrestrial biodiversity	Low	High	Low	Med	Low	High
	Marine environment	Med	Med	Med	Med	Med	Med
	Fisheries and shipping	Med	Med	Med	Med	Med	Med

Proposed sites at Ala-Ala, Obu Plantation, Cape Possession and Cape Cupola were assessed as having high-risk social sensitivities, which were likely to create or exacerbate community disputes and in-migration or require resettlement and economic restoration. Ala-Ala and Cape Cupola also have environmental sensitivities, including highly significant monsoonal forest at Ala-Ala and the potential for the presence of International Union for Conservation of Nature (IUCN)-listed species at Cape Cupola. Cape Possession would require significant capital investment to implement environmental and social mitigations and avoid adverse off-site impacts to the coastal and marine environment.

The location south of the existing PNG LNG Facilities at Caution Bay was assessed as having several medium environmental and social sensitivities, and high cultural heritage values that could be managed appropriately through standard construction practices and suitable community engagement.

As a result of the screening study, the recommended site for the LNG plant was south of the existing PNG LNG Facilities at Caution Bay. Once Caution Bay was selected as the preferred site, two concepts were considered for its development:

- Construction of a greenfield standalone plant.
- Integration with the existing PNG LNG Facilities.

TEP PNG and ExxonMobil began discussing adding gas processing facilities at the existing PNG LNG Facilities in 2017. Integrating the Papua LNG Project downstream LNG facilities with the existing PNG LNG Facilities is the preferred option, subject to a suitable commercial arrangement. Additional trains will use the spare capacity of the existing utility, storage and loading facilities, and existing common facilities can be expanded as needed to meet additional requirements of the expanded facility (Figure 5.1).

This EIS does not address the downstream LNG plant; however, the plant design influences the design of upstream Project components, and it has therefore been included in this report for context.

5.2.2 Condensate Export

The Project team considered several options for exporting the condensate of the Elk-Antelope reservoirs during the preliminary study (see Section 5.1.1). This involved assessing the feasibility of using one of the two existing locations for condensate export (i.e., the Kumul terminal or the PNG LNG Facilities) or of developing a new condensate export terminal closer to PRL-15.

In particular, the option to use the Kumul terminal, which already exports oil produced from operated fields, was considered. This option was rejected due to additional operational complexity and the need for an additional 100 km of offshore pipeline to the terminal, which would increase the Project footprint.

Barging condensate on the Purari River was also considered, but discarded because of the pollution risk and to avoid the potential adverse impacts of high boat traffic on communities. A comparison of these options confirmed that the preferred option was to pipe the condensate to the existing PNG LNG Facilities at Caution Bay.

5.2.3 Gas and Condensate Export Optimization

Optimizing gas and condensate export pipelines into one multiphase (i.e., gas and condensate) pipeline was evaluated. The two-pipeline option was chosen based on the following operational and environmental benefits:

- Less vegetation clearing required at the CPF departure when gas and condensate are separated. Gas and condensate are less volatile when exported in separate pipelines. The reduced volatility requires a smaller exclusion zone around the pipelines, which requires less vegetation clearing.
- The absence or the reduction of compression requirements when condensate is separated from gas before transport, generating fewer greenhouse gas emissions.
- The possibility to operate at lower flowrates than those allowed by multiphase transportation.
- Laying the two pipelines in parallel, which does not affect significantly the construction ROW width, as the two pipelines can be laid in the same trench.

EXPANSION POTENTIAL AT THE PNG LNG FACILITIES AT CAUTION BAY

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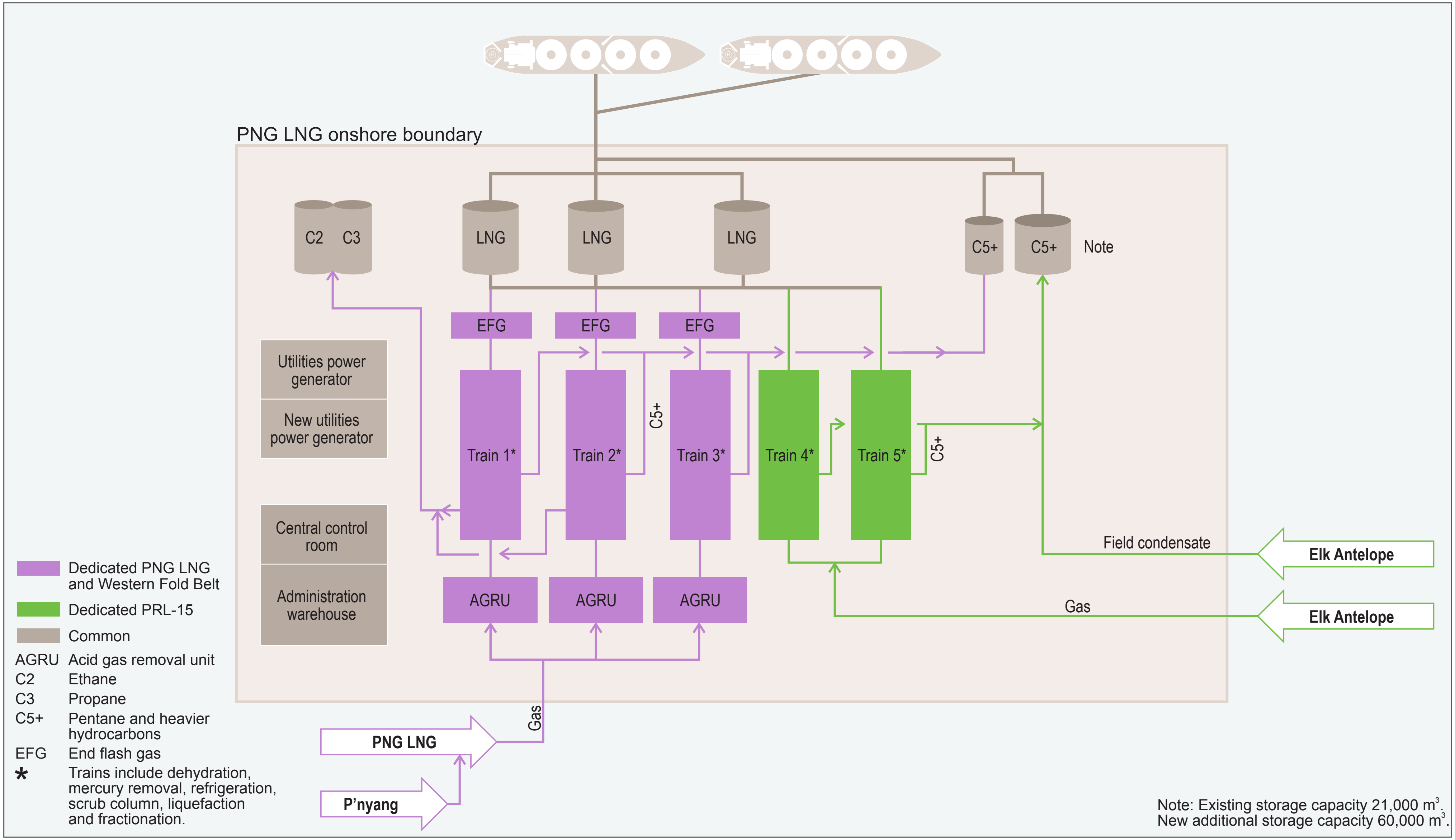
FIGURE 5.1



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5.3 Location and Layout Alternatives

Assessment of alternatives for facility locations and layouts aimed to minimize the number and size of facilities, while ensuring that they were in the optimal location for Project operations and had considered environmental and social constraints.

5.3.1 Central Processing Facility

Several locations were considered for the CPF during the conceptual phase of Project development, including sites near the wellpads (i.e., E1-A, F1 and F2), near Herd Base (i.e., P1 and P2) and near the Purari River (Figure 5.2). These locations were evaluated based on the requirement for clearing and fill material, and the potential need to build or upgrade roads to allow heavy equipment access, especially during construction.

Sites CPF-F2, CPF-P1 and CPF-I3 were identified as having high environmental, landform and water sensitivities, respectively at the conclusion of the screening study. Sites CPF-F1 and CPF-P2 showed medium risk for all three sensitivities, and CPF-E1 showed medium risk for soils and landform and for biodiversity and conservation, and low risk for water resources.

The access road must be able to accommodate large trucks carrying loads greater than 1,000 tonnes as the CPF site will contain large pieces of prebuilt equipment. An investigation of the roads connecting the nearest unloading point on the Purari River to the potential CPF locations F1, F2 and E1 found that these roads would require significant upgrades to meet the Project needs during construction, and this was seen as a major factor against selecting these sites. A CPF location near the Purari River (i.e., P1 or P2) was chosen; therefore, to avoid the additional cost, potential delays to the Project schedule, and adverse impacts from road improvements or extensive changes and potential navigation risks to Hou Creek.

Table 5.4 summarizes the assessment criteria for each site.

Table 5.4 – CPF Alternatives Analysis Summary

Criteria	CPF Site					
	F1	F2	P1	P2	I3	E1
Technical or logistical difficulty	High	High	Med	Med	High	High
Environmental sensitivity	Med	High	High	Med	High	Med
Social sensitivity	Low	Low	Low	Low	Low	Low

During the pre-Project phase, geophysical surveys and civil engineering studies confirmed the suitability of site P2 over P1, as P1 showed a higher risk of flooding and associated operational and environmental impacts. In the P2 area, the exact CPF location was defined more specifically to minimize the site preparation requirements. Two subsites, P2C and P2A, were assessed.

Table 5.5 highlights the attributes of the two sites that were assessed in detail to select P2C as the final proposed CPF location.

POTENTIAL CPF LOCATIONS

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FIGURE 5.2

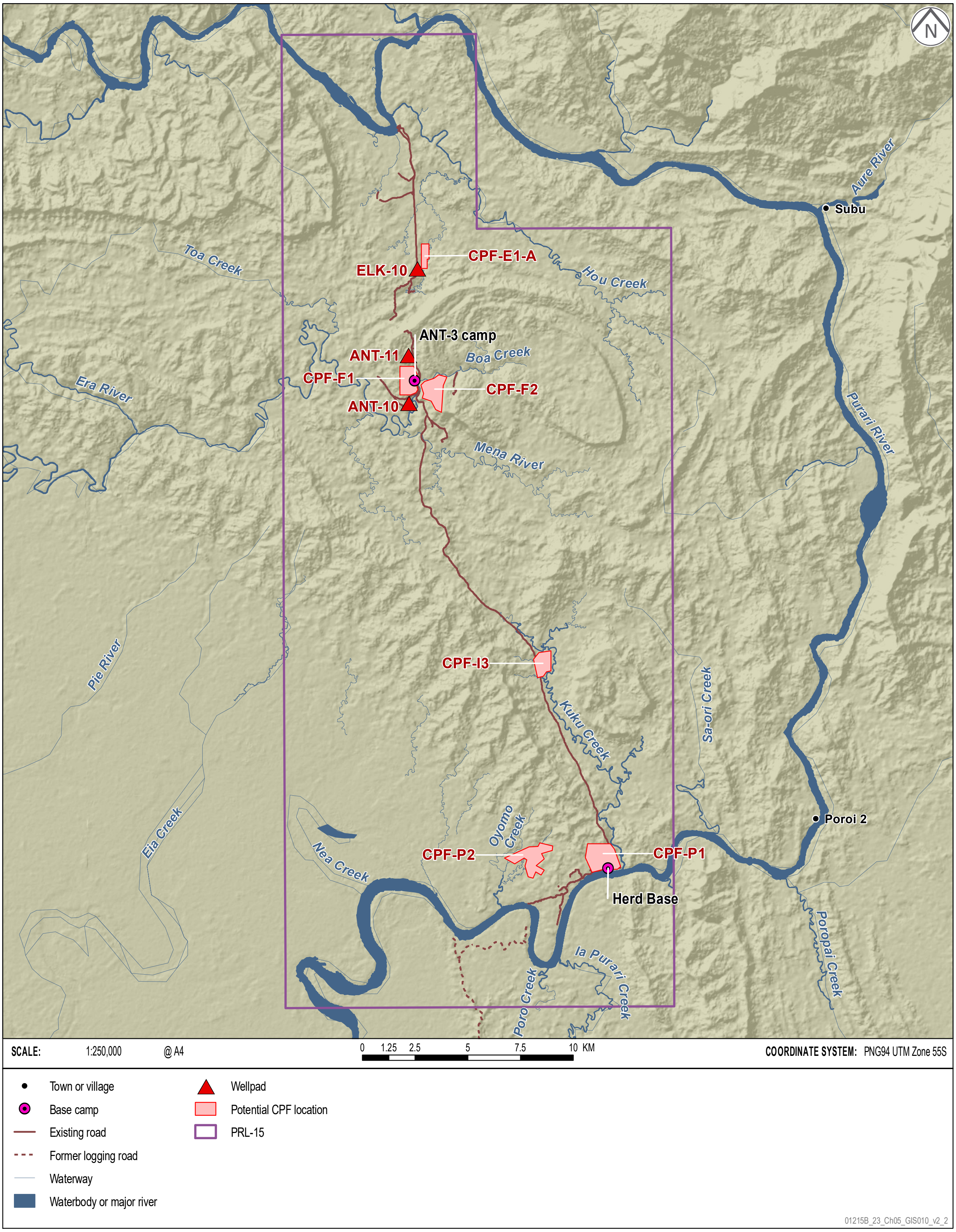

Table 5.5 – Key Attributes in Determining the Final CPF Location

Attribute	P2C	P2A
Physical		
Vegetation	Hill forest.	Hill forest.
Population centers	None (closest is Poroi 1).	None (closest is Poroi 1).
Soil type	Rocky, suitable base for process equipment foundations.	Gravel/conglomerate at depths, overlaid with softer clays.
Drainage	Lower risk of flooding due to being built into the foothills.	Higher risk of flooding from the nearby creeks.
Technical and Design		
Geohazards	Harder soils, less risk of seismic movement. Less exposed to landslides.	Softer clay soils, higher risk of seismic movement.
Site preparation	Does not require deep soil improvement but requires more excavations.	Deep soil improvement required. An additional eight months' preparation time required.
Access and logistics	Access from the Purari River. Can reuse excavated material as backfilling material.	Access from the Purari River. Large quantities of aggregates would need to be imported for site preparation.

5.3.2 Wellpads and Gathering Station

Up to eight wellpads were identified to develop the reservoir at the end of the conceptual phase. As appraisal drilling took place during the pre-Project phase, the data showed that optimizing the number of wellpads was possible. Consequently, the Antelope production wells have been grouped on a single wellpad, reducing the disturbance footprint from pads and interconnecting pipelines.

Reusing two appraisal wellpads is planned for the new production (ELK-10, formerly Elk-1) and water injection (ANT-11, formerly ANT-1) wells, so that only the Antelope production wellpad (ANT-10) will be new. Grouping wells and reusing existing wellpads has significantly reduced the overall wellpad disturbance footprint.

A separate gathering station, where the gas will be collected from the wellpads, was also assumed at the beginning of the pre-Project phase; however, with the improved reservoir knowledge enabling the single wellpad for Antelope, it was decided to locate the gathering station at the Antelope production wellpad, thus further reducing the overall footprint and minimizing vegetation clearing and ground disturbance.

5.3.3 Logistics Facilities

Herd Base is an existing logistics base in PRL-15 and was used during appraisal drilling. The Kuku Ridge separates it from the CPF location, and access between the two would require the existing track, which has several steep sections, to be upgraded. These steep sections would require extensive grading, leveling, and realignment to meet the heavy haul requirements of the CPF equipment (e.g., up to 1,000 tonnes and large modules) and to support the large traffic volume likely during CPF construction.

Herd Base is also physically constrained in its expansion capacity beyond its existing footprint to meet the projected construction personnel requirements and is at risk of inundation at the quay level.

The following three options were assessed for their capacity to meet the construction and operations logistics needs because of these limitations:

- Option 1 – develop a new logistics base of approximately 20 ha on the northern bank of the Purari River, approximately 5 km downstream from Herd Base, and construct an approximate 2.6-km, flat, heavy transport road to the CPF.
- Option 2 – upgrade and expand the existing facilities at Herd Base (to be used as a logistics base for the duration of the Project) and construct an approximate 5-km, steeper, heavy transport road to the CPF.
- Option 3 – upgrade and use Herd Base for early works with the construction of a 'light-duty' road, using the existing track, to support initial mobilization and the development drilling campaign, then develop a smaller, approximate 7-ha, new logistics base and a 2.6-km heavy haul road to the CPF at a later stage.

These options were developed based on the logistics sequences of early works, Project construction and Project operation. Options 1 and 2 have approximately the same total footprint, as the heavy haul road requires more earthworks and the heavy haul and light-duty roads from Herd Base would need to be longer than one heavy haul road from a new logistics base.

Option 3 has been selected as the preferred option because it enables early mobilization of personnel and equipment to begin the construction of Project infrastructure, which better meets the Project timeline (Table 5.6).

Table 5.6 – Logistics Base Alternatives Analysis Summary

Criteria	Option 1	Option 2	Option 3
Technical or logistical difficulty	High	High	Med
Environmental sensitivity	Med	Med	Med
Social sensitivity	Low	Low	Low

5.4 Routing Alternatives

This section outlines the processes followed to determine the preferred routes for each section of the Project pipelines, including the gathering network, and onshore and offshore export pipeline routes.

5.4.1 The Gathering Network

The gathering network comprises two 22-inch trunklines connecting the Antelope production wellpad (ANT-10) to the CPF and a 14-inch flowline connecting the Elk production wellpad (ELK-10) to the CPF.

5.4.1.1 Elk Production Flowline

Three alignments were assessed for the Elk production flowline routing; the western, central and eastern routes (Figure 5.3 and Table 5.7).

INFIELD FLOWLINE SHOWING THE PREFERRED WESTERN ROUTE

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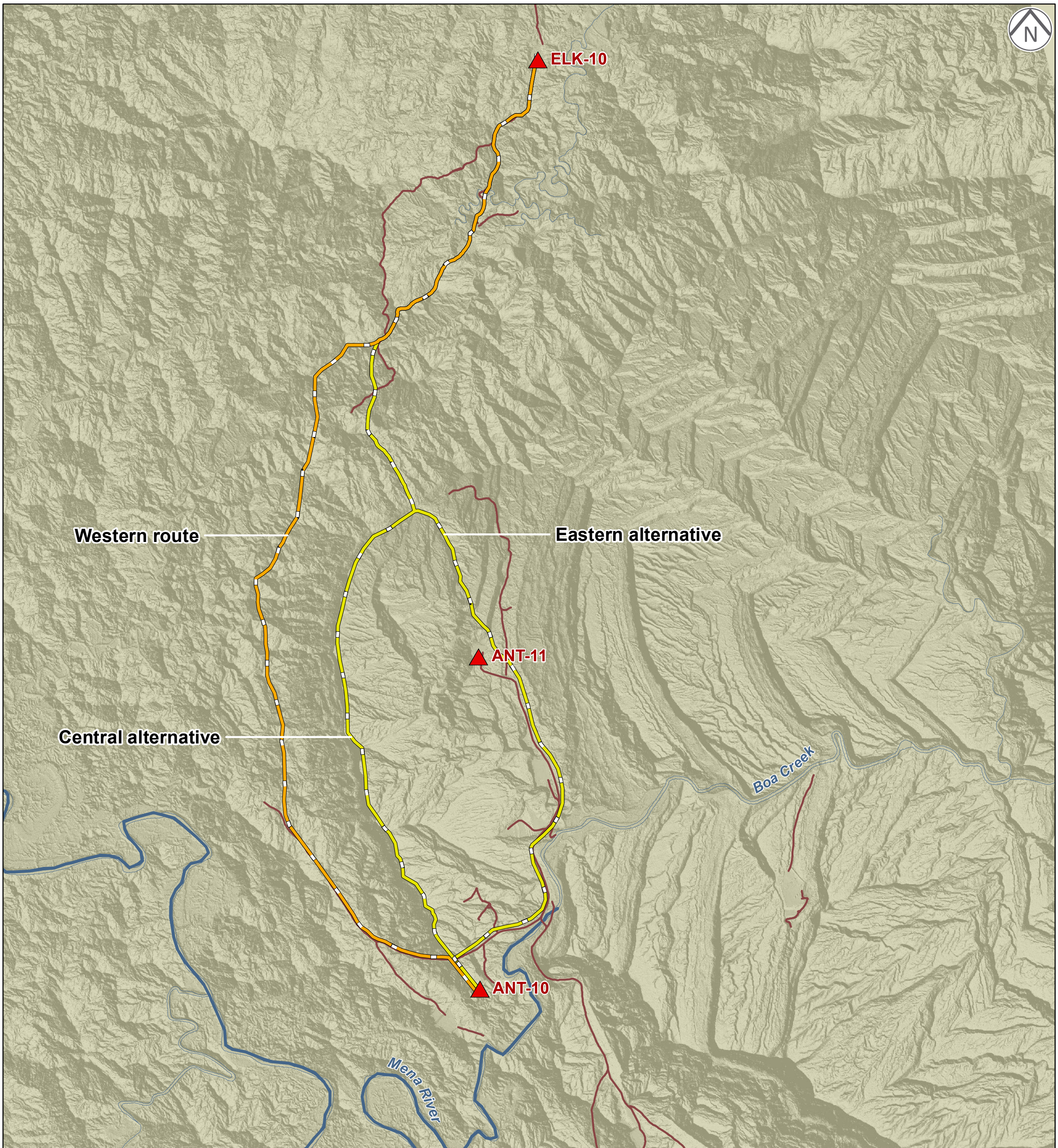
FIGURE 5.3



SCALE: 1:40,000 @ A4

0 250 500 1000 1500 M

COORDINATE SYSTEM: PNG94 UTM Zone 55S

Existing road
Waterway
Waterbody or major river
Wellpad
Preferred flowline route
Alternative flowline route

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Table 5.7 – Flowline Routing Alternatives Analysis Summary

Criteria	Western	Central	Eastern
Technical or logistical difficulty	Med	High	High
Environmental sensitivity	Med	Med	Low
Social sensitivity	Low	Low	Low

During initial investigations, the central route was the preferred option from a pipe-laying and integrity perspective; however, studies noted that constructing and maintaining the service track in this area would present a challenge because it follows a narrow and eroding ridge. The eastern route, which follows an existing track and therefore would require less clearing, was discarded as a viable option as it crosses more varied terrain than the central route, including active planar landslides. Consequently, the western route became the preferred 'base case' option.

The western route connecting ELK-10 to ANT-5 via Elk-4 is the longest option, but it crosses the fewest geohazard zones and follows a relatively homogeneous terrace and slope setting. Building an access road close to the pipeline ROW is feasible.

A specialist pipeline construction contractor will further optimize the infield routing prior to finalizing the alignment.

5.4.1.2 Trunklines

Trunkline routing considered several constraints, including swampy areas, fault crossings and landslides, river crossings, slopes, environmentally sensitive forest areas, soil conditions, the availability of aggregates and accessibility for construction.

Table 5.8 and Figure 5.4 show the five route options considered.

Table 5.8 – Trunkline Routing Alternatives Analysis Summary

Criteria	Western	Western New	Alternative 1 Options A-E	Alternative 2	Central
Technical or logistical difficulty	High	High	High	High	Med
Environmental sensitivity	High	High	Med	Low	Low
Social sensitivity	Med	Med	Low	Low	Low

As a result of the analyses, the central route was selected as the preferred option. The main reasons for this choice were:

- The alignment minimizes the length to limit pressure drops, enabling a free-flow CPF design.
- Combining the access road and the pipeline ROW reduces the vegetation clearing and earth disturbance footprint.
- Construction and maintenance will be easier due to the pipeline ROW running parallel to the road.
- The environmentally sensitive alluvial forest south of the Kuku Ridge was avoided.

TRUNKLINE ROUTE OPTIONS INVESTIGATED DURING THE PRE-PROJECT DESIGN PHASE

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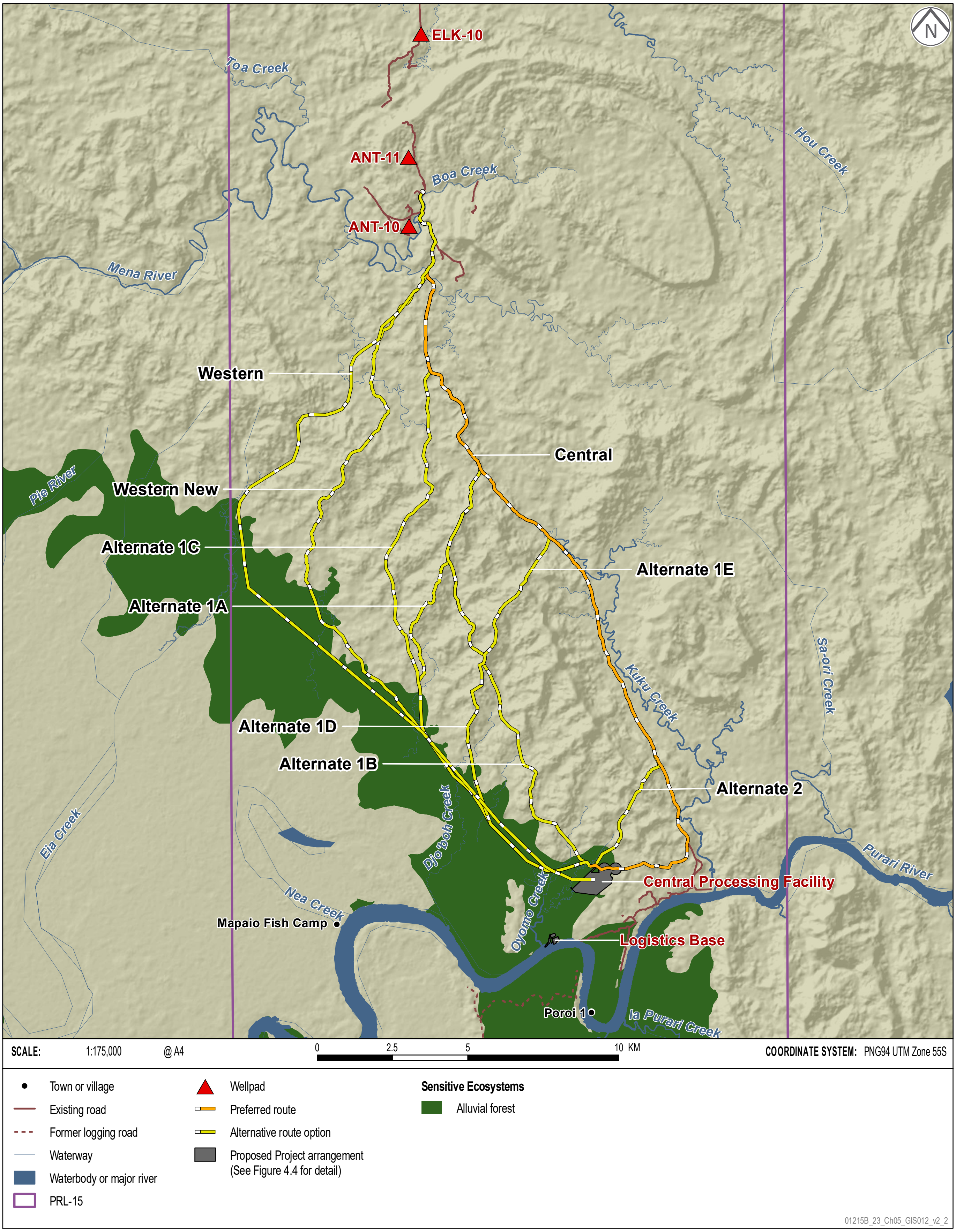
FIGURE 5.4



- The Pie River catchment, which is remote, relatively untouched by development and identified as a high priority for avoidance due to the upstream terrestrial biodiversity baseline study (Part 6 of Volume 2) and the possibility of increasing the number of affected communities downstream of pipeline works, was avoided.

Optimizing the pipeline trench design allowed co-location of the four pipelines (i.e., three production and one water injection) south of ANT-10 and the electric and fiber optics cables in only two trenches, decreasing the width of the pipeline ROW.

As the Project develops, the proposed routing will be refined, as additional data is collected, and final alignment and preconstruction surveys are undertaken.

5.4.2 Onshore Export Pipelines

The main export pipeline system will consist of separate gas and condensate pipelines connecting the CPF to the downstream LNG plant. Two early scenarios considered and discarded due to environmental, social, logistical and safety constraints were:

- An onshore route only – this scenario considered a fully onshore export pipeline alignment from the CPF to the LNG plant near Port Moresby. This option was found to have the following disadvantages:
  - Many coastal areas are swampy and would present severe logistical challenges.
  - Many rivers drain Gulf Province and would need to be crossed.
  - More land would need to be acquired and more adverse community impacts would occur.
- A Purari River route – this scenario was an adaptation of the onshore route above and considered laying the pipelines in the Purari River. In this case, the disadvantages were:
  - The water level in the Purari River is prone to seasonal variations, which could destabilize the pipelines.
  - Accidents may occur due to boat anchors and fishermen’s nets damaging the pipelines or others’ property.

After discarding the fully onshore options, the Project considered laying the pipelines from the CPF to the Gulf of Papua coast, where they would connect to offshore pipelines. This approach would minimize the clearing footprint, the social implications and the engineering challenges of onshore routing.

Assessing these options began with identifying a western alignment to Orokolo Bay and a central alignment crossing the Vailala River and up to the Bluff coastline (Figure 5.5), which were ranked for social and environmental sensitivities, pipeline constructability and environmental (e.g., flooding, geophysical) constraints. This study determined that the western alignment to Orokolo Bay was preferred, as it had a lesser risk of landslides and had a significantly shorter onshore section (i.e., 60 km compared to 94 km) and thus was more commercially advantageous and generating less onshore footprint.

While the northern part of the western alignment largely followed an existing logging trail to minimize the disturbance footprint, the coastline south of the alignment has villages, marshes (including mangroves) and cultural sites, resulting in a risk of increased adverse impact on communities and the environment if a suboptimal crossing location was chosen.

ONSHORE EXPORT PIPELINE OPTIONS

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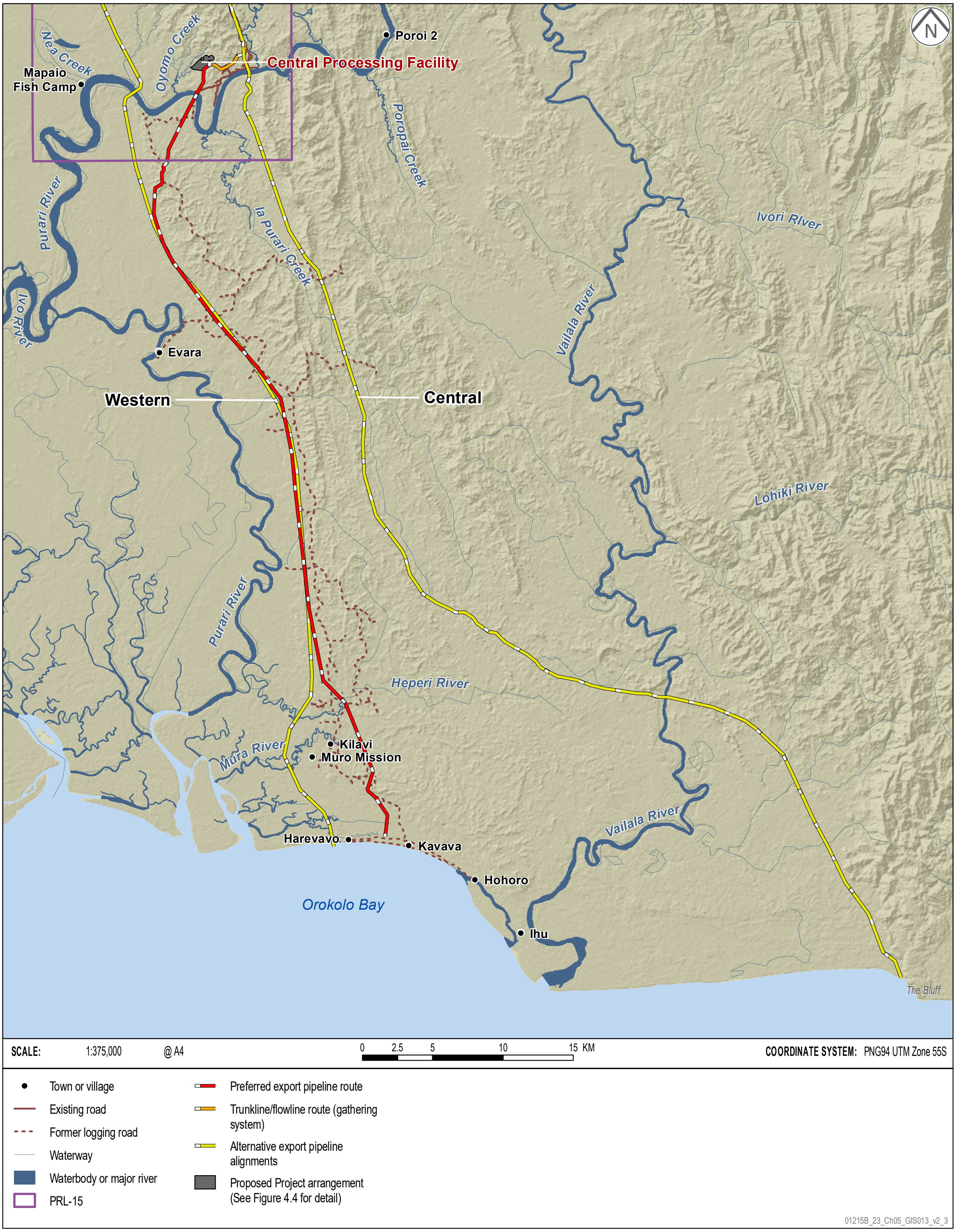
FIGURE 5.5



An early buffer forming a corridor was applied around the western alignment to support the assessment of social and environmental sensitivities. Constraints mapping was undertaken to optimize the corridor in the southern section from the village of Kilave to the coast at Orokolo Bay where the corridor was narrowed further. This refined export pipeline corridor, extending from approximately 2 km west of the village of Harevava in the west of Orokolo Bay to the village of Hororo in the east was the area mapped and characterized during the environmental and social baseline surveys (see Chapters 7 to 10).

Several potential alignments in this corridor were ranked according to their environmental and social sensitivity to determine the most appropriate shore crossing location for the pipelines. The Project team used this ranking to inform the final alignment recommendation. Figure 5.6 and Table 7.10 show the five route options considered. It shows that corridor E crosses sensitive herbaceous swamps and mangrove areas, and corridors A, B, C and D intersect with cultural sites and populated areas.

This assessment concluded that corridor B, passing between the villages of Iuku and Mareke, was the most suitable alignment. Environmental and social sensitivities are still present in corridor B, but this corridor is likely to cause the fewest potential adverse social, cultural and environmental impacts, provided cultural sites can be avoided (Table 5.9).

Table 5.9 – Onshore Export Pipeline Shore Crossing Alternatives Analysis Summary

Criteria	A	B	C	D	E
Technical or logistical difficulty	Low	Low	Low	Med	Low
Environmental sensitivity	High	Low	Low	Low	High
Social sensitivity	Med	Med	High	Med	Med

A narrower export pipeline corridor and proposed export pipeline route were defined based upon this preferred alignment, after further Project development and refinement. These form the 'base case' in the Project description (see Chapter 4). The proposed routing is expected to be adjusted slightly within the export pipeline corridor during the FEED phase to include all the findings from geophysical and geotechnical pipeline surveys. Thereafter, any further adjustments made, in response to unknown environmental and social sensitivities that are identified during the Detailed Design phase and preconstruction surveys, will be to avoid any localized sensitivities.

5.4.3 Offshore Export Pipelines

The offshore export pipelines route extends for approximately 260 km from Orokolo Bay to the PNG LNG Facilities in Caution Bay. Route selection for the offshore pipelines was informed by the following criteria:

- Selecting an appropriate site for the LNG facilities.
- Identifying the shore crossing in Orokolo Bay and Caution Bay.
- Remaining at least 5 km from shore to avoid interference with customary land and community livelihood activities.
- Optimizing the pipeline length to be as short as practicable.
- Maintaining a minimum distance of 100 m between the PNG LNG Gas Pipeline and the Project pipelines.

EXPORT PIPELINE CORRIDOR ORKOLO BAY SHORE CROSSING ALTERNATIVES

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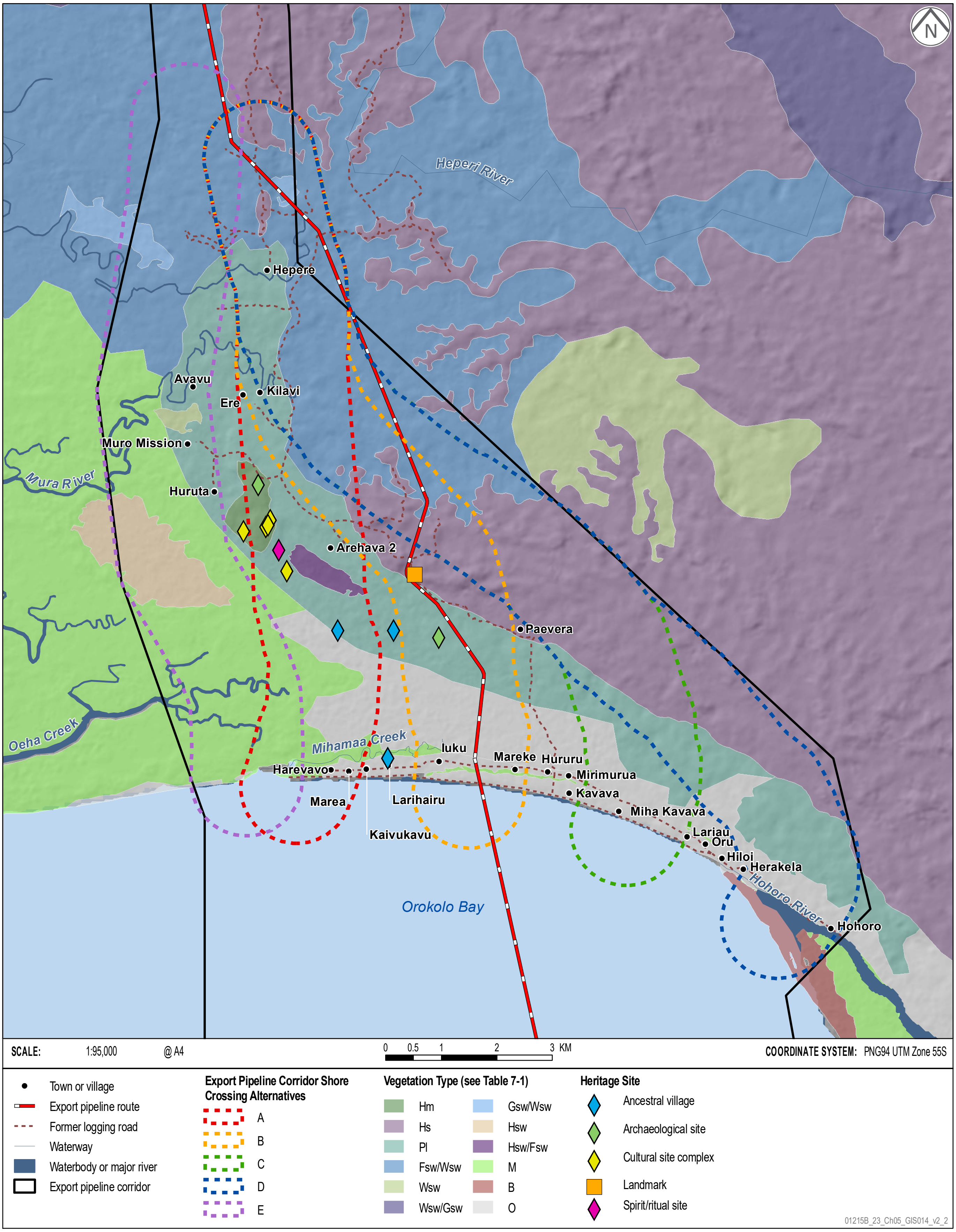
FIGURE 5.6



- Maintaining the crossing angle of the existing PNG LNG Gas Pipeline at between 60° and 90°.
- Minimizing the pipeline depth as much as practicable.

Seven route options were studied in 2017 to assess how well they met these design criteria. This analysis initially preferred option 7, assessed alongside option 2, because it was the shortest route and remained in shallower water until it crossed the PNG LNG Gas Pipeline.

An additional analysis was then performed using marine geophysical survey data collected for the PNG LNG Gas Pipeline, which highlighted that the option 7 corridor showed several seabed surface disturbances (i.e., depressions or pockmarks) and soil variations, which needed to be avoided to prevent free spans of the laid pipeline.

Option 2 was finally selected as it minimized pipeline length, avoided geohazards and used the existing PNG LNG pipeline corridor as much as possible (Table 5.10).

Table 5.10 – Offshore Export Pipeline Alternatives Analysis Summary

Criteria	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Technical or logistical difficulty	Med	Low	Med	Med	Med	Med	Med
Environmental sensitivity	Low	Low	Low	Low	Low	Low	Low
Social sensitivity	Low	Low	Low	Low	Low	Low	Low

Further surveys during FEED will be undertaken to refine the Caution Bay shore crossing in particular to avoid the sensitive marine and coastal environments in this area as much as practicable.

5.5 Process and Technology Alternatives

5.5.1 Acid Gas Management

The gas produced from the Elk-Antelope reservoirs contains native carbon dioxide (CO_2) and hydrogen sulfide (H_2S) and is referred to as acid gas. It must be removed prior to liquefaction to achieve the technical and commercial specification of less than 45 ppm for CO_2 and less than 3 ppm for H_2S.

5.5.1.1 Acid-gas Removal and Management

A commonly used technology to remove acid gas is to route it to an acid gas removal unit (AGRU) where it passes through amine, which absorbs the H_2S and CO_2. Several options were and are still being assessed that variously consider acid gas removal, e.g., incineration and injection:

- Full Incineration: The acid gas is treated with a thermal oxidizer and vented to the atmosphere.
- Partial Reinjection: Incineration, followed by acid gas reinjection into the reservoir after approximately 4 years.

In the case of full incineration, the entire flow of effluent gases from the AGRU is routed to the thermal oxidizer for combustion without sulfur removal causing full venting of acid gases for the life of the Project.

Carbon dioxide and H_2S injection back into the reservoir can be considered where technologically feasible in a cost-effective manner. The capacity of the reservoirs to accept injected CO_2 and H_2S was studied during the pre-Project phase. It was found that, although acid gas could potentially be injected into the Antelope reservoir from the beginning of gas production, injected acid gases are expected to rise to the surface with hydrocarbon gases after a few years, thereby potentially significantly increasing the CO_2 and H_2S content of the produced raw gas. This would then force the installation of a much larger amine unit and other design changes, and increase the power requirements for both gas production and reinjection. This option has been rejected, as this would significantly increasing the need for fuel gas and consequently the release of flue gas in the atmosphere.

The injection study showed that, after approximately four years of Elk reservoir depletion, sufficient capacity would be available for CO_2 and H_2S injection. The subsurface studies showed that the Elk reservoir appears to be independent from the Antelope reservoir, so the likelihood of CO_2 and H_2S circulation into the Antelope reservoir during ongoing production seems low. The actual separate behavior of both reservoirs will have to be assessed during the first years of production.

The outcome of the preliminary acid gas management assessment highlighted the relative differences between potential acid gas management concepts with respect to CO_2 as the primary greenhouse gas (Table 5.11), rather than in association with H_2S/SO_2, which have different management requirements; this is discussed further in Section 5.5.1.2. In any case, most of the SO_2 will be removed to minimize any adverse impacts of SO_2 emissions on sensitive receptors near the Project.

Table 5.11 – Indicative GHG Emissions Over the Project Lifetime

Concept	CO_2 (kt)
Full incineration	30
Partial reinjection	16

The partial reinjection concept has been further developed in the EIS to address GHG requirements; however, all concepts are being investigated further as a better understanding of the following Project characteristics and requirements is gained during FEED:

- Reservoir characteristics.
- More detailed project design considerations.
- The cost implications of each concept.
- Ongoing technological advances.
- Potential environmental benefits.
- Production constraints.

5.5.1.2 Sulfur Removal and Treatment

Options that would allow acid gas to be safely discharged to the atmosphere in case of acid gas incineration have and are still being investigated. Acid gas would go from the AGRU through a thermal oxidizer to convert sulfur compounds including H_2S into SO_2.

The main options assessed to manage the SO_2 are:

- Venting SO_2 to the atmosphere.
- Solid sulfur disposal in a landfill.

- Converting SO_2 to liquid effluent (flue gas desulfurization) for injection with produced water.

The results are summarized in Table 5.12.

Table 5.12 – Sulfur Removal and Treatment Alternatives Analysis Summary

Criteria	Venting SO_2 to the Atmosphere	Solid Sulfur in a Landfill	Conversion of SO_2 to a Liquid Effluent for Injection
Technical or logistical difficulty	Low	High	High
Environmental sensitivity	Assessment Ongoing	Med	Low
Social sensitivity	Med*	Low*	Low

* While direct impacts on communities are likely to be medium or low (respectively) for these scenarios, any potential adverse impacts to vegetation, due to sulfur emissions, could raise stakeholder concerns from both Project-affected communities and the wider public.

Sulfur dioxide venting to the atmosphere would reduce the CPF complexity and footprint and would avoid constructing a solid sulfur landfill and vegetation clearing. No solid sulfur handling would be required; however, venting SO_2 is likely to raise community concern due to the pungent odor, and has potential adverse health and environmental effects (e.g., acid rain).

Producing and disposing of solid sulfur presents several challenges, including:

- The operational complexities associated with a remote location.
- The low sulfur content of the acid gas (e.g., when compared to acid gases from a refinery) did not allow a technology to be selected that would produce marketable solid sulfur.
- No market for low-quality sulfur was known in Papua New Guinea.
- The absence of a suitable existing landfill for solid sulfur in Papua New Guinea.
- Solid sulfur, if sent for disposal elsewhere would require loading and transporting by barge up to seven tonnes per day. This would lead to additional combustion impacts associated with the transport of solid sulfur.

The overall approach of venting or sulfur recovery and landfill construction was also compared to an option of flue gas desulfurization, consisting of converting SO_2 to a liquid effluent. This option minimizes the need to vent SO_2, as the flue gas desulfurization liquid effluent can be injected with the produced water into the Antelope reservoir at ANT-11. It also reduces potential land disturbance and removes any adverse environmental impacts associated with the solid sulfur landfill. The SO_2 conversion into a liquid effluent via desulfurization, followed by reinjection with produced water, has been further developed in the EIS to address air quality requirements.

5.5.2 Produced Water Management

While the reservoirs are not expected to produce a large volume of water during production (i.e., produced water), the process of treating acid gas at the CPF will create a small volume of sulfur- and hydrocarbon-contaminated process water. The feasibility of injecting this water, and the treatment required for both injection and discharge of both produced and process water was evaluated. The study examined the following options:

- Option 1 – Reed bed (natural infrastructure) technology is considered to have an insufficient level of maturity, has not been proved by TOTAL and has a perceived lack of benefit compared with conventional biological treatment.
- Option 2 – Discharge on soils or irrigation is only recommended for very low water flow rates and when there is no river or sea nearby for disposal.

- Option 3 – Solar or mechanical evaporation is unlikely to be feasible in the Papua New Guinea context, given the rainfall rate is much higher than the evaporation rate. Further, a huge surface area of approximately 600 m by 300 m at the CPF or 500 m by 300 m at the LNG plant would be required to install evaporation ponds, resulting in greater vegetation clearing.
- Option 4 – Dilution during upset conditions involves the use of open drain water to dilute treated produced water prior to discharge during upset conditions. TEP PNG considers this option to be unacceptable even during degraded mode operations.
- Option 5 – Discharge to the sea would require additional pipelines to be installed and a costly water treatment plant to be installed so that discharged water can meet water quality specifications.
- Option 6 – Discharge to the Purari River would require a costly water treatment plant to be installed so that discharged water can meet water quality specifications.
- Option 7 – Full reinjection minimizes the potential negative effects on the receiving environment and the Project-affected communities that use it for fishing, drinking water and transportation.

Table 5.13 summarizes the analysis undertaken.

Table 5.13 – Produced Water Management Alternatives Analysis Summary

Criteria	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Technical or logistical difficulty	High	Med	High	Low	Med	High	Med
Environmental sensitivity	Low	Med	High	High	Med	High	Low
Social sensitivity	Low	Low	Med	High	Med	High	Low

Injection of all produced and process water, i.e., Option 7, was therefore adopted as the preferred option for normal operations. The Project proposes to reuse an appraisal-phase pad for water injection and collocating the water injection pipeline in the same trench as the trunkline (Section 5.4.1.2) pipeline for much of its length.

5.6 Construction Alternatives

5.6.1 Quarries

Constructing the upstream facilities will require a large volume of aggregate to provide a firm foundation for process equipment. Locations and layouts for these facilities have been chosen in part to minimize the need for aggregate by reusing excavated material and placing heavy equipment on naturally firmer areas.

Suitable quarry locations were sought near the CPF to limit the import of aggregate by river from outside the Project area. In identifying quarries, preference was given to existing quarries to reduce disturbance. Quarry locations (see Figure 4.11) were identified through several detailed geotechnical earthworks studies that estimated cut and fill volumes for the roads, wellpads, CPF, Purari airstrip extension and the Logistics Base; by analyzing material composition; and by considering environmental and social sensitivities.

Thirteen quarry locations (i.e., seven inside and six outside of PRL-15) were screened. Four quarries inside PRL-15 (see Figure 4.11) may be developed to supply construction backfill material for the Project because of their reliability, accessibility, material suitability and lesser environmental sensitivities. The remaining rocky material will be sourced from off-site quarries described in Section 4.8.4.3 after further assessment of aggregate requirements and an analysis of environmental and social constraints during FEED.

5.6.2 River Crossings and Shore Crossings

Constructing the export pipelines will require crossing the Purari River and several small streams. Several different options for constructing the Purari River crossing were studied during the pre-Project phase, including horizontal directional drilling (HDD), micro-tunneling, direct piping and a bridge (Table 5.14).

Table 5.14 – Purari River Crossing Construction Alternatives Analysis Summary

Criteria	HDD	Micro-tunneling	Direct Pipe	Bridge
Technical or logistical difficulty	Med	Med	High	Med
Environmental sensitivity	Med	Med	Med	Low
Social sensitivity	Low	Low	Low	High

HDD was selected as the preferred technology for the Purari River crossing due to its lower cost and its significant successful track record compared to micro-tunneling.

Three routes across the Purari River were evaluated for their suitability for HDD construction (Figure 5.7). The eastern and western routes were discounted due to a low-lying, muddy entry platform required for the eastern route and the longer length of HDD required for both. The central route was chosen as the preferred route because of the gravel material available on the hills above the Purari River, which will provide a good platform with adequate drainage for construction, and because it is the shortest route.

HDD, micro-tunneling, direct pipe and open trench construction methods were assessed for the Orokolo Bay shore crossing. The Project team determined that no strong drivers for underground techniques existed, as the pipelines cross the coastline between two villages.

The open trench construction method is; the overall preferred option for Orokolo Bay shore crossing, due to technical and cost advantages (Table 5.15), despite its higher social sensitivity. With an open trench, local communities may experience temporary access restrictions, and increased exposure during the construction works; which are further assessed in Chapter 13.

Table 5.15 – Pipeline Shore Crossing Approach Construction Alternatives Analysis Summary

Criteria	HDD	Micro-tunneling	Direct Pipe	Open Trench
Technical or logistical difficulty	Med	Med	High	Low
Environmental sensitivity	Low	Low	Low	Low
Social sensitivity	Med	Med	Med	High

The Papua LNG downstream EIS shall address the Caution Bay shore-crossing construction methods.

PURARI RIVER CROSSING ALTERNATIVES

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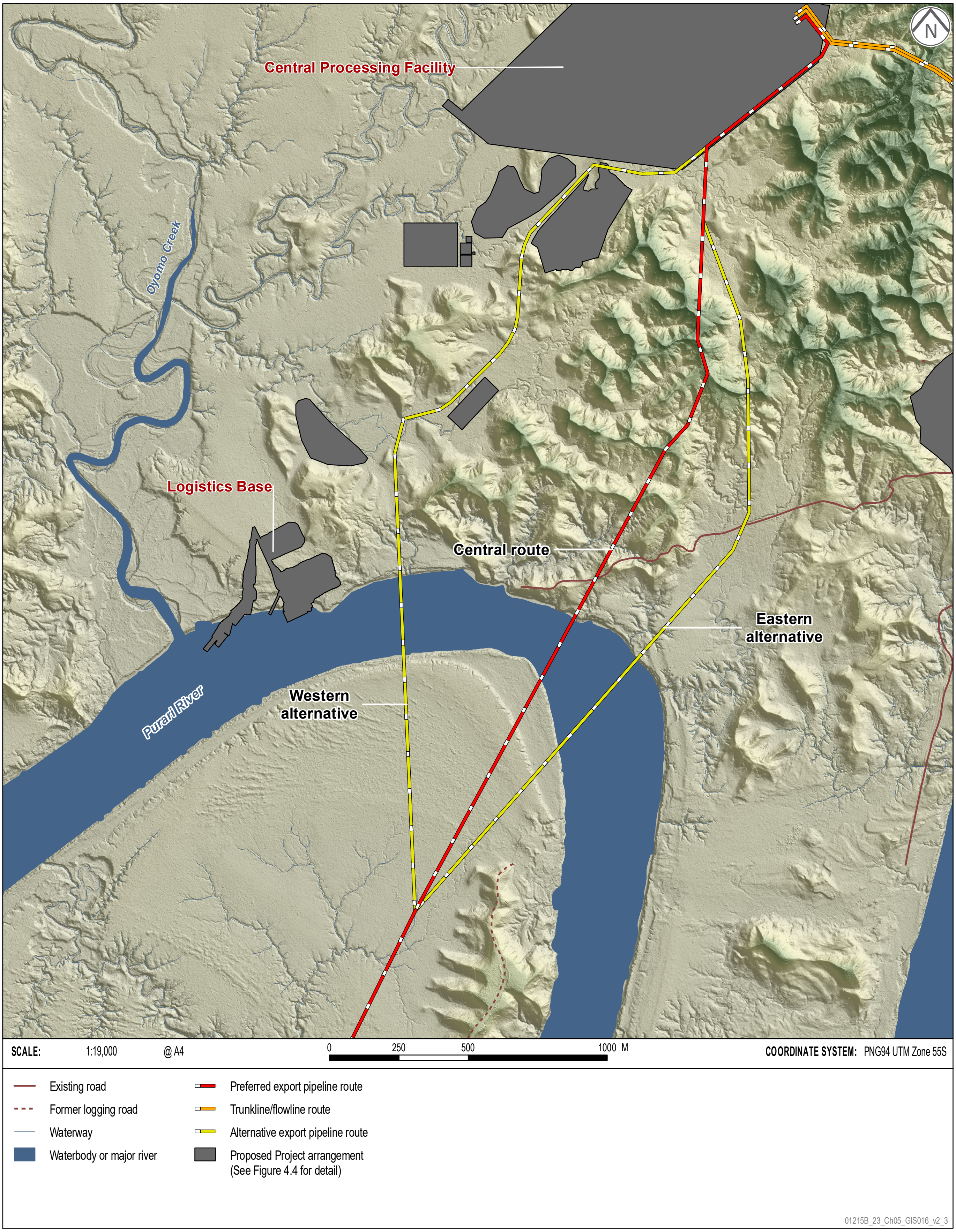
FIGURE 5.7



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5.7 Transportation and Logistics Options

5.7.1 Air Transport

Air transport of personnel will be an important component of Project logistics due to the remoteness of PRL-15, particularly during the construction phase when peak personnel requirements are estimated to be up to 6,000.

Air transport was determined to be the most feasible option for personnel transport. Consideration was given to fast crew boats, which can make the trip from Port Moresby in 1 to 2 days; however, this was deemed impracticable due to the large number of personnel required during the construction phase. Road access from Port Moresby is currently impossible and 100 to 150 km sections of road from Kerema would have to be built, which would be very costly, have significant environmental and social impact both in construction and operations, and still result in long transportation times and associated risks of accidents.

The existing airfield in PRL-15 is also currently too small to land the larger aircraft required to meet the personnel transfer demand during the construction period.

The following three options for personnel transport during construction were subsequently assessed:

- Option 1 – Develop a new 1,800-m Code 2 airstrip located on the same side of the Purari River as the CPF, new logistics base and accommodation.
- Option 2 – Use and expand the existing airstrip on the southern side of the Purari River to Code 2. This option requires upgrading the existing ramp to allow personnel to be transported across the river to the new logistics base. It would allow emergency landings of Code 3 aircraft.
- Option 3 – Design and build a new smaller Code 1 airstrip north of the Purari River while also upgrading the existing Code 1 airstrip south of the river, which would be used only during the construction phase.

TEP PNG undertook a qualitative analysis of these options, which considered:

- Technological hazards – landslide and flood risks, and soil quality.
- Human exposure – impacts on nearby communities, the risk to personnel associated with the river crossing and the access to medical evacuation.
- Logistics transport – the ease and comfort for personnel, and the access in case of unplanned or emergency events at site.
- Operational complexity – the operations of aviators for landing and takeoff operations, the access for maintenance and fueling, and the constraints associated with two airstrips operating simultaneously.
- Construction hazards – earthworks required, the access to the temporary construction camps and construction areas, construction permissions and the access to expand areas if required.
- Environmental and social impacts – of affecting new areas, on communities during the construction and also of continuously using the river, especially during the peak of the construction phase.

Results are summarized in Table 5.16, and the new and existing airstrip layouts, overlain with vegetation types are shown in Figure 5.8.

NEW AND EXISTING AIRSTRIP LAYOUT COMPARISON

Papua LNG Project | Environmental Impact Statement

FIGURE 5.8

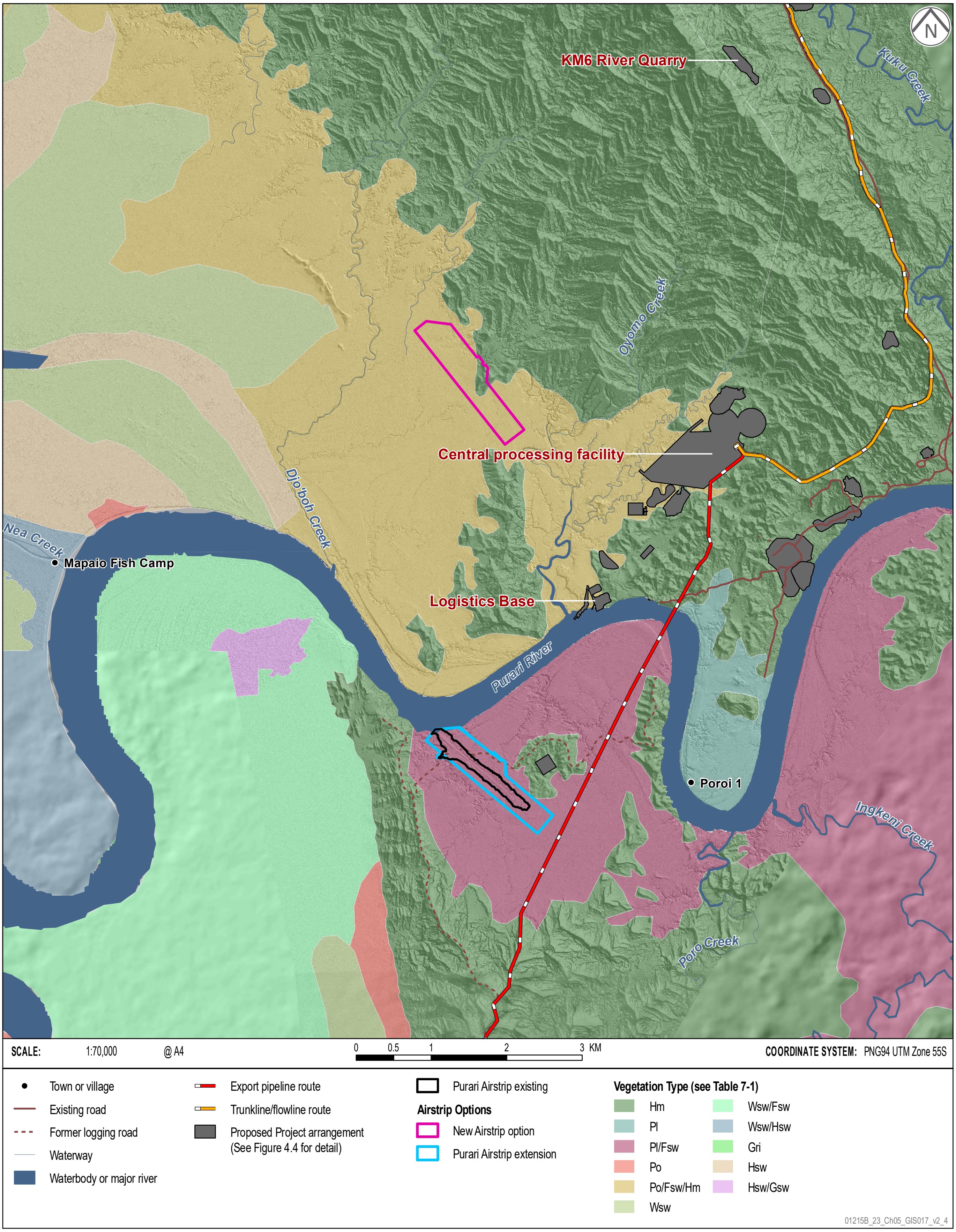

Table 5.16 – Airstrip Alternatives Analysis Summary

Criteria	Option 1 (New)	Option 2 (Existing)	Option 3 (Combination)
Technical or logistical difficulty	Med	High	High
Environmental sensitivity	High	Med	High
Social sensitivity	Med	Med	Med

Option 3 was discarded because of its limitations (e.g., emergency evacuation and transportation of materials).

Option 1 of a new airstrip north of the Purari River was the preferred option to negate the need for personnel transfers across the river; however, it carried significant adverse environmental and social impacts, e.g., the need to clear a large area of vegetation, and its closeness to the environmentally sensitive PRL-15 oxbow wetlands.

Option 2, involving the upgrade of the existing airstrip to Code 2 (see Section 4.8.7), is the preferred option because of its lower capital costs and reduced environmental footprint (Figure 5.8). The Purari Airstrip House is the nearest receptor and Poroi 1 is the nearest village to the existing Purari Airstrip. Potential impacts associated with noise and air quality are discussed and assessed in Chapter 15.

5.7.2 Water Transport

Equipment and construction materials will be stored at either the Motukea supply base or the Avenell Engineering Systems (AES) supply base 3 km away. Materials and equipment will be barged across the Gulf of Papua and up the Purari River to PRL-15 from either of these bases.

The Purari River finishes in a complex delta with many arms, and there are several entry points from the sea. An analysis of river transport routes was undertaken to assess the best option for transporting equipment from the Motukea or AES base to the logistics base.

Three branches were assessed for navigability and their capacity to support high-draught barges: the Purari River (eastern branch), the Urika-Ivo River (central branch) and the Wame-Varoi River (western branch) (see Figure 4.15).

Water level variability is a key issue with water transport on the Purari River and its delta rivers. Water levels can change very quickly and are not seasonally predictable.

The analysis initially recommended the Ivo as the most navigable route for river transport, but the preferred route is via the Aiele Passage and the lower Purari River. Local vessel masters currently use this route, which has a river mouth crossing that is considered easier than the Ivo river mouth crossing. The Urika-Ivo River is; therefore, considered as a secondary transport route to be used when the lower Purari River is not navigable, and the Wame-Varoi is unlikely to be used for Project transport.

5.8 No-Project Option

The direct alternative to developing this Project is for it not to proceed. If the Project failed to go forward, no adverse environmental or social impacts associated with Project development in Papua New Guinea would occur, as no construction or operational activities would take place; however, this needs to be balanced against the fact that no beneficial impacts associated with the Project would occur. Should the Project not proceed, the following benefits would not be realized:

- Up to an estimated 6000 jobs during peak construction.

- Direct benefits to national and provincial governments, and legally recognized landowners through equity, royalty and development levy benefits.
- A direct contribution of up to 5% of the exported gas to Papua New Guinean electrical power generation.
- National business development opportunities through supply of equipment and materials required for construction and operations.
- Socio-economic development of communities in the Project area.

The no-Project option also means that any adverse impacts associated with the Project, as outlined in Chapters 11 to 18, would not occur.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 6: Stakeholder Engagement

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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6. Stakeholder Engagement

6.1 Introduction

Stakeholder engagement is an important aspect of any project development and an internal requirement of TEP PNG Societal Policy.

Since early 2015, TEP PNG has implemented a program of consistent, planned and targeted engagement with Project stakeholders, using a range of approaches designed to address the specific needs of each stakeholder group. In particular, TEP PNG has emphasized frequent, respectful engagement with local communities in the Project area of influence (PAOI), so that ongoing Project design and development can incorporate feedback and concerns raised.

This chapter outlines TEP PNG's engagement process and activities, specifically:

- The objectives, principles and methods used to design stakeholder engagement for the Project.
- The stakeholder engagement activities undertaken by TEP PNG to date, including resourcing arrangements.
- The key issues raised by stakeholders and how stakeholder input has been addressed in this environmental impact statement (EIS).
- How stakeholders will continue to be engaged through the next Project phases, and how engagement activities will be verified, monitored and reported.

6.2 Objectives, Principles and Engagement Methods

6.2.1 Objectives

TEP PNG recognizes the importance of developing and maintaining relationships with Project stakeholders. As the Project has developed, TEP PNG's approach to stakeholder engagement has been informed by regulatory requirements, TEP PNG internal standards and specifications, and International Finance Corporation (IFC) performance standards and guidance notes (IFC, 2012a and 2012b). A full analysis of the IFC performance standard's applicability to stakeholder engagement and how TEP PNG meets these requirements is provided in Attachment 6.1.

TEP PNG will work closely with local stakeholders to ensure early, regular and informed participation, through an on-going presence in Project-affected communities. The objectives of TEP PNG's stakeholder engagement program are to:

- Comply with the laws and standards that govern the Project.
- Build understanding and support for the Project and its potential outcomes that will contribute to the Project's informal 'social license to operate'.
- Assist in identifying key socio-economic, human rights, health and safety, and environmental issues that need to be addressed.
- Secure feedback on the effectiveness and suitability of existing and proposed impact mitigation, compensation and management measures and the Project's initiatives to deliver socio-economic benefits.
- Undertake a process of free, prior and informed consent (FPIC) in the Project area in accordance with the IFC performance standard (PS) 7.

- Contribute to the management of stakeholders' concerns, expectations and issues.
- Minimize the risks to the Project of poor stakeholder relations.
- Build the capacity of TEP PNG's Community Relations team to implement effective stakeholder engagement to Papua New Guinean and international social standards over the Project life cycle.

6.2.2 Principles

TEP PNG has adopted 10 principles for stakeholder engagement:

- Open and transparent: All information is open and transparent to stakeholders unless legitimate reasons for commercial confidentiality or the protection of stakeholders require that it be kept confidential.
- Listening: Stakeholders are listened to, their concerns are taken seriously, and responses are provided when required.
- Participation: Stakeholders are invited and encouraged to actively participate in the Project, as it concerns them.
- Proactive: Potential risks are communicated proactively with stakeholders, particularly when stakeholders may be unaware of a particular risk.
- Impact-focused: Engagement with stakeholders is focused on the potential and actual negative impacts/benefits that may concern them in relation to the Project.
- Safe participation: Stakeholders that participate in engagement should be participating in a safe and protected manner, without risk or fear of retaliation by anyone.
- Effectiveness: Information and forms of engagement are effective to the individuals for whom they are intended. Information and forms of engagement are accessible, legitimate, transparent and human rights–compatible.
- Appropriate form of engagement: Different forms of engagement may be required for different purposes, e.g., sometimes information is sufficient, but other times consultation, deeper engagement, full approval or consent is required.
- Empowerment: Engagement empowers stakeholders to make their voices heard.
- Respect for equality and human rights: Everyone, without any discrimination, has the right to participate on equal terms.

These principles underpin all engagement activities undertaken by TEP PNG. The approach used for the EIS process was also guided by the following community engagement guidelines:

- Inclusive consultation: Efforts are made to identify and engage with all those interested in, or affected by the Project, and this process is iterative. Specific focus is given to identifying vulnerable groups and supporting the inclusion of their voice in the engagement process.
- Free of external coercion: Engagement is undertaken in a timely manner to support the incorporation of feedback into Project design, and relevant information is disclosed in a way that helps stakeholders understand the issues.
- Timely consultation: Sufficient time is built into engagement processes and activities to enable and support customary landowner decision-making processes.
- Respectful consultation: Communities are not unnecessarily occupied by engagement activities thus keeping them away from their subsistence and/or income generating activities.

- Use of appropriate methods of communication: Methods and approaches are tailored to the needs of particular stakeholder groups, which includes translating written materials into *Tok Pisin* and local languages, making translators (i.e., Pawaian, Motu or Tok Ples-speaking) available during public meetings, and using pictures and symbols to help communicate information.
- Recording grievances and consultation activities: TEP PNG records and tracks efforts to resolve grievances raised by local community stakeholders, and data associated with every community meeting, information session and site visit in an internal database.

6.2.3 Stakeholder Identification and Mapping

TEP PNG's approach to engagement has been tailored to meet the specific needs and interests of particular stakeholder groups and the potential level of impact of the Project on each group. Stakeholder identification and mapping underpins TEP PNG's stakeholder engagement program so that engagement is tailored appropriately.

The Project stakeholder engagement plan was developed in October 2016 so that Project stakeholders were identified and categorized at an early stage, and in a systematic and comprehensive way. Figure 6.1 outlines this process.

6.2.3.1 Defining Project Stakeholders

Stakeholders are people or groups who are directly or indirectly affected by a project or who have an interest in or the ability to influence a project's outcomes (IFC, 2007). Stakeholders can include Project-affected communities (PACs) (including Project-affected persons and vulnerable or disadvantaged cohorts), customary landowners, government authorities, nongovernmental organizations (NGOs) and industry groups.

The Project's stakeholders fall into two groups; those who:

- Are directly affected by the Project (Project-affected persons (PAPs) and PACs).
- Have an interest and the ability to influence the outcome of the Project.

6.2.3.2 Identifying Project Stakeholders

Stakeholder identification and categorization have been undertaken at key stages throughout the Project's development, and to-date approximately 220 Project stakeholders (individuals or groups) have been identified. Table 6.1 summarizes these stakeholder groups, and Chapter 13 provides descriptions of the different groups. Vulnerable groups are not identified as a separate stakeholder group in Table 6.1, however where they have been identified (Section 6.2.3.3), engagement is managed using differentiated measures where appropriate (Section 6.2.4).

STAKEHOLDER IDENTIFICATION PROCESS

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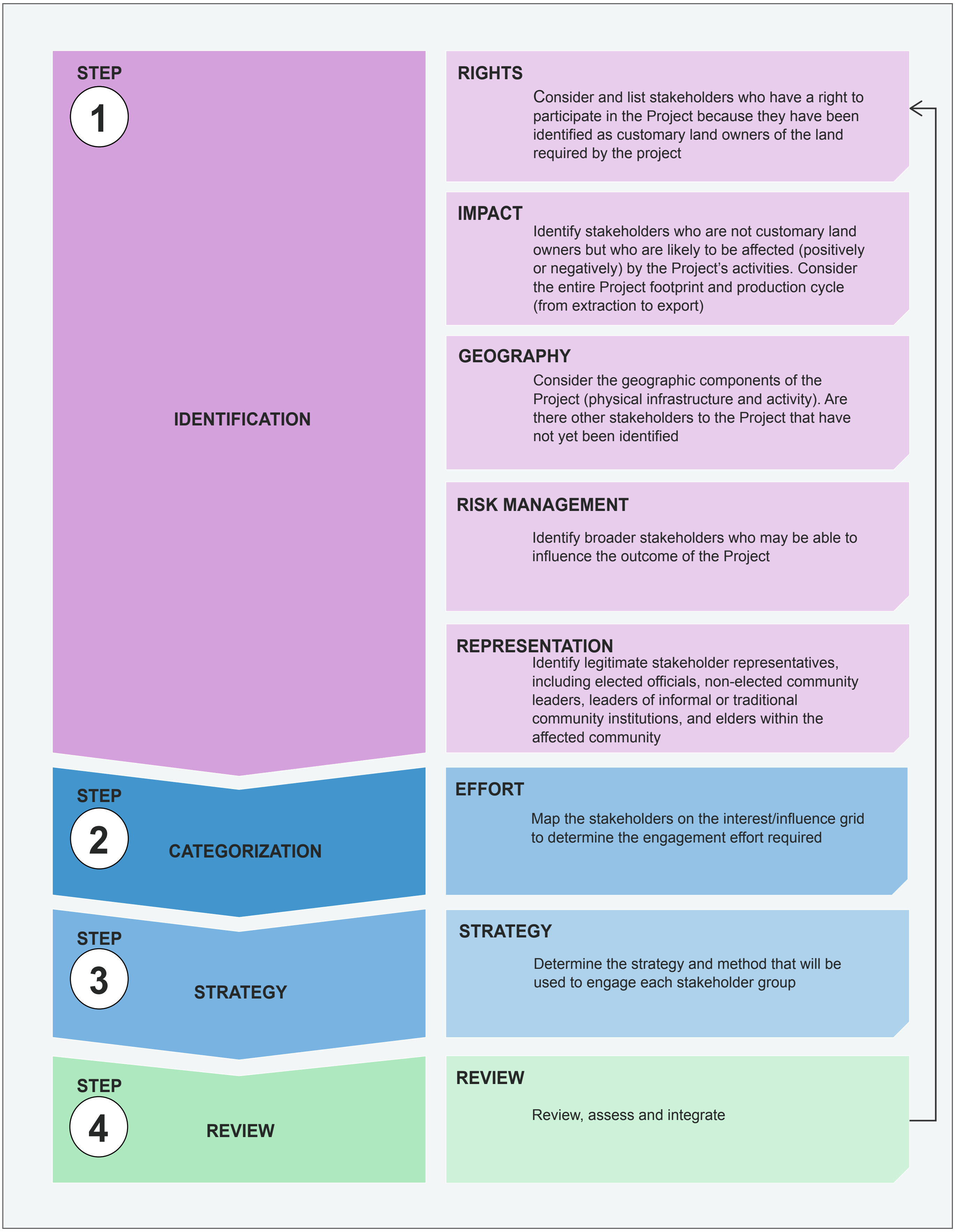
FIGURE 6.1



Adapted from: IFC (2007)

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Table 6.1 – Stakeholder Groups

Group	Description
Project-affected communities, local communities, customary landowners and community leaders[1]	Communities beneficially or adversely affected by Project impacts, including people from the following villages and settlements: ♦ In and around PRL-15: Mapaio Fish Camp settlement, Purari Airstrip house settlement, Poroi 1, Poroi 2, Poroi 3 (Suarido), Subu, Subu 2, Ura, Uraru, Wabo, and Wabo Station. ♦ Along the onshore export pipeline corridor: Arehava 2, Avavu, Ere, Evara, Harevavo, Hepere, Herakela, Hiloi, Hohoro, Hururu, Huruta, Iuku, Kaivukavu, Kavava, Kilavi, Lariau, Larihairu, Marea, Mareke, Miha, Mirimurua, Muro Mission, Oru, and Paevera. ♦ Along the river transport corridors: Purari River – Apiope, Aumu, Aivai*, Kaevaria; Urika-Ivo River – Mapaio, Akoma/Kairu'u, Ikinu. *Aivai village is also close to the onshore export pipeline corridor.
Community-owned companies	♦ Community-owned companies in the PAOI. ♦ Incorporated Land Groups in the PAOI.
Provincial and local-level government (LLG) areas	Provincial government administration covers the Gulf and Central Provinces, and Port Moresby. Provincial-level government stakeholders include: ♦ Gulf Province Working Group (GPWG). ♦ Gulf Provincial Government. ♦ Provincial Executive Council. ♦ Governor for Gulf Province. ♦ Gulf Economic Development Authority. ♦ Central Provincial Administration. ♦ Gulf Provincial Police District and LLG areas where Project components or Project activities are located. District and local-level government stakeholders include: ♦ Kikori District Administration. ♦ Baimuru LLG. ♦ Ihu LLG. ♦ Kerema District Administration. ♦ Gulf LLG Working Group. ♦ Representatives from schools and health centers/aid posts in the PAOI. ♦ Local government councilors. Ward stakeholders include: ♦ Village court magistrates. ♦ Ward development committees. ♦ Ward councilors.
Papua New Guinea national government agencies and authorities	National government stakeholders include: ♦ Civil Aviation Safety Authority. ♦ Conservation and Environmental Protection Authority (CEPA). ♦ Department of Petroleum and Energy (DPE). ♦ Department of Lands and Physical Planning. ♦ Department of Commerce and Industry. ♦ Department for Community Development and Religion.

1 As the Project progresses, the extent that communities and individuals may be affected will continue to be refined, and engagement activities tailored appropriately. Communities downstream (i.e., in Caution Bay and surrounding the PNG LNG Facilities) are not considered project stakeholders for this EIS; however, will be engaged by Caution Bay LNG plant site Operator as part of the downstream component of the Papua LNG Project.

Table 6.1 – Stakeholder Groups (cont'd)

Group	Description
Papua New Guinea national government agencies and authorities (cont'd)	♦ Department of Education. ♦ Department of Finance. ♦ Department of Treasury. ♦ Department of Works and Implementation. ♦ Department of Labor and Industrial Relations. ♦ Department of Justice and Attorney General. ♦ Department of National Planning and Monitoring. ♦ Department of Provincial and Local Government Affairs. ♦ Department of Higher Education, Research, Science and Technology. ♦ Department of Prime Minister and National Executive Council - Gas Projects Coordination Office. ♦ Environment Council. ♦ Investment Promotion Authority. ♦ National Agriculture Quarantine and Inspection Authority. ♦ National Department of Health. ♦ National Council of Women. ♦ National Maritime and Safety Authority. ♦ National Fisheries Authority (NFA). ♦ National Museum and Art Gallery (NMAG). ♦ National Petroleum Company of PNG. ♦ Minister for Police. ♦ Papua New Guinea Forest Authority. ♦ Papua New Guinea Civil & Identity Registry. ♦ Provincial Police Commander. ♦ Minister for Petroleum and Energy. ♦ Minister for Environment, Conservation and Climate Change. ♦ Royal Papua New Guinea Constabulary. ♦ Mineral Resources Development Company (MRDC). ♦ United Nations Human Rights Office of the High Commissioner (Human Rights Advisor to Papua New Guinea).
Civil Society Organizations	This group includes organizations that have an interest in the Project, including but not limited to health and social service organizations and providers, environmental conservation organizations, cultural affairs organizations, educational institutions and medical institutions. Civil society stakeholders include: ♦ Akoma Health Centre. ♦ Baimuru Vocational Training Centre. ♦ Catholic Health Services (Kerema). ♦ Don Bosco Technical School. ♦ Evara Health Centre. ♦ Centre for Environmental Law and Community Rights. ♦ Conservation International. ♦ Digicel Foundation. ♦ Extractive Industry Transparency Initiative. ♦ Gulf Focus Group. ♦ Gulf Provincial News. ♦ Kerema General Hospital. ♦ Kapuna Health Centre (managed by Gulf Christian Services). ♦ Institute for Banking and Business Management. ♦ Institute of Biological Research.

Table 6.1 – Stakeholder Groups (cont'd)

Group	Description
Civil Society Organizations (cont'd)	♦ National Volunteer Service of Papua New Guinea. ♦ Oil Search Foundation. ♦ Oxfam International. ♦ Mapaio Health Centre. ♦ Pacific Maritime Training College. ♦ Port Moresby General Hospital. ♦ Port Moresby Nature Park. ♦ Provincial Health (Kerema). ♦ Papua New Guinea Forest Research Institute. ♦ Port Moresby Wildlife Conservation Society. ♦ Research and Conservation Foundation. ♦ Rotary Against Malaria. ♦ Sago Network. ♦ Save the Children. ♦ The Nature Conservancy. ♦ Tribal Foundation Inc. ♦ University of Papua New Guinea. ♦ United Health Services (Kerema). ♦ Wabo/Ura Health Centre. ♦ Wildlife Conservation Society. ♦ World Wildlife Fund. ♦ Worldvision International.
Industry and Business Groups	This group includes businesses that have an interest in the Project, including but not limited to other oil and gas companies, suppliers and contractors. Industry and business stakeholders include: ♦ Joint venture partners. ♦ PNG LNG Plant site Operator. ♦ AES Supply Base. ♦ Chamber of Mines and Petroleum. ♦ Gulf Investment Trust Fund. ♦ Kumul Petroleum. ♦ OilMin. ♦ PNG Chamber of Commerce and Industry. ♦ Pacific Project Logistics (PPL).

The Project stakeholder engagement plan describes two types of PAPs:

- Individuals/families using or owning physical assets (i.e., buildings) or productive assets (i.e., cultivated gardens and plants) in the Project footprint area.
- Individuals/families/clans with exclusive user rights in the Project footprint area (e.g., to forest resources, hunting areas, medicinal plants, fishing, etc.).

Both categories will be systematically identified by the land and asset inventory and census surveys to be carried out on the final footprint of the Project to establish the relevant Land Access and Livelihood Development plans.

In compliance with the requirements of the *Oil & Gas Act 1998*, Project-affected customary landowners with interests in the land within the Project footprint area will be identified by the full-scale Social Mapping and Landowner Identification (SMLI) studies. The SMLI studies are subject to the review and validation by the regulator (the Department of Petroleum and Energy) prior to Ministerial Determination. In accordance with the provisions of the Act, the Minister for Petroleum and Energy will issue a Ministerial Determination identifying the legitimate owners of land within the Project area. Landowning clan leaders will then be invited by the Government to participate in a Development Forum for the Papua LNG Project to discuss the sharing of statutory benefits detailed in the Act.

6.2.3.3 Identifying Vulnerable Groups

In accordance with IFC performance standard 1 and 5, and good international industry practice, particular consideration was given to identifying vulnerable groups or disadvantaged stakeholders in local communities who may be disproportionally affected by the Project, or who may find it difficult to participate in engagement activities.

Using household and community level surveys, sources of pre-existing vulnerability and vulnerable groups were identified in consultation with village leaders and women in PAOI communities. Chapter 9 outlines the approach used to identify pre-existing vulnerability. Groups who may be vulnerable to Project development are identified in Chapter 13 and the process of identification is ongoing, as the Project develops.

6.2.4 Information Disclosure and Data Management

The Project’s stakeholder engagement plan supports the adoption of good international industry practice and provides a structured process to guide engagement activities. Underpinning the plan is a stakeholder management system, which is used to record interactions with stakeholders.

6.2.4.1 Information Disclosure Methods

TEP PNG’s approach to engagement with PAOI communities includes the following types of engagement:

- Information sharing: Making relevant information about the Project and activities of the entity available in an accessible format to stakeholders.
- Consultation and dialogue: Sharing information, and listening and engaging with stakeholders to understand their perceptions, views and understanding of the Project or activities so that their perspectives can be considered in decision-making processes.
- Negotiation: Reaching agreement on a specific issue or set of issues that may be complex (e.g., to agree on compensation rates or packages or on access to land).
- Participation: Involving stakeholders in specific activities such as impact identification or joint planning (e.g., implementing social investment projects).
- Grievance management: Recording and addressing stakeholder concerns and grievances.

Engagement methods are adapted to different stakeholder needs, to consider the location and duration of activities, the presentation of information (i.e., written, verbal or visual) and languages (Attachment 6.2). Engagement is performed through community leaders and local translators, and aims to also identify and include potentially disadvantaged or marginalized cohorts.[2]

Table 6.2 outlines the methods used for informed consultation and participation during the EIS process.

2 The IFC (IFC, 2012a) makes specific mention of the need to make considered effort in the stakeholder analysis and engagement planning phase of a project to ensure disadvantaged and vulnerable people are identified and engaged using differentiated measures where appropriate and to verify community representatives.

Table 6.2 – Methods for Informed Consultation and Participation

Method	Description	Stakeholders	Phase
Information and awareness sessions	These forums were used to advise the locations and nature of intended Project technical surveys, request land access, present Project information and answer questions. Meetings were held in village communal areas and all residents were invited to attend.	Communities in the PAOI (Figure 6.2).	♦ Scoping and Environment Inception Report (EIR) disclosure phase. ♦ Baseline studies phase. ♦ Impact assessment phase.
Focus group discussions	Focus group discussions offered an opportunity for more targeted conversations with specific groups, including women and youth.	Groups of PAOI women, youth and village leaders.	Baseline studies phase.
Key informant interviews	Meetings to gather data for planning and decision-making.	Representatives from education and health organizations in the PAOI. Representatives from CEPA, NMAG, DPE, NFA.	Baseline studies phase.
Community Liaison Officer (CLO) and Village Liaison Officer (VLO) visits	CLOs and VLOs regularly visited and/or engaged with PAOI villages to provide informal updates on Project activities and receive any issues or complaints.	Communities in the PAOI.	♦ Baseline studies phase. ♦ Impact assessment phase.
Tok Save newsletter	The Project established a regular newsletter, distributed in English and *Tok Pisin* (Attachment 6.3). Newsletters were distributed by hand and placed on five community noticeboards (Wabo, Sub, Poroi 2, Evara and Kaevaria) throughout the PAOI.	Communities in the PAOI.	♦ Baseline studies phase. ♦ Impact assessment phase.
Toll-free line	In addition to face-to-face engagement, TEP PNG also maintains a toll-free number to enable stakeholders to ask questions or provide information over the phone. The toll-free line receives approximately 60 calls each month.	All stakeholders.	♦ Scoping and EIR disclosure phase. ♦ Baseline studies phase. ♦ Impact assessment phase.

TEP PNG's stakeholder management system is used to record all interactions with community stakeholders, including grievances and commitments.

6.2.4.2 Grievance Mechanism

A grievance is a complaint, or an expression of dissatisfaction, associated with a real or perceived impact related to the Project. The IFC performance standard 1 requires that if the proponent

VILLAGES WHERE INFORMATION AND AWARENESS SESSIONS WERE HELD

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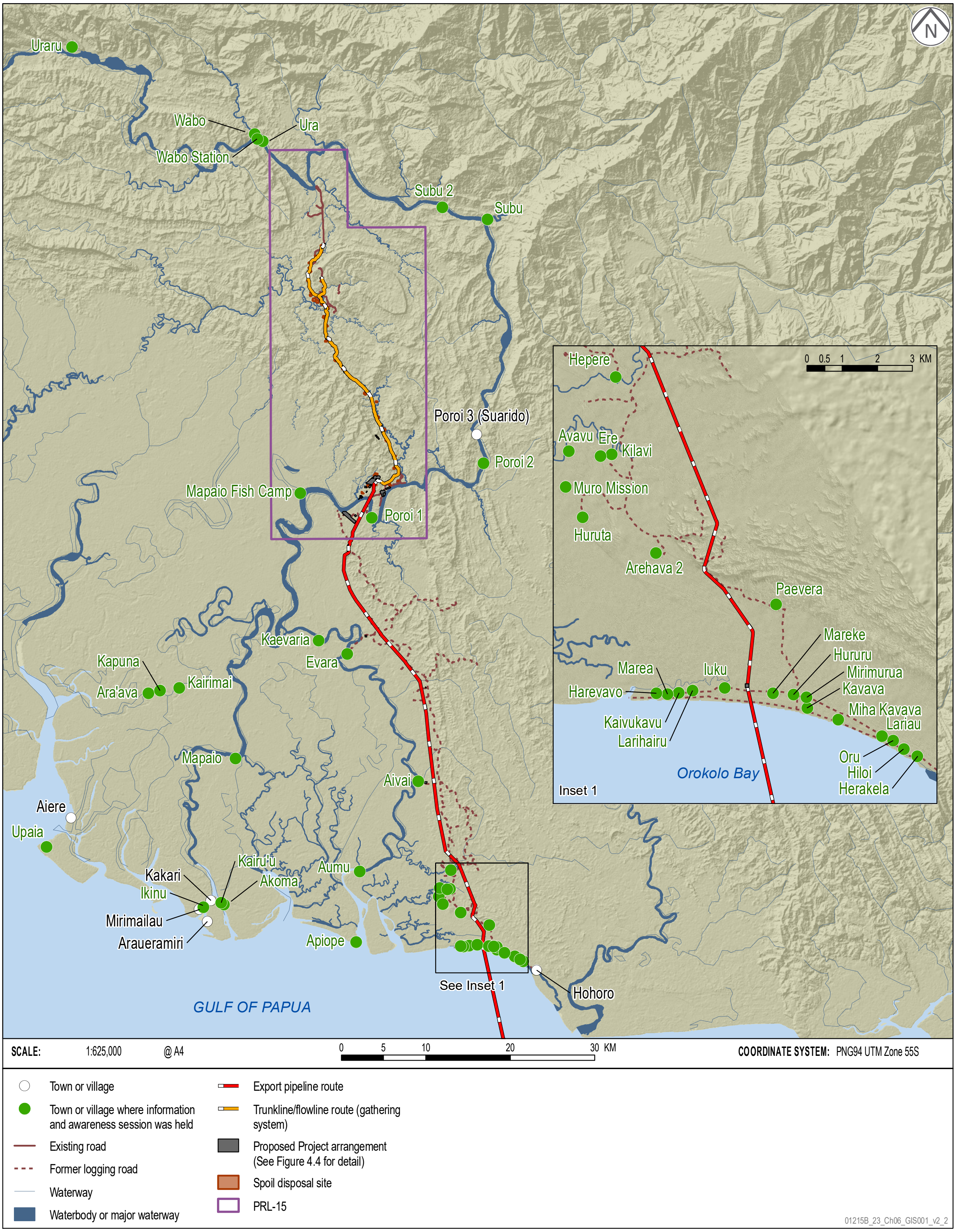
FIGURE 6.2



anticipates ongoing risks to or adverse impacts on affected communities, it will establish a grievance mechanism to receive and facilitate resolution of affected communities' concerns and grievances about the Project's environmental and social performance.[3]

A grievance mechanism is the process by which grievances are received, recorded and managed through to resolution. The process must be fair, accessible, transparent and properly documented. The process is being used to identify trends, and to adapt practices and/or operating procedures where appropriate.

TEP PNG has in place a stakeholder grievance management process (see Attachment 6.4). The purpose of this is to find a mutually acceptable resolution, (both to the complainant and to TEP PNG) of these grievances in an acceptable timeframe; to help build and maintain TEP PNG's informal 'social license to operate'; and to help its operations to run smoothly.

Grievance management comprises four steps:

- Receive and acknowledge grievance.
- Record and assess grievance.
- Investigate and resolve grievance[4].
- Close out grievance.

When a grievance is recorded by a CLO, the presence of a VLO serves as a witness and translator so that any community member wishing to lodge a grievance fully understands the process. The VLO also assists the CLO in providing feedback from TEP PNG to the complainant. To achieve these objectives, the VLO is usually someone that maintains a constant presence in their home community.

The grievance mechanism has been communicated widely and clearly explained to the affected stakeholders through regular stakeholder engagement activities and the development of support materials in local languages.

TEP PNG aims to maximize the accessibility of this procedure to all potential complainants by providing different avenues for the registration of a grievance, e.g., regular visits to the villages, the community relation's office is opened every day in Herd Base and a toll-free line. TEP PNG provides explanatory materials to facilitate the understanding of the grievance mechanism (Attachment 6.5), which include:

- Material in Tok Pisin, Motu, and other local languages (where applicable);
- Material designed to reach illiterate audiences.
- A grievance database is maintained in accordance with the procedure.

6.2.4.3 Resources Supporting Stakeholder Engagement

Responsibility for community engagement rests primarily with TEP PNG's Community Relations teams, supported by local community and technical specialists who will facilitate ongoing engagement for the life of the Project. The Community Relations team currently comprises:

- A Community Relations Coordinator.

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3 Grievance mechanisms are also referenced in performance standards 2, 4 and 7.

4 Investigation and resolution considers four levels of resolution; 1: immediate resolution through dialogue; 2: resolution requiring intervention from site management (i.e., Onsite Grievance Committee); 3: resolution requiring intervention from company management (i.e., Societal Steering Committee); and 4: resolution requiring external mediation.

- Heads of Community Relations based on site: for the PRL-15 area and for the export pipeline route and waterways communities.
- CLOs based on site: divided into two groups based on their area of coverage, for Project-affected communities in PRL-15 and along the onshore export pipeline corridor and river transport corridor communities[5].
- CLOs based in Kerema, Gulf Province: to liaise with the Gulf Province administration and institutional stakeholders.
- VLOs: based full time in five villages surrounding PRL-15 – Wabo, Subu, Poroi 2, Kaevaria, and Evara. They support the CLOs by disseminating information and relaying community concerns.

This team is supported by:

- Business Development Officers (BDOs): for engagements relative to national content and local business development.
- Technical specialists in health and cultural heritage, gender and human rights, aquatic and terrestrial ecology, and hydrology and geotechnical studies.
- Local assistants and translators.

The CLOs, VLOs and BDOs are all Papua New Guinean, both males and females, and fluent in the languages spoken by the communities in the Project area (i.e., Pawaia, Iare, Orokolo and Kaura), enabling the team to connect culturally with the communities and facilitating more effective engagement. They have been provided with training and information to support their on-ground roles, and women have been employed including a female CLO recruited from the Pawaian communities so that women from affected communities are engaged and their views are captured.

Other stakeholder groups (e.g., government, civil society and industry, see Table 6.1) are engaged by other relevant teams in TEP PNG; i.e., the environment team engages regularly with environmental conservation organizations and CEPA; the national content team engages with vocational training institutions, and maintains regular contact with PRL-15 community-owned businesses; and other departments communicate regularly with Project stakeholders at a regional and national level.

6.3 EIS Engagement Program

6.3.1 Background

InterOil operated the Elk-Antelope gas field prior to February 2015, during which time they undertook stakeholder engagement in PRL-15. These stakeholder engagement activities primarily focused on land access and community support of the communities in PRL-15 given the exploratory nature of InterOil's activities prior to TEP PNG's involvement.

On 1 August 2015, TEP PNG was officially appointed as operator of PRL-15 to develop the upstream facilities component of the Papua LNG Project. Under a six-month transition agreement, InterOil continued to provide certain services for TEP PNG, including stakeholder engagement activities. The joint InterOil/TEP PNG Community Relations team adopted a

5 The main role of the CLOs is to implement the stakeholder engagement plan so that Project-affected communities are fully informed about the Project and that they are able to participate meaningfully in programs and activities, including in female to female engagement, grievance management, community investment and land access negotiations.

procedure and protocol to conduct community information disclosure campaigns explaining the changes in operatorship.

Since August 2015, TEP PNG has been engaging regularly with Project-affected communities and other key stakeholders so that they are kept informed and have opportunities to provide input or raise issues.

Figure 6.3 shows the number of activities, (including community meetings, awareness campaigns and public exhibitions), and the number of participants in these activities across the PAOI from 2016 to 2019. Figure 6.4 highlights activities across each Project area (i.e., PRL-15, the export pipeline corridor and the river transport corridors) during the same period. Most of the activities were held with PRL-15 communities, which include the Mapaio Fish Camp settlement and Poroi 1 inside PRL-15, and seven villages near PRL-15, i.e., Poroi 2, Poroi 3 (Subarido), Subu, Subu 2, Wabo, Wabo Station and Ura.

The following sections describe the engagement activities undertaken across the different EIS phases; including, scoping and EIR disclosure, baseline studies and impact assessment. Table 6.3 summarizes these activities, which have been supported by regular meetings and site visits from TEP PNG to manage community issues and grievances, to provide updates to villages and local government on the Project and upcoming studies, to discuss land ownership and clan boundaries and to provide aid, support services and training. Plates 6.1 to 6.12 showcase some of the engagement activities that have occurred.

6.3.2 Scoping and Environmental Inception Report Disclosure

Early scoping and screening assessments; which involved selecting locations for the central processing facility (CPF) and the onshore export pipeline shore crossing, involved consultation with relevant government stakeholders (e.g., CEPA, NMAG, DPE), and local communities. Engagement activities incorporated site visits and public presentations; providing participants with information about the proposals and seeking feedback to inform the location decision.

Approximately 200 people attended the EIR disclosure sessions in Port Moresby in November 2016. Invitees included representatives from national government departments and authorities, nongovernmental organizations, industry and academia. These sessions provided information about the Project and preliminary findings of baseline studies. Disclosure engagement involved a public graphic display and hosted information sessions, staffed by representatives from TEP PNG and ERIAS Group. Disclosure to communities in the PAOI was also undertaken in the form of information sessions and focus groups (see Plate 6.12). More than 1,500 people attended these sessions. Figure 6.2 shows the locations where information and awareness sessions were held.

6.3.3 Baseline Studies

Field visits constitute an important stakeholder engagement activity. To date they have given participants the opportunity to discuss aspects of the Project, the EIS process and potential issues.

Field surveys were undertaken for the environmental and social baseline study from January 2016 to February 2017. CLOs conducted pre-awareness campaigns prior to each survey starting. These campaigns included a description of the study and context and requested permission for the study team to visit and perform the work. The presentations included information about why the studies were occurring, how they would be conducted and what the information collected would be used for. A repeat of the presentation occurred at the beginning of the survey in each village (see Figure 6.2).

COMMUNITY MEETINGS WITH PAOI COMMUNITIES 2016 - 2019

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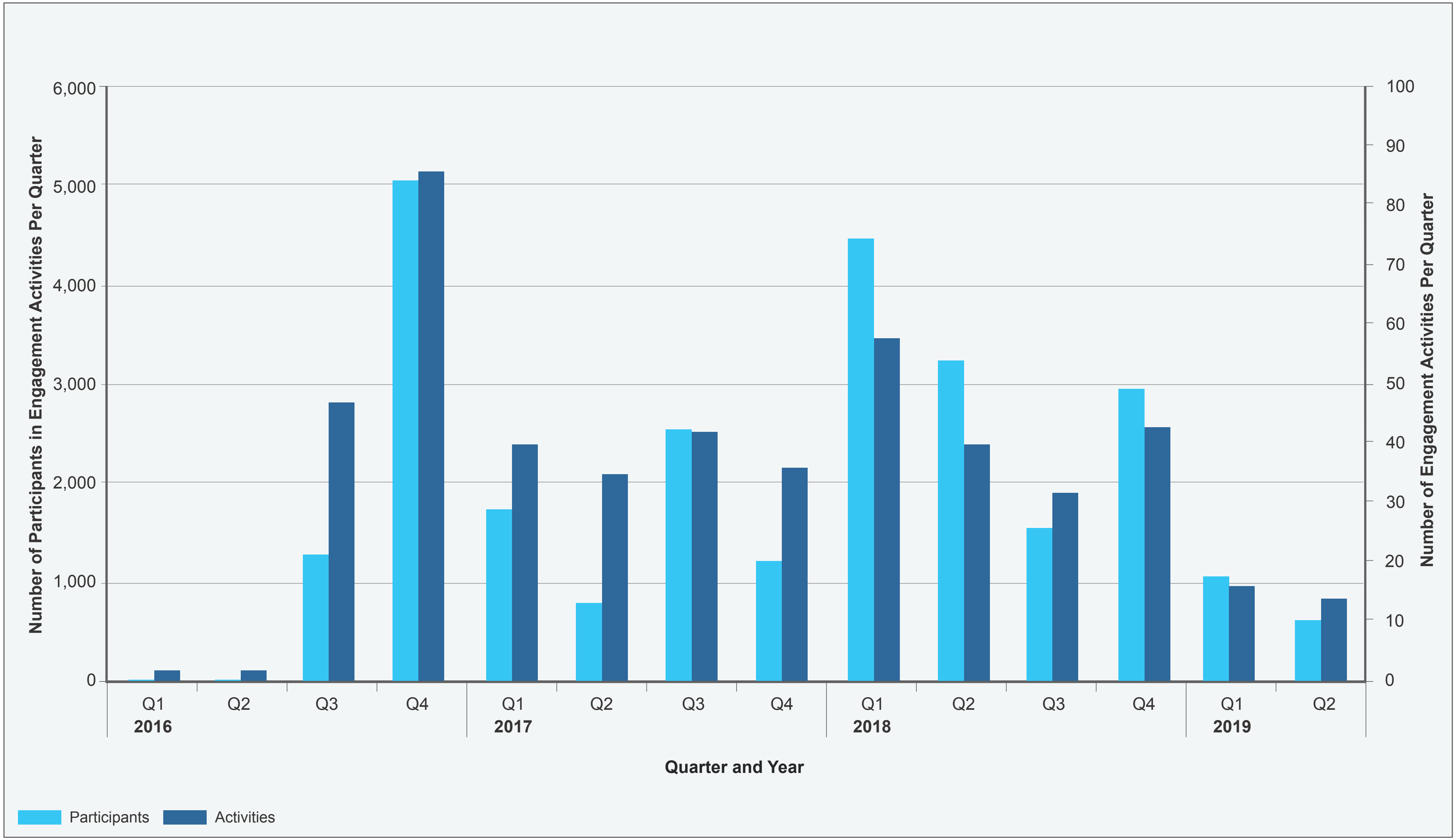
FIGURE 6.3



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COMMUNITY MEETINGS UNDERTAKEN BY PROJECT AREA 2016 - 2019

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FIGURE 6.4

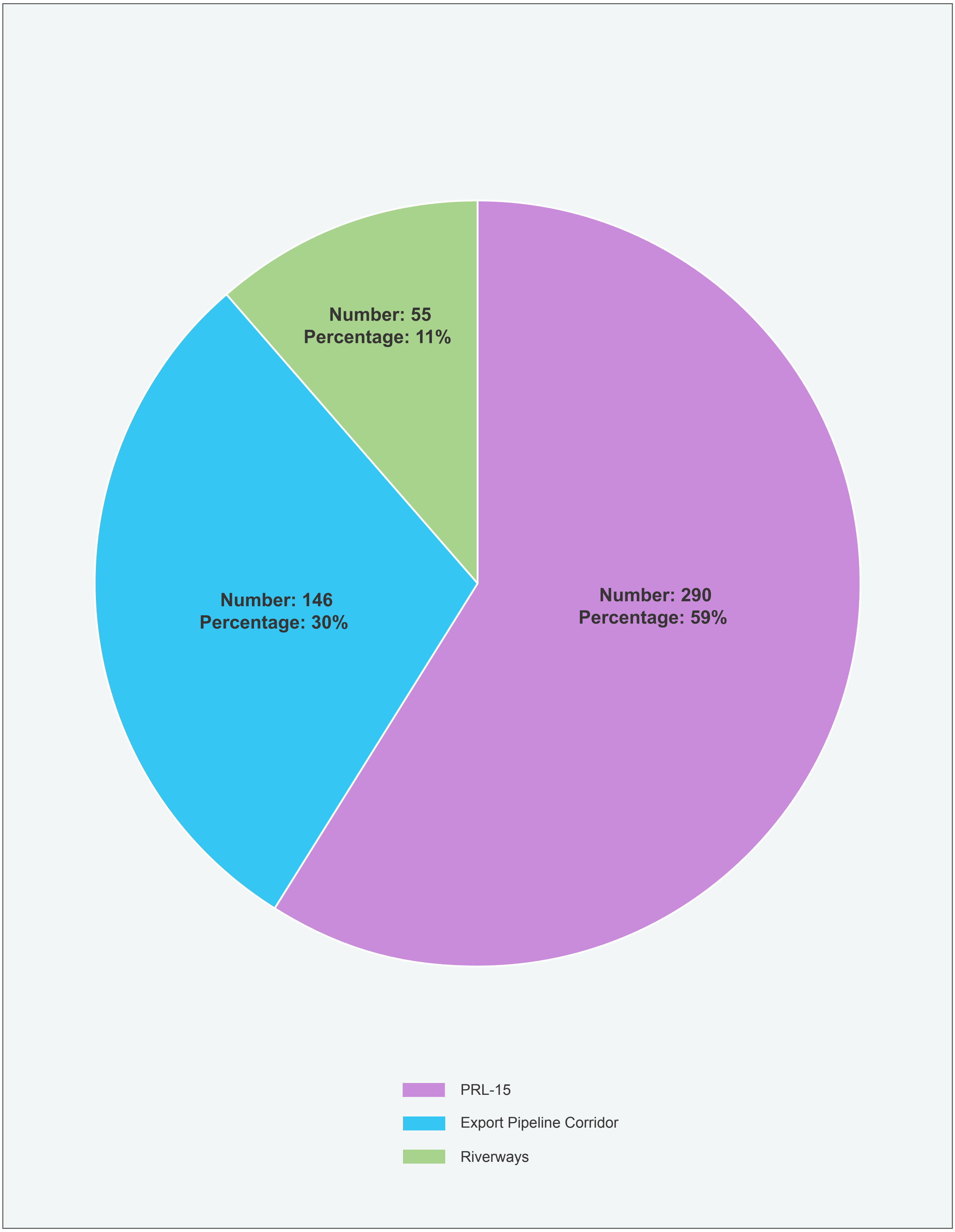

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Table 6.3 – Summary of Key Project Engagement Activities for the EIS

Date	Topic	Stakeholder Groups	Description of Activity
March to April 2015*	What is Liquefied Natural Gas (LNG)?	♦ Project-affected communities ♦ Provincial and local-level government	♦ Designed to assist communities understand LNG development, including both the beneficial and adverse impacts. Key messages presented in these meetings included: – Introduction to TEP PNG and the Project partners. – Explanation of what LNG is (including a notional project development timeline). – Potential beneficial impacts (e.g., employment and business opportunities). – Potential adverse impacts (e.g., damage to land and resources).
May to June 2015*	Papua LNG questions and answers	♦ Project-affected communities ♦ Provincial and local-level government ♦ National government	♦ Designed as a follow-up to 'What is LNG?' so that communities had time to consider the initial information and ask questions. ♦ Officials from the Gulf Provincial administration attended sessions to answer questions of government responsibility.
September 2015	Stakeholder Relationship Management (SRM+) consultations	♦ Project-affected communities (Community leaders) ♦ National government ♦ Provincial government ♦ Civil society organizations ♦ Industry and business groups	♦ Periodic review of TEP PNG's relationship with external stakeholders. ♦ Enables a continuous improvement and optimized engagement approach.
November 2015	Introduction to the community and pre-awareness campaign	Project-affected communities (Community leaders)	♦ Project personnel and community leaders were introduced to one another. ♦ CLOs contacted village councilors to identify key points of communication in those communities (i.e., clan leaders), before making introductions and conducting a pre-awareness campaign to advise communities about the Project.
December 2015 (recurring)	CEPA meeting	National government	♦ Meeting with CEPA to introduce the consultant team undertaking the EIS and to outline the proposed program of work, including technical studies, scope of work and the process to complete the EIR. ♦ Monthly meetings occur to provide updates on Project permitting, Project progress, study findings, stakeholder concerns and other matters.
January to July 2016	EIS terrestrial baseline studies (including awareness campaigns)	Project-affected communities	♦ CLOs conducted awareness campaigns (in each study location, i.e., each village) before the terrestrial studies commenced, providing a description of the study and context, and seeking permission from communities for the study team to visit and perform the work. ♦ During the studies informal meetings were held with knowledgeable community members to support data collection.

Table 6.3 – Summary of Key Project Engagement Activities for the EIS (cont'd)

Date	Topic	Stakeholder Groups	Description of Activity
May 2016 (recurring)	DPE meeting	National government	♦ Monthly coordination meeting with DPE to provide Project updates, feedback and discussions on key subject areas related to Project milestones.
April and August 2016	EIS Social baseline studies (including awareness campaigns)	♦ Project-affected communities ♦ Provincial government ♦ National government ♦ Health organizations	♦ CLOs undertook awareness consultation with Project-affected communities to inform them of the intent to visit them to conduct social baseline surveys and to seek permission for the team to visit. ♦ During the studies, the following consultation with Project-affected communities occurred: – Toke Save, explaining the purpose of the surveys and introducing the team. – Focus group discussions with women, village leaders and youth (in 36 villages). – Key informant interviews on cultural heritage, health, education and natural resource use. – Household surveys with a total of 354 households. – Interviews with government agencies and security services.
August 2016	Environment Council	National government	♦ Meeting with the Environment Council to introduce the Project.
August 2016	What is LNG? Overview of the Project Project update	♦ NGO representatives ♦ Academic institutions	♦ Designed to assist communities understand LNG development, including both the beneficial and adverse impacts. Key messages presented in these meetings included: – Introduction to TEP PNG and the Project partners. – Explanation of what LNG is (including a notional project development timeline). – Potential beneficial impacts (e.g., employment and business opportunities). – Potential adverse impacts (e.g., damage to land and resources).
September 2016	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones and to receive feedback from provincial and district administrators.
October 2016	Operational details of the Gulf of Papua prawn and lobster fishery	National government	♦ TEP PNG Project team met with representatives from the National Fisheries Authority to determine the operating parameters of the fishery and any previous negative interactions with the oil and gas industry, so that these could be avoided or managed by the Project.
October 2016	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.

Table 6.3 – Summary of Key Project Engagement Activities for the EIS (cont'd)

Date	Topic	Stakeholder Groups	Description of Activity
November 2016 to February 2017	EIR and Project disclosure campaigns	♦ Project-affected communities ♦ Provincial government ♦ National government ♦ Industry representatives ♦ NGO representatives ♦ Academic institutions	♦ Approximately 200 people attended the EIR disclosure sessions in Port Moresby; these sessions provided information to interested parties about the Project and the preliminary findings of baseline studies. ♦ Information and awareness sessions coupled with focus groups were held for all affected communities in the PAOI. More than 1,500 people attended these sessions.
December 2016	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
January 2017	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.
March 2017	EIS human rights study (including awareness campaigns)	Project-affected communities	♦ Awareness campaign to inform the communities of the upcoming human rights study. ♦ During the studies informal meetings were held with knowledgeable community members to support data collection.
March 2017	EIS metocean surveys awareness campaign	Project-affected communities	♦ Awareness campaign to inform the communities of the upcoming human metocean surveys.
April 2017	Baseline EIS environmental and social studies preliminary findings presented to government and industry	♦ National government ♦ Provincial government ♦ Industry and business groups	♦ Preliminary results of the EIS environmental and social baseline studies were presented, and questions or concerns were fielded and answered.
August 2017	Geophysical surveys awareness campaigns	Project-affected communities	♦ Awareness campaign to inform the communities of upcoming geophysical surveys and why they were required.
August 2017	Vegetation audit (including awareness campaigns)	Project-affected communities	♦ Awareness campaign to inform the affected clans of upcoming vegetation audit and what is required including local participation. ♦ During the studies informal meetings were held with knowledgeable community members to support data collection.
December 2017	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.

Table 6.3 – Summary of Key Project Engagement Activities for the EIS (cont'd)

Date	Topic	Stakeholder Groups	Description of Activity
January 2018	PRL-15 social mapping and landowner identification study (SMLI) update	♦ Project-affected communities (customary landowners) ♦ Local-level government ♦ Provincial government ♦ National government	♦ Awareness campaign to inform affected clans and communities about the PRL-15 SMLI update study. ♦ Meetings were held with respective government authorities on this subject. ♦ Public notice on the performance of the PRL-15 SMLI advertised in the newspaper.
March 2018	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
May 2018	Pipeline route SMLI studies awareness	♦ Project-affected communities (customary landowners) ♦ Local-level government ♦ National government	♦ Awareness engagements for SMLI studies with communities in the proposed pipeline route. ♦ Meetings were held with relevant government authorities (i.e., DPE, DLPP) prior to beginning fieldwork, including with relevant administration divisions of Gulf and Central provinces. ♦ Public notice on the performance of the PRL-15 SMLI advertised in newspaper.
May 2018	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.
May 2018	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
January to May 2018	Land access engagement	♦ Project-affected communities (customary landowners) ♦ Local-level government ♦ National government	♦ A series of community meetings was held to address the purpose of the land investigation report (LIR) studies and how these would contribute to the identification of legally recognized landowners for the Development Forum and subsequent Development Agreement. ♦ Clan Land Use and Compensation Agreements (CLUCA) negotiated and signed for key sites (CPF and wellheads).
October 2018	EIS progress and information update	National government	♦ Meeting with CEPA about the proposed impact assessment methods and table of contents for the EIS, which was subsequently endorsed by CEPA.
November 2018	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.

Table 6.3 – Summary of Key Project Engagement Activities for the EIS (cont'd)

Date	Topic	Stakeholder Groups	Description of Activity
November 2018	SRM+ consultations	♦ Project-affected communities (community leaders) ♦ National government ♦ Provincial government ♦ Civil society organizations ♦ Industry and business groups	♦ Periodic review of TEP PNG's relationship with external stakeholders. ♦ Enables a continuous improvement and optimized engagement approach.
December 2018	Project update – PAOI communities	Project-affected communities	♦ A series of public meetings held in villages throughout the PAOI to provide community members with an update on the Project, including upcoming studies and National Identification campaigns performed by PNG Civil & Identity Register personnel with the logistical support of TEP PNG.
January 2019	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
February 2019	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.
March 2019	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
April 2019	Project update – PAOI communities	Project-affected communities	♦ A series of public meetings held in villages throughout the PAOI to provide community members with an update on the Project, including current and upcoming activities.
April 2019	Project update – Gulf Provincial Working Group	♦ Provincial government ♦ Local-level government	♦ Meetings in Kerema to provide Project updates and milestones, and to receive feedback from provincial and district administrators.
May 2019	Project update – PRL-15 Lidas Kibung	Project-affected communities (Clan leaders)	♦ Meeting held with the leaders of PRL-15 communities to provide Project updates and milestones, and to gauge and provide feedback on concerns raised by local communities.

* Engagements conducted during the transition agreement.

Plate 6.1 – Engaging with Community Leaders in a Focus Group Discussion

Photo: ERIAS Group.

Plate 6.2 – Cultural Heritage Interviews

Photo: ERIAS Group.

Plate 6.3 – Conducting Community Training in Akoma Village

Photo: ERIAS Group.

Plate 6.4 – Distributing the *Tok Save* Newsletter

Photo: TEP PNG.

Plate 6.5 – PRL-15 Lidas Kibung in Wabo

Photo: TEP PNG.

Plate 6.6 – Mapaio Community Meeting

Photo: ERIAS Group.

Plate 6.7 – Grievance Management in Evara Village

Photo: TEP PNG.

Plate 6.8 – GPWG Meeting in Kerema

Photo: TEP PNG..

Plate 6.9 – Mapaio Community Survey

Photo: ERIAS Group.

Plate 6.10 – Poroi 1 Community Survey (Women)

Photo: ERIAS Group.

Plate 6.11 – Aivaikoki Women's Engagement

Photo: ERIAS Group.

Plate 6.12 – EIR Roadshow Engagement

Photo: TEP PNG.

Engagement during the environmental and social baseline study social field visits (i.e., May to June and August to September 2016) incorporated a range of survey methods, including focus group discussions (see Plate 6.1), community leader interviews and interviews with local, provincial and national government representatives (see Addendum H and I of Part 23 of Volume 2 for detail on these surveys). Women (see Plates 6.10 and 6.11) and youth were surveyed separately so that information and questions from these cohorts were accurately captured. Pre-awareness campaigns were also undertaken prior to each of the social surveys.

6.3.4 Environmental Impact Statement Disclosure

Once the EIS has been submitted to CEPA, it will be disclosed for public comment. A roadshow will be organized to raise awareness of the EIS findings and present the identified impacts and proposed mitigation measures. Feedback received from stakeholders on the impacts and mitigation will inform the EIS process and the environmental and social management plans for construction and operational Project phases. Comments received will inform CEPA's decision on whether to approve the Project, and the conditions of the environment permit. CEPA will lead the disclosure process, with support from TEP PNG where required.

Table 6.4 identifies the key consultation activities during EIS preparation and approvals.

Table 6.4 – EIS Consultation Schedule

Milestone	Consultation
Notice of intent EIR	The draft EIR was submitted to CEPA in October 2016, and engagement campaigns were conducted with Project-affected communities and interest groups in November 2016. A roadshow with CEPA was held between 5th and 16th December 2016 and visited villages in the PAOI and Port Moresby. An updated EIR was submitted to CEPA in June 2019 and approved in July 2019.
EIS assessment process	Pre-awareness campaigns and consultations with Project-affected communities were held during the EIS environmental and social baseline surveys, and preliminary results presented and discussed in 2016 and 2017. A roadshow presenting the EIS to communities, industry and non-government and government officials with a summary of the impact assessment, key issues and risks, how they will be treated or mitigated and the process for providing feedback on the draft EIS report and associated management plans. This is anticipated to take place in Q1 2020. The EIS will be available in hard copy for public comment. Summaries will be distributed to communities near the Project area.
EIS approval	Consultation with CEPA to satisfy requirements under s. 55 of the *Environment Act 2000*.

6.4 Engagement Outcomes

Engagement activities have been planned to coincide with key milestones to enable timely capture of issues and input of these issues into the Project design process. This section summarizes the issues raised by stakeholders during engagement activities undertaken between 2016 and 2018.

6.4.1 Issues Raised by Stakeholders

Stakeholders have raised a broad range of issues with TEP PNG during the engagement program to date. Key themes center on employment opportunities, loss of livelihoods or economic loss, land and housing, safety, environment and health, and social conduct and security.

Table 6.5 summarizes these themes, which are categorized broadly according to topic, and how the themes have informed Project design and development during the preparation of the EIS or will be actioned by the Project in the future.

Table 6.5 – Issues Raised by Project Stakeholders

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
General Project Understanding			
Project status and key decision points for its assessment. Opportunities for stakeholder participation in decision-making.	♦ Project-affected communities ♦ National government ♦ Provincial and local-level government ♦ Civil society organizations ♦ Industry and business groups	♦ Interest in the Project has created a need for regular and frequent communication with key government and community stakeholders. ♦ TEP PNG maintains a regular and frequent on-ground presence so that project affected communities are met with frequently and any questions, issues and expectations are managed.	Chapter 6
Location of Project infrastructure and potential impacts on social, cultural and environmental values.	♦ Project-affected communities ♦ Local communities outside of the PAOI ♦ National government ♦ Provincial and local-level government ♦ Civil society organizations ♦ Industry and business groups	♦ The location of Project infrastructure has been progressively refined through information from social, cultural, environmental and geotechnical surveys, and in consultation with Project-affected communities and government. ♦ Surveys, stakeholder feedback and local knowledge have refined and will continue to refine infrastructure placement and alignment.	Chapter 4 Chapter 5 Chapter 6
Management of solid sulfur and sulfurous emissions.	♦ National government	♦ Alternative options have been considered and air dispersion modeling completed to assess the potential off-site impacts. Gas processing will no longer produce solid sulfur.	Chapter 4 Chapter 5 Chapter 15
Environment and Health			
Potential impacts on the PRL-15 oxbow wetlands, which have environmental, social and cultural sensitivities.	♦ Project-affected communities ♦ National government	♦ Project has been designed to avoid to the PRL-15 oxbow wetlands.	Chapter 5
Potential impacts on Threatened and Nationally Protected species.	♦ Project-affected communities ♦ National government ♦ Civil society organizations	♦ Project design is based on a risk-management approach, anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features). ♦ The baseline studies that have been completed support the assessment of potential Project impacts on threatened or nationally protected species in the EIS.	Chapter 5 Chapter 11 Chapter 12

Table 6.5 – Issues Raised by Project Stakeholders (cont'd)

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
Environment and Health (cont'd)			
Potential impacts on Threatened and Nationally Protected species (cont'd).		♦ Preconstruction surveys will identify sensitive sites and habitats, and threatened species sites to be subject to specific mitigation measures along the proposed final alignment and footprint. ♦ Management measures, including avoidance, minimization, restoration and offsets are considered where appropriate to mitigate potential impacts of the Project on threatened or nationally protected species.	
Potential impacts on the Purari River, including: ♦ Sedimentation. ♦ Pollution from vessels. ♦ River bank erosion.	♦ Project-affected communities ♦ National government	♦ Potential impacts from Project activities on the Purari River system, including sedimentation, scour, and accidental releases have been assessed in the EIS. ♦ Erosion and sediment control measures will be implemented for infrastructure components according to good international industry practice. ♦ Standard industry practices will be employed to prevent and minimize the potential impacts of accidental spills, including the development of an Oil Spill Contingency Plan. ♦ Low speed limits will be implemented through areas sensitive to vessel wash.	Chapter 4 Chapter 11 Chapter 13 Chapter 18
Potential impacts on Orokolo Bay, including: ♦ Sedimentation. ♦ Pollution (i.e., oil spill).	♦ Project-affected communities ♦ National government	♦ Sediment dispersion modeling has been completed, and potential impacts from Project activities in Orokolo Bay, including sedimentation and accidental releases have been assessed in the EIS. ♦ Where required, adaptive management will be implemented to minimize impacts due to sedimentation. ♦ Standard industry practices will be employed to prevent and minimize the potential impacts of accidental spills including the development of an Oil Spill Contingency Plan.	Chapter 12 Chapter 18
Waste potentially causing pollution during operations.	♦ Project-affected communities ♦ National Government	♦ Waste will be managed to reduce, reuse and recycle / recover the waste where practicable. Requirements will be set in relation to waste inventory, segregation, storage, disposal, tracking, recording.	Chapter 4

Table 6.5 – Issues Raised by Project Stakeholders (cont'd)

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
Environment and Health (cont'd)			
Waste potentially causing pollution during operations (cont'd).		♦ The landfill will be designed to comply with TOTAL's general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices.	
Increased human access potentially causing poaching and spread of weeds.	♦ Project-affected communities ♦ Staff and contractors	♦ Project personnel, workers, contractors or third-party operators, while engaged in Project activities, will be prohibited to hunt, fish, collect or disturb forest or wildlife resources and possess hunting or fishing equipment. ♦ Project personnel, workers, contractors and third-party operators will be educated about: wildlife values, and weed, pathogen and animal pest hygiene and control measures. ♦ Project will develop management controls for its activities, considering weed, pathogen and pest that pose a significant threat to biodiversity	Chapter 11
Rehabilitation.	National government	♦ Sites will be actively or passively rehabilitated as soon as possible to promote a stable self-sustaining landscape.	Chapter 11
Noise and light potential impacts on communities, particularly at night.	Project-affected communities	♦ Noise modeling has been completed, and potential noise and light impacts from Project activities have been assessed in the EIS. ♦ The noise from mechanical plant will be minimized, and fixed / mobile equipment used and / or located in consideration of sensitive receptors. ♦ Direct lighting outside facilities at night will be avoided and use of fixed night lighting minimized for safe operations.	Chapter 4 Chapter 15
Potential impacts on cultural heritage, including: ♦ Loss of heritage sites. ♦ Loss of traditional knowledge. ♦ Loss of cultural heritage values. ♦ Access to places of significance.	♦ Project-affected communities ♦ National government	♦ Sites of cultural significance (of tangible and intangible heritage value) have been avoided where facilities and infrastructure occur. ♦ A chance find procedure is defined and will be implemented via a Cultural Heritage Management Plan.	Chapter 6 Chapter 14

Table 6.5 – Issues Raised by Project Stakeholders (cont'd)

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
Environment and Health (cont'd)			
Potential impacts on cultural heritage (cont'd).		♦ Ongoing consultation with Project-affected communities and regulatory authorities (i.e., NMAG) during the preconstruction surveys will help identify archaeological artifacts and cultural heritage sites along final alignment and footprint. The findings of these surveys will inform appropriate management controls to be implemented during the construction phase.	
Perception that the Project is responsible for environmental damage.	Project-affected communities	♦ The Project will pursue continuous stakeholder engagement to respond to questions and concerns about environmental impacts and their origins. The Project will maintain a grievances procedure and register and ensure that all issues raised are addressed and the actions recorded.	Chapter 6
Expectations of improved health and education facilities.	♦ Project-affected communities ♦ Provincial and local-level government ♦ Civil society organizations ♦ Industry and business groups	♦ The Project will develop a Community Health, Safety, Security Development plan and a Community Development Plan in consultation with Project-affected communities outlining initiatives to support health, education, law and economic services.	Chapter 13
Economic Loss			
Waves from barges causing damage to canoes, property and people.	Project-affected communities	♦ Low speed limits will be implemented through areas sensitive to vessel wash. ♦ The Project will maintain a grievances procedure and register so that all issues raised are addressed and the actions recorded.	Chapter 13 Chapter 16
Potential impacts to subsistence resources (hunting, fishing and gardens) and fresh water.	Project-affected communities	♦ Potential impacts will be incorporated in the development of land access and livelihood development plans for economic displacement and compensation.	Chapter 13 Chapter 16
Safety, Social Conduct and Security			
Potential project-induced in-migration causing problems such as: ♦ Law and order problems. ♦ Increased drug and alcohol abuse.	Project-affected communities	♦ A Project-induced In-migration Management Plan will be developed. ♦ Management measures are proposed to minimize the indirect impacts associated with in-migration.	Chapter 13 Chapter 16

Table 6.5 – Issues Raised by Project Stakeholders (cont'd)

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
Safety, Social Conduct and Security (cont'd)			
♦ Threats to women's safety. ♦ Exacerbated landowner disputes.			
Lack of capacity and presence of local authorities on the ground in the PAOI.	♦ Project-affected communities ♦ Provincial and local-level government	♦ The Project will develop a Community Health Safety and Security Plan, a Community Development Plan and a Project--induced In-migration Management Plan in consultation with Project-affected communities outlining initiatives to support health, education, law and economic services.	Chapter 13
High expectations for employment benefits from the Project.	Project-affected communities	♦ Management measures are proposed to support training and capacity-building opportunities and maximize employment for communities in the PAOI. ♦ Ongoing stakeholder engagement (including a robust grievance mechanism) will be maintained during all phases of the Project to manage expectations in Project-affected communities.	Chapter 6 Chapter 13
Opportunities for training, employment and community development. Concerns regarding equal participation of women.	Project-affected communities	♦ Management measures are proposed to maximize employment for women in the PAOI. ♦ The Project will continue to target engagement activities towards women. ♦ The Project will develop a National Content Plan and a Community Development Plan, outlining initiatives for training, employment and community development with a particular consideration of gender issues.	Chapter 6 Chapter 13
Land and Housing			
Potential impact on and benefits for individuals outside of the PAOI.	Project-affected communities	♦ The beneficiaries and the administration of development funds established for the allocation of Project-derived royalties and other benefits will be determined by the Minister for Petroleum and Energy in compliance with the requirements of the *Oil & Gas Act 1998*.	Chapter 13

Table 6.5 – Issues Raised by Project Stakeholders (cont'd)

Theme and Issue	Stakeholder Group	How the Issue has Informed or Been Actioned by the Project	EIS Section Reference
Land and Housing (cont'd)			
Appropriate compensation to legally recognized landowners.	Project-affected communities (customary landowners)	♦ The Project has been engaging with affected clan customary landowners through a structured process to support free, prior and informed consent in the development of clan land use agreements.	Chapter 13 Chapter 16
Appropriate compensation to legally recognized landowners (cont'd).		♦ TEP PNG maintains a Land Access and Compensation procedure and has engaged a trusted third party to oversee the negotiations. ♦ TEP PNG is developing a Land Access and Resettlement Framework, which involves a market assessment survey to review market prices and develop full replacement compensation rates. ♦ TEP PNG maintains a grievances procedure and register so that all issues raised are addressed and the actions recorded.	
Accuracy of capturing landowner data and landowner disputes.	Project-affected communities (customary landowners)	♦ SMLI studies[6] have been as detailed as possible, identifying customary ownership to individual landowners, not just groups. ♦ These studies recorded details of all customary landowners in the project footprint, including land disputes in the area. ♦ A directory is being developed to keep on file details of all customary landowners and, where land is communal, the detail of the 'karikara' (group).	Chapter 13

6 The SMLI studies consider the findings of two Land Investigation Reports, developed by the Department of Land: 2010 LIR report for the PRL-15 area and the 2019 LIR report for the Onshore Pipeline Export Route.

6.4.2 Community Support for the Project

Feedback gathered through consultation during the EIR and Project disclosure campaigns in 2016 was positive in relation to TEP PNG's engagement approach and on-ground presence in Project-affected communities.

TEP PNG engagement activities with identified customary landowners and Project-affected communities has conveyed overall support for the Project. In particular, communities along the onshore export pipeline corridor are generally supportive of the Project; and villagers are keen for the Project to commence. While communities around PRL-15 are also generally supportive of the Project, there is also a growing frustration that progress, particularly with respect to business development opportunities, has been slower than expected. Formal support for the Project will be sought during the EIS disclosure roadshow (Section 6.3.4).

6.5 Continuing Engagement Activities

6.5.1 Update of the Stakeholder Engagement Plan

TEP PNG will prepare an updated stakeholder engagement plan for the Project's construction, operations and decommissioning phases, according to TOTAL General Specifications and IFC PS 1 and PS7.

The updated stakeholder engagement plan will build upon the existing plan and provide a formal structure and processes for continuing to keep Project-affected communities, government and other project stakeholders informed of Project updates and milestones. It will focus on regular reviews of new stakeholder and issue identification, engaging with affected communities concerning preconstruction surveys and land access agreements, ongoing consultation related to livelihood development, community benefits and employment, managing grievances according to TEP PNG's stakeholder grievance management procedure (Section 6.2.4.2), and continuing to build productive positive relationships with Project-affected communities and customary landowners.

6.5.2 Planned Activities

TEP PNG is committed to continuing to build long-term relationships with stakeholders, fostering economic development and contributing to local talent and skills development throughout the life of the Project. Ongoing, meaningful and gender-appropriate engagement will continue through preconstruction, construction, operations and decommissioning phases. Table 6.6 outlines some of the planned engagement activities for the next phases of the Project.

Table 6.6 – Ongoing and Planned Engagement Activities Post EIS

Activity	Estimated Timing
The Project will prepare an updated stakeholder engagement plan for the Project's construction, operations and decommissioning phases, according to TOTAL's General Specifications and IFC PS1 and PS7. The updated stakeholder engagement plan will include the following key requirements:	2019 to 2020
♦ Regular engagement with Project-affected communities on Project impacts, action plans and grievance mechanism.	Ongoing
♦ Notification as early as possible to affected communities in advance of Project works, which describes the activities and how long they are expected to take. Particular focus is to be given to communities that may be affected by Project-induced in-migration.	Ongoing
♦ A mechanism for enquiries and feedback.	Ongoing
♦ Ongoing grievance and issues management [SEM002]	Ongoing

Table 6.6 – Ongoing and Planned Engagement Activities Post EIS (cont'd)

Activity	Estimated Timing
Government-led Development Forum in accordance with s. 48 of the *Oil and Gas Act 1998*.	2020-2021
As part of the Land Access and Resettlement Framework (LARF): ♦ Provide a framework for stakeholder engagement on land access and livelihoods including public consultation, disclosure and grievance resolution. ♦ Provide preliminary information to stakeholders (e.g., government, civil society) about the standards and procedures for the LARF [SEM003]	2020
Through its stakeholder engagement programs and activities, the Project is undertaking a process of free, prior and informed consent (FPIC) in the Project area in accordance with the International Finance Corporation (IFC) performance standard (PS) 7. For example: ♦ The Project will engage an independent organization to provide legal support to project-affected persons regarding land access, so that they are fully informed of their rights and obligations, and that they enter into agreements willingly and without duress. ♦ The Project will document a mutually accepted process between the Project and Project-affected persons, and evidence of agreement between the parties as the outcome of negotiations [SEM001]	2020
EIS disclosure.	2020
Deliver agreed community development programs.	Operations phase

6.5.3 Achieving Free, Prior and Informed Consent

In accordance with IFC performance standard 7, the Project aims, through its stakeholder engagement programs and activities, to achieve FPIC in the Project area.

FPIC builds on the concept of informed consultation and participation outlined in IFC performance standard 1 and will be established through good faith negotiation between TEP PNG and Project-affected persons. IFC performance standard 7 applies where a project may cause risks or impacts 'to communities or groups of Indigenous Peoples who maintain a collective attachment, i.e., whose identity as a group or community is linked, to distinct habitats or ancestral territories and the natural resources therein' (IFC, 2012a). While the communities in the PAOI do not refer to themselves as Indigenous People, nor do the PNG authorities recognize them as such, all the communities in the Project area meet the IFC performance standard 7 criteria for being Indigenous People.

Obtaining FPIC involves multiple activities and processes and a cascading series of consents. For example, the Project will document a mutually accepted process between the Project and Project-affected persons, and evidence of land and compensation agreement between the parties as the outcome of negotiations. Other more general activities and processes that involve formal documentation and agreement will also contribute to achieving FPIC, (e.g., EIS process, SMLIs, Development Forum). Consultations providing relevant information that is understandable and provides sufficient time for decision-making and agreements with Project-affected persons will cumulatively contribute to achieving FPIC. Obtaining FPIC also requires independent verification that engagement activities have occurred appropriately (Oxfam, 2014). The Project will engage an independent organization to provide legal support to Project-affected persons, so that they are fully informed of their rights and obligations, and that they enter into agreements willingly and without duress.

6.5.4 Monitoring and Reporting

6.5.4.1 Monitoring

TEP PNG has established its own internal monitoring framework so that the stakeholder engagement plan is correctly implemented during EIS preparation to the satisfaction of national and international requirements, and good practice.

The monitoring framework focuses on TEP PNGs performance against the following engagement categories:

- Pre-awareness.
- EIS roadshows.
- Land access engagement.
- Government engagement.
- Community liaison program.
- Grievance management engagement.

TEP PNG undertakes regular internal monitoring of its own performance. One example of this is the monitoring of stakeholder issues using the SRM+ process[7] (see Table 6.3). These workshops canvass Project stakeholders from Project-affected communities, PNG authorities, business and civil society, and seek to gauge the quality of relationships, stakeholder satisfaction with consultation processes, key issues and concerns, and improvement actions.

Once the Project begins construction, an independent consultant will be engaged to monitor stakeholder engagement and other activities [SEM004].

6.5.4.2 Reporting

The Project will develop public reports that outline at least:

- The stakeholder engagement activities undertaken by the Project.
- Key feedback themes received by the Project from stakeholders.
- Key actions taken by the Project due to feedback from stakeholders.
- A summary of the results of the independent verification and consultation process.

The report will be made available on the Project website and provided to relevant stakeholders.

The independent third-party provider will produce a biannual report that will be provided to the Societal Steering Committee.

6.6 References

DEC. 2001. Environmental Code of Practice for Sanitary Landfill Sites. Department of Environment and Conservation, Port Moresby, Papua New Guinea.

EPA. 2013. The Equator Principles. A WWW publication accessed on 21 February 2019 at https://equator-principles.com/. Equator Principles Association.

7 SRM+ (Stakeholder Relationship Management) is an in-house management tool to structure, optimize and improve the social strategy and performance. The output is a gap analysis between the internal vision and the stakeholders perception and an associated action plans in line with the operational context.

IFC. 2007. Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets. International Finance Corporation. World Bank Group, Washington, D.C., USA.

IFC. 2012(a). Performance Standards on Environmental and Social Sustainability. International Finance Corporation, World Bank Group, Washington, D.C.

IFC. 2012(b). International Finance Corporation's guidance notes: performance standards on environmental and social sustainability. International Finance Corporation. Washington, D.C., USA.

Oxfam. 2014. Guide to Free, Prior and Informed Consent, 2014. Oxfam Australia, Carlton, Victoria, Australia.

TOTAL. 2018. Elk-Antelope Development Studies Pre-Project Environmental and Societal Report. Paris, France.

Attachment 6.1
IFC Performance Standards (2012) and Relevance to Project Stakeholder Engagement

IFC (2012) Performance Standard	Project Relevance (Stakeholder Engagement)	Actioned by the Project
PS1: Assessment and Management of Environmental and Social Risks and Impacts	♦ Provides guidance for the assessment and management of environmental and social risks and impacts in consultation with affected communities and other stakeholders. ♦ Establishes the importance of effective community engagement through disclosure of Project-related information and consultation with local communities on matters that directly affect them. ♦ Requires that engagement: – Is an ongoing process. – Is scaled appropriately to Project risks and impacts. – Incorporates a range of measures to enable effective participation, in particular by those identified as disadvantaged or vulnerable. – Provides affected communities with relevant information and genuine opportunities to express their views. – Is two-way. – Incorporates a grievance mechanism to manage affected community concerns and grievances.	♦ TEP PNG has developed and maintained a stakeholder engagement program that began in 2015 and continues to date. ♦ The program has: – Identified stakeholders through early and ongoing mapping and consultation. – Prioritized early, consistent, planned and targeted engagement with stakeholders. – Ensured that Project design has incorporated feedback and concerns raised by stakeholders. – Incorporated a range of methods and approaches for two-way communications, suitable to different stakeholder groups. – Addressed grievances and concerns as they are raised (Attachment 6.4). ♦ A stakeholder engagement plan has been developed to support the adoption of good industry practice and provides a structured process to guide engagement activities.
PS2: Labor and Working Conditions	♦ Requires Project proponents to develop and make easily accessible a grievance mechanism for workers and their organizations (where applicable) to raise reasonable workplace concerns.	♦ TOTAL maintains a grievance and conflict resolution process that applies to its staff. ♦ TEP PNG will develop a Labor Management Plan to address any grievances from contractors.
PS5: Land Acquisition and Involuntary Resettlement	♦ Ensures proponents engage with communities affected by land acquisition and resettlement, evidenced through demonstration of informed participation of affected persons and communities in decision-making processes. ♦ Requires that proponents establish grievance mechanisms to receive and address concerns specific to compensation and resettlement. ♦ Livelihood restoration plans (LRP) must incorporate the results of stakeholder engagement.	TEP PNG maintain a stakeholder grievance management process (Attachment 6.4). ♦ TEP PNG has undertaken full-scale social mapping and landowner identification (SMLI) studies and a program of engagement with customary landowning clans in Project-affected communities. ♦ Supported by an independent consultant, a land use engagement toolkit was developed and training for team members involved in negotiating land access agreements was delivered to ensure that agreements are made with free, prior and informed consent. ♦ TEP PNG maintain a stakeholder grievance management process (Attachment 6.4).

IFC (2012) Performance Standard (cont'd)	Project Relevance (Stakeholder Engagement) (cont'd)	Actioned by the Project (cont'd)
PS5: Land Acquisition and Involuntary Resettlement (cont'd)		♦ TEP PNG is developing a Land Access and Resettlement Framework that will define the processes of consultation and engagement that should take place with the project affected persons during the land access process and the development of livelihood development programs.
PS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	♦ Risk and impact identification should address the differing values attached to biodiversity and ecosystem services by affected communities and other stakeholders. ♦ Ensures that natural habitats are not significantly converted or degraded without prior consultation with affected communities on the extent of conversion or degradation. ♦ Ensures that potential impacts to critical habitats or listed or endangered species are derived through consultation with competent professionals.	♦ Competent specialists have been engaged by TEP PNG to provide advice on critical habitat assessment. ♦ Competent and experienced professionals in consultation with affected communities and relevant government authorities undertook environmental and natural resources baseline surveys. ♦ Consultation with affected communities is continuing and will address potential impacts to community natural resource use.
PS7: Indigenous Peoples	♦ Requires that engagement: – Ensures indigenous peoples are included in stakeholder analysis and engagement planning. – Provides for disclosure of information, consultation and participation in a culturally appropriate manner. – Provides sufficient time for Indigenous People's decision-making processes. – Seeks to establish and maintain an ongoing relationship with Project-affected Indigenous people. – Comprises informed consultation and participation. ♦ Ensures free, prior and informed consent of affected communities and Indigenous peoples on certain matters that affect them directly.	♦ While not formally recognized by PNG authorities nor commonly referred to by the communities themselves, the Indigenous Peoples status is considered to be applicable and international standards and conventions aimed at protecting them and safeguarding their collective rights will be adopted by the Project. ♦ TEP PNG will engage an independent trusted third party to raise awareness, provide legal advice and assistance to customary landholders and occupiers prior to, during and after their entering into land use and compensation agreements for the Project. ♦ Consultation is designed to achieve free, prior and informed consent in the Project area.
PS8: Cultural Heritage	♦ Requires consultation with affected communities who use, or have used within living memory, any Project-affected cultural heritage for longstanding cultural purposes, and the incorporation of the affected communities' views on such cultural heritage into the Project's decision-making process. ♦ Requires involvement of the relevant national or local regulatory agencies that are entrusted with the protection of cultural heritage.	♦ Cultural heritage studies have engaged Project-affected communities and relevant national and local authorities in the identification and management of cultural heritage values. ♦ TEP PNG has maintained ongoing engagement with the PNG National Museum and Art Gallery (NMAG) during the planning and execution of cultural heritage mapping and archaeology surveys.

Attachment 6.2
Example of Community Consultation Materials during the EIR Roadshow, 2016

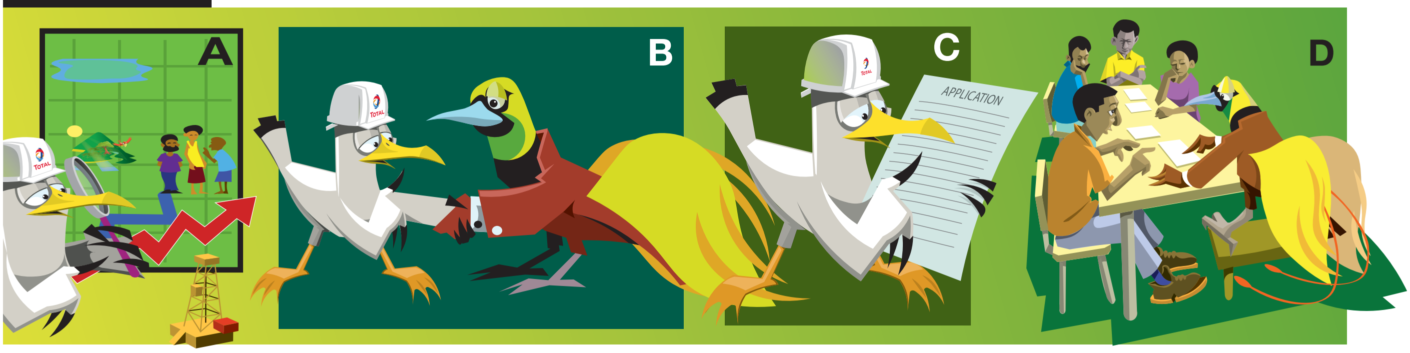
Lo Bilong Oil na Gas i save wok Olsem Wanem?
Wei bilong wokim wok.

Step 1

Petroleum Prospecting Licence (PPL)
Wok Painim Aut laisens we i givim tok orait long kampani long painim oil na gas.

Step 2

PRL-Petroleum Retention Licence
Dispela em i Laisens we i givim tok orait long kampani long wokim sampela moa wok painim aut long save gut sapos igat inap oil/gas i stap.



A: Ol wok painim aut bilong ol ples, bik bus, wara na solwara, sindaun bilong ol ples lain na sampla technical wok bai kamap lo dispela taim.

B: Gas Agrimen bai kamap namel long Nesenol gavman na developer.

C: Kampani bai putim pepa or application igo long gavman long kisim PDL laisens

D: **Taim bilong Developmen Forum:** Ol papa/mama giraun bai sindaun wantaim gavman na toktok long ol benefits we i stap aninit long lo bilong Oil na Gas 1998.

Step 3

PDL-Petroleum Development Licence
Dispela laisens em i givim tok orait long kampani developim ol oil na gas ol i painim long en.

Gavman bai givim PDL wantaim narapela tupela Laisens. Laisens bilong wokim Pipeline na Facilities.

Construction Phase: Planti kain kain wok bai kamap long taim bilong wok konstraksen.

Sans long painim wok tu long disla taim.

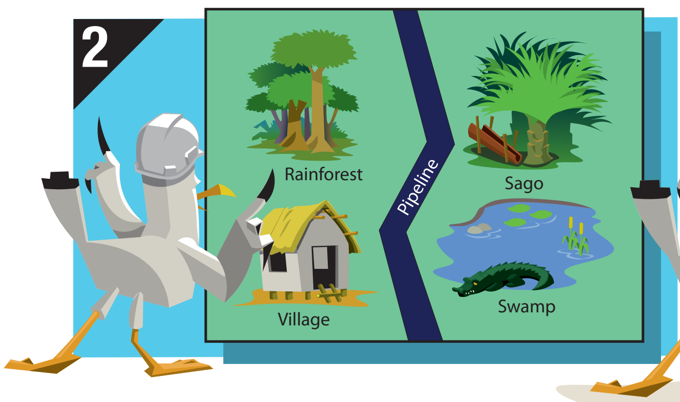
Nesinol, Provinsol na Local Level Gavman na papa giraun bai kisim kain gutpla samting olsem: Equities, Royalties, Development Levies wantaim Infrastructure Business Grants.

TOTAL

Environment Impact Statement (EIS)

Environmental and Social Baseline Studies

Total be ita eda tura namona ta, badina ia ena ura badana be ita eda uda, sinavai bona davara ia diba namonamo. Una dainai tahua gaukara ia karaia noho ita eda uda bona hanua lalodiai noho mauri daladia ia itaia noho. Inai tahua gaukara lalonai be ia ura ia diba ita eda gabu be edena dala ita gaukara laia, labana bona haoda totona, ma danu, hanua gorere, noho mauri ihanamoa bona ita eda tubu dae be ede bamona ita naria. Gau ta danu be ita eda sene noho maurina bona ena kara idia ura diba namonamo.



Impact assessment

Inai tahua gaukara be projek ena palani bona taunimanima ena noho mauri do idia itaia, ma dala namona idia abia-dae umui idia durua dala maoro dekenai bona edenabamona do idia durua.

Social and Environmental Management Plans

Tahua gaukara idia karaia hanua lalonai be hanua ena mauri bona sene sivarai do idia abia. Inai tahua gaukara be hanua dekenai idia vadivadi ma sivarai namona umui henia.

Create positive community outcomes

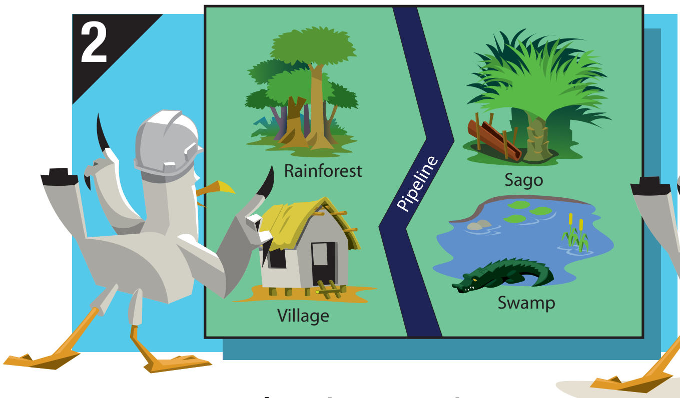
Inai tahua gaukara be ia namo badina ai bona umui do ia durua, ita ena noho mauri do ita diba namonamo, ita eda bese o ita eda hanua lalonai. Inai tahua gaukara ese dala namona do ia abia mai ita eda hanua, muramura gabu, sikuli bona ita ena mauri be do ia senisi.

TOTAL

Environment Impact Statement (EIS)

Environmental and Social Baseline Studies

Total em i wanpela gutpela poroman bilong yumi olsem na em laik save gut long ol bik bus, wara na solwara olsem na em i wokim wok painim aut bilong bus, ples na sindaun bilong yumi. Dispela wok painim aut i laik luksave long wei we ol ples lain i save usim bus arere long ol long painim abus, pis na tu sampla wei we ol i save usim bus long taim bilong sik, long seifti bilong ol yet, long lukautim ol yet long samting nogut na tu save sapos i gat tumbuna samting na passim i stap.



Impact assessment

Ol dispela wok painim aut i halivim long luksave long sampla wei we plen bilong projek i ken kisim hevi kam long bus na tu ples na sindaun bilong ol pleslain.

Social and Environmental Management Plans

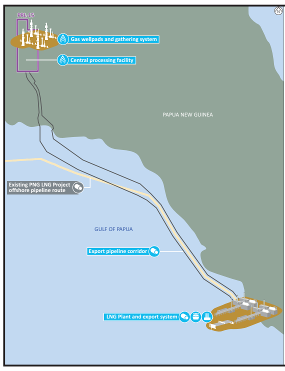
Dispela wok painim aut bai halivim Kampani long wokim sampla plen bilong abrusim, limitim, kisim kam bek na tu rausim ol dispela hevi ol i bin luksave long en.

Create positive community outcomes

EIS wok I halivim long luksave long rot bilong kisim planti gutpela halivim na gutpela samting long projek na slowim daun ol hevi we projek i kamapim. Dispela wok em i wok we em bai halivim gavman luksave gut na tok orait long Kampani long statim projek.

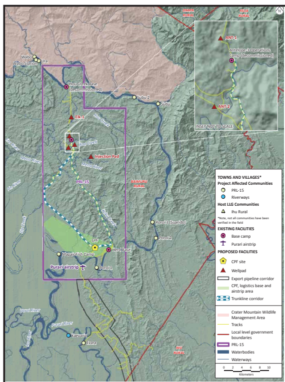
TOTAL

Projek ena durua kohu haida be



Inai Projek i gaukara laina kohu bada dia be:

- **Gesi Guri Gabudia Bona Gogoa Dalana**
  Gesi ia noho guri ibounai be gwauta-hani (14) mai kahana , ranu negea guri be rua bona gesi negea guri be tamona Elk-Antelope projek ena heau lalonai.
- **Gesi Hanamoa Bona Hagoevaia Gabuna**
  Inai Gesi Hanamoa bona Hagoevaia gabuna ena noho daudau be kilomita toi ahui (30km) bamona ia lao Elk-Antelope gesi kokia gabuna amo laurabada kahanai ma ena daudau be kilomita ima (5km) bamona ia lao Herd Base bona Purari sinavai badi nai. Inai Gesi Hanamoa Bona Hagoevaia Gabuna be mai ena gesi gogoa gabudia, gesi bona oela hanamoa gaukaralaia gabudia bona mai ena gesi dikadia kokia gabuna bona ranu hanamoa gabuna.
- **Abia Rakalasi Paipa**
  Abia rakalasi paipa be rua do idia a heaua; ta be gesi ena bona ta be oela ena. Inai paipa edia lata gesi hanamoa bona hagoevaia gabuna ia lao LNG karaia gabuna be 325 kilomita bamona. Gesi paipa edia bada be 40 ia lao 44 inches bona oela paipa ena bada be gwauta ia lao gwauta rua inches. Gesi bona oela keoa bona koua gabudia be toi ia do atoa paipa lata diai.
- **LNG Karaia Gabuna**
  LNG karaia gabuna be Caution Bay, Central Province amo bona ena e hagini tano ena bada be 700ha. Gesi bona oela be Gesi Hanamoa Bona Hagoevaia Gabuna amo do idia siaia mai LNG karaia gabuna ma unuseni ai hoi hoi kohu idau idau do idia karaia ma gabu idau idau tanobada lalonai idia siaia lao. Nese ta bona sisima ena kamokau gabuna ta do idia karaia.



Projek haginia durua gau haida be:

- **Noho gabudia**
  Gesi Hanamoa Bona Hagoevaia Gabuna dekenai noho gabuna ta do idia haginia gaukara hematama taimi nai. Gabeai do idia habadaia badina gaukara taunimanima be 3200 mai kahana unuseni do idia noho projek gaukara ia hematama neganai. Inai murinai noho gabuna ta ma idia haginia gesi gaukara laia taunimanima 120-150 bamona do idia noho. LNG karaia gabuna Caution Bay dekenai be noho gabuna ta do idia karaia taunimanima 10,000 bamona idia noho. Inai nega lalonai gaukara taunimanima 300 bamona do idia noho gesi hanamoa bona hagoevaia gabunai.
- **Kohu atoa gabu dia**
  Kohu balaia heni gabu maragi dia aida be do idia karaia tano dekenai idia noho paipa dia edia noho gabudia.
- **Dala bona Nese Hanai**
  Dala matamata aida do idia karaia Herd Base amo ia lao Gesi Hanamoa Bona Hagoevaia Gabuna bona gesi guri gabudia. Hari idia noho dala dia bona nese hanai dia be do idia hanamodia danu.
  Hari idia noho au utua dala dia Purari sinavai laurabada kahana be do idia hanamo dia diba bema gesi hoi hoi laia paipa idia gaukara laia neganai.
  Bema LNG Karaia Gabuna ia maoro Caution Bay ai hari ia noho dala badana be idia sivaia diba bona nese hanai ibounai do idia hanamo dia diba eiava dala matamata ta do idia karaia diba LNG Karaia Gabuna ia lao Port Moresby amo.
- **Gaukara Palani bona kohu hatoa bona abia Gabuna**
  Peleini gabu matamatana ta do idia karaia inai kkohu atoa gabuna ena kaira kaira dekenai, PRL 15 ena gaukara do idia durua.
- **Peleini Diho Gabuna**
  Peleini Dio Gabuna ta ena lata be 1.8km be do idia hagini inai Gaukara Palani bona Kohu Abia Gabuna badinai PRL 15 dekenai projek ena gaukara durua totona.
- **Nese**
  Nadi abia gabudia be hari idia tahua noho projek gaukarana durua totona.
- **Nadi Abia Gabuna**
  Nadi abia gabudia be hari idia tahua noho projek gaukarana durua laia totona.
- **Sinavai Lao Mai**
  Projek ena kohu badadia be sisima laodiai do idia abia mai Herd Base ena kohu balaia heni gabuna dekenai. Ini kohu badadia be Purari sinavai rigina toi ladadia; Purari, Ivo-Urika bona Wame-Varoi amo Purari Sinavai amo do idia abia vareai lao Herd Base dekenai. Paipa haginia gaukara ena nega ia gini dae neganai, sisima edia heau daekau bona diho sinavai dekenai do ia bada. To inai murinai bema Projek gaukara ia hematama neganai do ia dio sisina. EIS ese kohu idia udaia sisimadia do ia gwauraia lasi.

Project Timeline

Environmental Approvals	2015	2016	2017	2018	2019	2020	2021	2022	2023
Environment permit application sumission, review and granting									
Project Development Activities									
Pre-project engineering design									
Basic engineering design and FEED									
Final investment decision									
Construction and commissioning **(not untill 2020)**									
First cargo LNG									

TOTAL

Attachment 6.3
Example of Tok Save Project Newsletter

Komuniti Tok
Save N° 4

Jean-Marc NOIRAY
Managing Director
Total E&P PNG Limited

Dabai namona iboudiai !

It is with great pleasure that I share this Komuniti Tok Save Newsletter with you all!

I believe this 4th edition of Total E&P PNG Limited Komuniti Tok Save Newsletter is an important way for us to reach out and update you on the progress of the Papua LNG Project, not only in communities in PRL-15 but also along the pipeline corridor area and on the riverways. As key stakeholders within our Project Area Of Influence (PAOI), I consider it important to keep you informed.

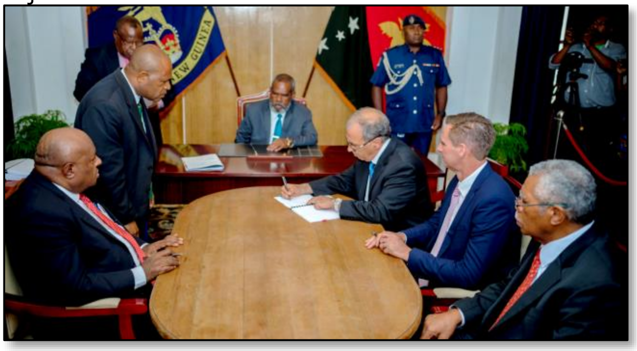
This newsletter complements the efforts of our Community Relations team, whose function is to maintain dialogue with you and to provide you with information on a regular basis. Should you need to get direct information on the Project, please ask them or call the TEP PNG Toll free line (70 111 777).

Papua LNG Gas Agreement

Total and its partners ExxonMobil and Oil Search signed the Gas Agreement for the Papua LNG Project with the Independent State of Papua New Guinea on Tuesday 9th April 2019. This is an important event for us all and, as expressed by Total Chairman and CEO Patrick Pouyanne, '...*the finalization of the Gas Agreement is a major milestone for the Papua LNG project that confirms the commitment of all partners and the Government of Papua New Guinea to make the project a success for all stakeholders'* .

Prime Minister Hon. Peter ONeill, Governor General Grand Chief, Sir Bob Dadae, Gulf Governor Hon. Chris Haiveta attended the signing ceremony alongside State dignitaries.

The Gas Agreement is a key milestone and essentially sets out the agreed fiscal terms framework for the Papua LNG project.



TEP PNG Managing Director signing the Gas Agreement

Gulf Provincial Executive Council (PEC) at Government House for the Papua LNG Gas Agreement Signing

Project Milestones and Next Steps

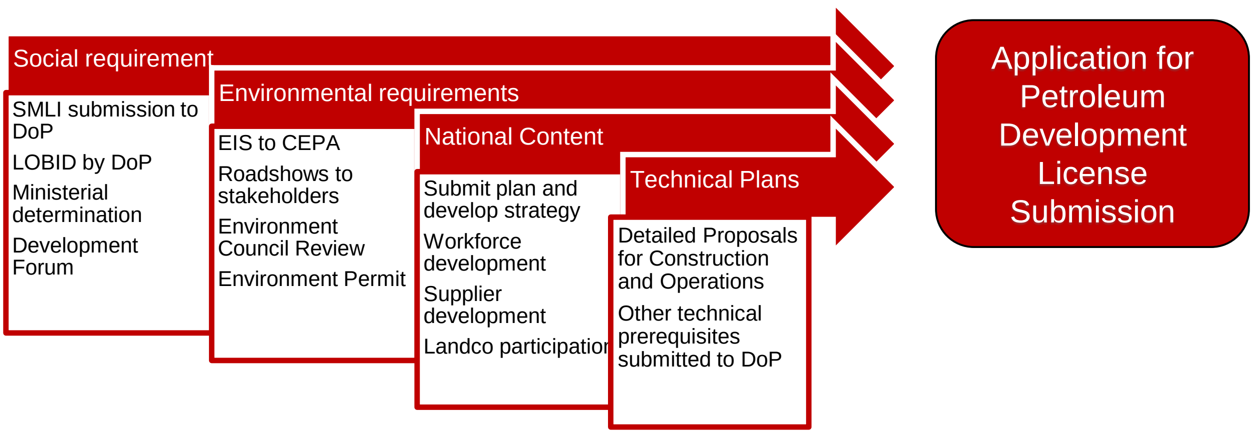
The signed Gas Agreement allows the partners to launch Front-End Engineering Design (FEED), which will then be followed by detailed engineering and procurement and to finalize Project Financing and Final Investment Decision (FID), which is also known as "Project sanction".

It is important not to confuse the Gas Agreement with the Development Forum. The Development Forum is the venue where the State, through the Director *Oil and Gas Act*, will present the Development Proposal to the Provincial Government, Local Level Government and the representatives of the landowning communities of the project footprint, including the buffer zones. Negotiations will take place and the Development Agreement will be signed by all parties. The time of the Development Forum is set up by the Department of Petroleum.

I would like to make it clear to you all that there are still many regulatory requirements that need to be completed and complied by both the developer and the State authorities.

Construction can only begin when the Petroleum Development License is granted and the Project is approved.

A high-level outline of the process is presented below.



There is still a lot of work that needs to be done, which will require a concerted effort by all parties and stakeholders to achieve the key Project milestones.

SMLI Updates

Many of you will be wondering about the current status of the Social Mapping and Landowner Identification studies (SMLI). Three lots of SMLI were completed for the Upstream part of the Project:

1. Full Scale PRL-15 SMLI
2. Full Scale SMLI for the onshore Pipeline export route
3. Full Scale SMLI for the offshore Pipeline export route

In the downstream area (LNG facilities at Caution Bay) discussions continue with the Department of Petroleum (DoP).

All three Upstream SMLIs have been completed by the social consultant hired by TEP PNG. Upon submission of the reports, the next key activities will include:

1. Analysis of the SMLI Reports by DoP;
2. Landowner Beneficiaries Identification (LOBID) process will be undertaken by DoP;
3. "Ministerial Determination" of the project area landowners by the Minister of Petroleum;
4. Invitations from the Minister of Petroleum to the identified landowner representatives and LLGs to attend the Development Forum;
5. The State's presentation of the Development Proposal to landowners and LLGs during the Development Forum; and
6. Signing of the Development Agreement, between the State and Project Area Landowners, Local Level Governments and the Provincial Government.

Business Development - Appointment of Business Development Officers

Many of the questions handled by the Community Liaison Officers relate to local business development. To better manage these queries, TEP PNG is recruiting two Business Development officers.
These Business Development officers will be able to manage these queries, provide advice on business opportunities, suggest potential opportunities, including agriculture and other projects. They will also be able to provide advice and support with the formal establishment and registration of businesses.
They will be based initially at Herd Base and are expected to start in May 2019.

Community Investment Projects

Evara Aid Post

The Evara Aid Post was inaugurated on 26th February 2019. A partnership between the Digicel Foundation, the Papua LNG project, the Gulf Provincial Government and Evara community delivered this important service to the community.

Hon. Governor Chris Haveita, TEP PNG MD Jean-Marc Noiray and Digicel Foundation representatives during the inauguration at Evara on 26th February 2019.

New aid post in Evara.

New Poroi 2 Aid Post Building to be Built

The ground breaking ceremony for the Poroi 2 Aid post was held on 5th April 2019. The new building will improve health services for the local population.
Materials are currently being procured in Port Moresby and will be transported to site. Construction is expected to commence in May 2019. The Papua LNG project will fully fund the project.

Poroi 2 aid post ground-breaking ceremony on 5th April 2019

Upcoming Community Investment Projects

Orokolo

The Papua LNG project has also undertaken to work in partnership with the Digicel Foundation, the Sago network and the people of Orokolo to develop two projects in mid 2019.

1. 1 x double classroom project for Orokolo Primary School
2. 1 x double classroom project for Arahava Harevavo Primary School.

The two classrooms will be complemented with separate ablution units for the students to use as part of promoting health and hygiene. I have been briefed that the site inspection and discussion with the respective school administrations and communities were completed already. I also understand that the communities have demonstrated their support by consenting to land being allocated for the projects and I would like to commend this gesture. I trust and ask for your utmost support and commitment so that these projects are completed successfully on time. I also look forward to attending the inaugurations.

Mosquito Net Donations

Papua LNG donated 6,000 treated mosquito nets to 2,055 households in the Project area. This came about with the outbreak of malaria in Wabo and other communities in the Project area. Each household received 2-3 mosquito nets. The distribution will continue to other communities along the Aivei and Ewoe river way.

Photograph (Above Left): TEP PNG CLO distributing the mosquitoes nets at Aumu, (above Right) VLO recording the distribution at Kaevaria community.

Donations of Health Clinic Books and School Stationery

There is a need to update the medical history of patients who visit the aid posts. Papua LNG donated 8,000 health clinic books to the 11 aid posts in the Project area. At the same time, our Community Relations team distributed much needed school stationery in 11 primary and 23 elementary schools in the Project area.

Apiope Community

Maipenaru Community

Kaivukovu-Lairihairu Community

Iuku Elementary

NID Program Deployment

Thank you for your participation in the NID exercise undertaken by the Papua New Guinea Civil Identity Registry and supported by Papua LNG Project. Since commencing in late 2018, we have covered PRL 15 Communities and we will move to the Pipeline Export Route (PER) communities in May. This is a National Government Initiative that we are pleased to support, so that the people in the Project area can register and have birth certificates and National ID cards.

Your National ID Card will provide your official identification and enable you to provide verification for employment, opening your bank accounts, enroll in schools, right to access health services.. The NID Card becomes a formal identification for many uses in PNG.

Department of Petroleum has for example advised that they are considering using the NID card when they undertake the LOBID exercise previously known as clan vetting to clearly identify true members of the clans within the project footprint, and set aside those who may be visiting your villages during this process. At the Landowner Forum, clan leaders and community representatives invited by the Minister for Petroleum to the Forum must produce the NID card so they can enter the Forum. You will agree that this is important to ensure that outsiders do not come in to the process unnecessarily. The Mineral Resource Development Company (MRDC) will also use the NID to registers clan members, then open their individual bank accounts, for the purpose of royalties and equity for identified clan members.

I appeal to all clan leaders to register, and encourage your clan members to register as well. Do not hesitate to discuss with our Community Liaison Officers if you have any doubts of queries, because this is very important for your people.

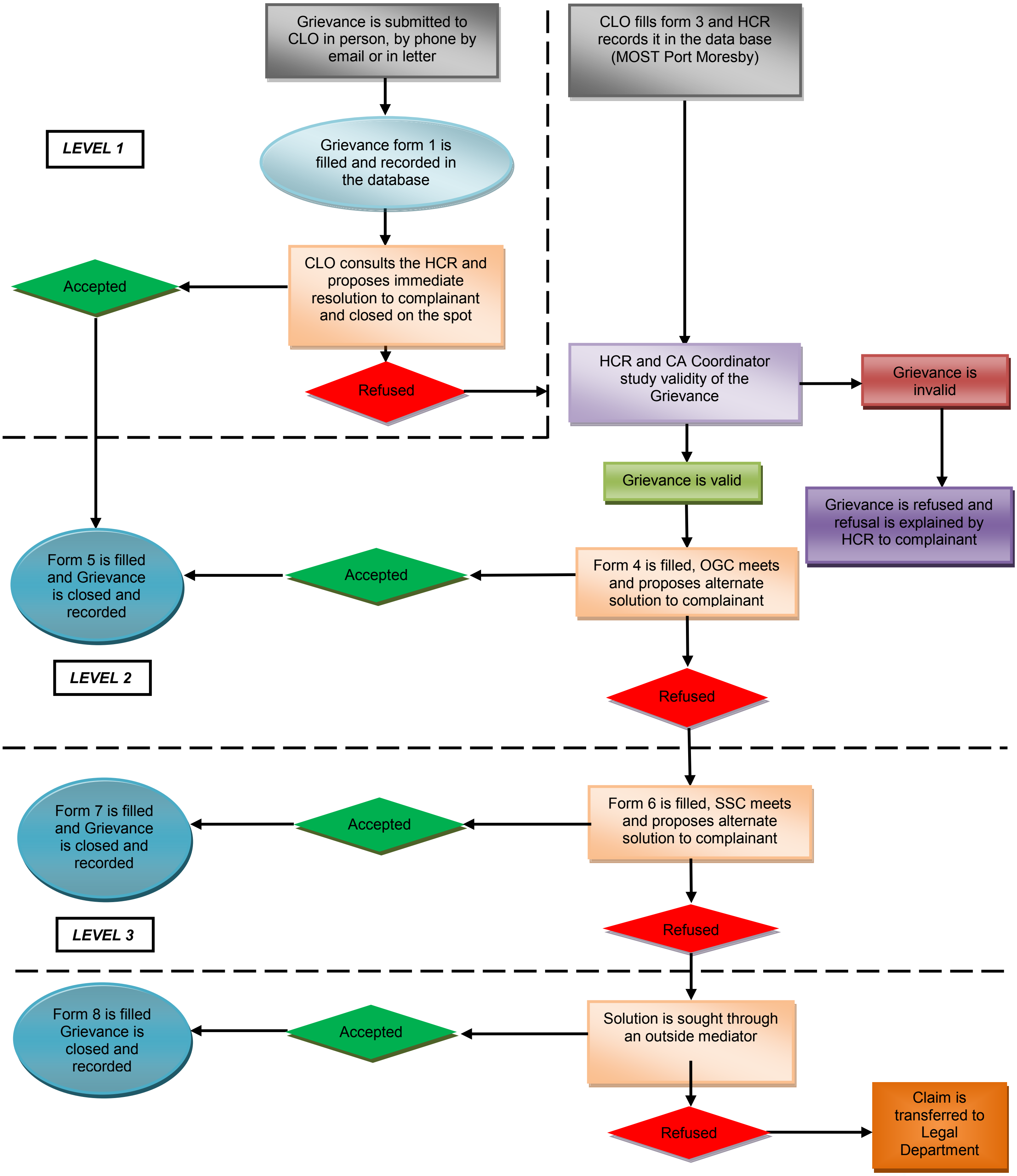
Evara Village community Hall – NID deployment.

Jean Marc NOIRAY
Managing Director, Total E&P PNG Limited
April 2019

Attachment 6.4
Stakeholder Grievance Management Flowchart

APPENDIX 1

GRIEVANCE MANAGEMENT PROCEDURE FLOW CHART



Attachment 6.5
Example of Dual-language Grievance Mechanism Communication Materials

In the instance Total E & P PNG will convene a meeting internally or alternatively with you and a third party from the district or from any relevant authority to find a solution.

FOURTH SOLUTION

Once a solution is found and is acceptable to you, the corrective measure will be implemented. You will be asked to sign the **"close-out"** section of the **Grievance Form** to close the case.

If you are not satisfied with the third solution, Total E&P PNG will propose a third party mediator or you are at liberty to choose a third party mediator. If the mediator is able to propose a solution acceptable to both parties

The Total E&P PNG CLO will be your contact person during the process of the grievance resolution. Please note, however, that he/she is not entitled to take any decision on behalf of the company.

FOR FURTHER INFORMATION PLEASE CONTACT THE COMMUNITY LIAISON OFFICER (CLO) OF YOUR AREA AS LISTED BELOW:

HERD BASE
BILL ARUA/HANNAH PHILIP

+675 7999 2057

WABO
KAUSU SOIDO/CANICE AIDABOE

+675 7999 2057

CAUTION BAY
SIMON ALK/HOSEA JAMES

+675 709 2033

TOTAL

COMMITTED TO BETTER ENERGY

GRIEVANCE PROCEDURE

WHAT DO YOU DO

IF YOU

HAVE A COMPLAINT ABOUT TOTAL E& P PNG ACTIVITIES IN YOUR COMMUNITY

COMPLAINT

If you are an individual, an association, a community or an institution and you believe that Total E&P PNG or one of its contractors is responsible for an unfair situation, you can bring your grievance to Total E&P PNG's attention through the following procedure.

Please note that this grievance procedure does not apply to:

- requests for projects and donations
- requests for jobs,
- complaints about your working conditions.

FIRST SOLUTION

If you have a complaint please fill in a Grievance Form that you can find at a Total E&P PNG Community Relation Office or with a Total E&P PNG Community Liaison Officer (CLO).

If you do not know how to read or write, a person selected by yourself will check all the information given on the **Grievance Form**

If your complaint is legitimate and if an appropriate solution can immediately be agreed with you, Total E&P PNG will proceed with the corrective measure.

Once the corrective measure is implemented, you will be asked to sign the **"close-out"** section of the **Grievance Form** to close the case

SECOND SOLUTION

If you are not satisfied with the first solution proposed, you will fill-up the **"Acknowledgement of Receipt of Grievance"** section of the **Grievance Form** and remain with a copy.

An internal investigation will be conducted by Total E&P PNG to find a solution to the case.

This second solution will then be presented to you and if you accept, the corrective measure will be implemented. You will be asked to sign the **"close-out"** section of the **Grievance Form** to close the case

THIRD SOLUTION

Nega aida be Total E & P PNG Ltd ese oi bona taunimanima aida do ia boiboi hebou totona bona emui lalo metau eiava lalo isi isi ia hanamoa diba.

HANAMOA DALA HANI

Bema kampani ena hanamoa dalana oi ura henia neganai, oi be do ia hamaoromu Lalo Metau eiava Lalo Isi isi pepana ta dekenai do oi saini emu lalo metau eiava lalo isi isi "koua" totona.

Total E&P PNG Ltd ena CLO gaukara taudia be umui idia durua diba Lalo metau eiava Lalo Isi isi hanamoa neganai. Umui be ai hadibamui inai CLO taudia be gwau maoro ta idia karaia lasi kampani ena gabunai .

BEMA OI URA DIBA MAORO EIAVA GWAU MAORO NEGANAI INAI COMMUNITY LIAISON OFFICERS (CLO) OI BOIRIA:

HERD BASE
BILL ARUA/HANNAH PHILIP
+675 7999 2057

WABO
KAUSU SOIDO/CANICE AIDABOE
+675 7999 2057

CAUTION BAY
SIMON ALK/HOSEA JAMES
+675 709 2033

TOTAL
COMMITTED TO BETTER ENERGY

LALO ISI ISI HANAMOA DALANA

OI BE DAHAKA DO OI KARAIA BEMA MAI EMU BADU BONA LALO METAU TOTAL E & P PNG LTD ENA GAUKARA TOTONA KERERE IA HAVARAIA EMUI KOMINITI LALONAI?

LALO ISI ISI/LALO METAU

Total E & P PNG Ltd eiava ena Contrak gaukara kampanidia be nega aida kerere do idia havaraia gaukara edia gaukara lalonai. Bema oi sibona, orea ta, hanua ta eiava gabu aida lalo isi isi o lalo metau umui abia neganai maoro maoro umui gwau lasi Total E & P PNG Ltd dekenai ma hanamoa daladia ia tahua ia ena isi isi hanamoa dalana enunai.

Umui be ai hadibamui inai hanamoa dalana be inai gau dekediai ia gaukara lasi:

- Noinoi karadia projek eiava kohu totona
- Noinoi karadia gaukara totona
- Bema umui moale lasi emui gaukara totona

HANAMOA DALANA TA

Bema mai emu badu neganai Lalo isi isi /Metau pepana ta be Total E & P PNG Ltd Community Relation Office dekenai eiava Community Liaison Officer (CLO).

Bema duai duai or toretore oi diba lasi, durua tauna ta oi ese oi do oi makaia inai **Lalo Metau/Isi isi** totona.

Bema oi emu lalo metau/Isi isi ia maoro bona bema hanamoa daladia oi ura henidia neganai, Total E & P PNG Ltd be emu badu hanamoa gaukara ia gaukaralaia.

Inai badu gaukara laina murinai oi be do oi saini diba **"kohua"** gabuna ta **Lalo Isi isi eiava Lalo Metau** pepana dekenai.

HANAMOA DALANA RUA

Bema oi moale lasi Hanamoa Dalana Ta ai oi be **"Revareva"** risit .gabuna, **Lalo Isi isi eiava Lalo Metau** pepana dekenai.

Total E&P PNG be tahua gaukara ta ia karaia oi emu lalo isi isi hanamoa totona.

Bema Hanamoa Dalana Rua ena maoro dalana oi moale henia bona hamomokania neganai oi be **"kohua"** gabuna **Lalo Isi isi eiava Lalo Metau** pepana lalonai do oi saini diba.

HANAMOA DALANA TOI

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 7: Existing Environment - Terrestrial

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

Table of Contents

Chapter

Tables

Figures

Plates

7. Existing Environment – Terrestrial

This chapter has drawn on information generated by a series of interdependent terrestrial studies that have involved detailed bibliographic reviews, numerical modeling (where required) and field surveys. Based on this information, descriptions are provided of the following components of the upstream terrestrial environment:

- Geology, terrain and soils (Section 7.2) derived from the Upstream Geology, Terrain and Soils Baseline Report (Part 1 of Volume 2).
- Hydrology and meteorology (Section 7.3) derived from the Upstream Hydrology and Meteorology Baseline Report (Part 2 of Volume 2).
- Surface water and sediment quality (Section 7.4) derived from the Upstream Surface Water and Sediment Quality Baseline Report (Part 3 of Volume 2).
- Groundwater (Section 7.5) derived from the Upstream Groundwater Baseline Report (Part 4 of Volume 2).
- Freshwater and estuarine biodiversity (Section 7.6) derived from the Upstream Freshwater and Estuarine Biodiversity Baseline Report (Part 5 of Volume 2).
- Terrestrial biodiversity (Section 7.7) derived from the Upstream Terrestrial Biodiversity Baseline Report and the Upstream Deforestation Baseline Report (Parts 6 and 7 of Volume 2, respectively).
- Vegetation regeneration (Section 7.8) derived from the Upstream Vegetation Regeneration Baseline Report (Part 8 of Volume 2).

The baseline characterization of the upstream terrestrial environment primarily focused on:

- PRL-15.
- The onshore export pipeline corridor.
- The Purari River catchment and subcatchments.

7.1 General Setting

The terrestrial biophysical setting of the upstream Project is the Purari River catchment, the third largest catchment in Papua New Guinea, covering a total area of approximately 33,730 km^2. The Purari River catchment lies between the Kikori and Vailala rivers and commences at Mount Wilhelm, which, at 4,150 m above sea level (asl), is the highest mountain in the Central Highlands of Papua New Guinea. The Project will be developed in the lower part of the Purari River catchment within PRL-15 and along the onshore export pipeline corridor to the coast at Orokolo Bay. While most of the Project is located in the Purari River catchment, waterways of the Era River catchment drain the central and western area of PRL-15, including the area of the Elk-Antelope gas field. The topography is a ridge and ravine landform of low-altitude hills to the north of PRL-15, descending to the broad, flat floodplains of the Purari River delta, featuring ephemeral oxbow lakes, alluvial floodplains and wetlands. Isolated perched, shallow groundwater occurs in superficial and weathered material throughout the Project area.

The Project area experiences a high-rainfall, humid tropical climate characterized by two distinct seasons, the southeast trade wind season and the northwest monsoon season. The climate, along with landform, topography, geology, flooding and tidal regimes, supports the growth of a dense and varied natural vegetation cover comprising hill and alluvial forests on inland hills and ravines, lowland swamp forests on river plains, nipa and sago palms lining river channels and mangrove-fringing estuaries and coastlines.

While human settlement is low and principally confined to villages along the coastal fringes and river banks, anthropogenic disturbance to natural forest cover resulting from commercial logging operations has been pervasive since the early 2000s. These logging activities have resulted in degradation of large areas of primary forest south of PRL-15 to the coast at Orokolo Bay. Other minor anthropogenic effects on forest cover relate to subsistence farming and more recent oil and gas exploration activities, including those relating to this Project.

7.2 Geology, Terrain and Soils

7.2.1 Regional Context

The geology, terrain and soils study area, encompassing PRL-15, including the production, processing and related facilities, and the onshore export pipeline corridor is located in central Papua New Guinea in the foothills, alluvial plains and beach areas south of the Central Range. Geologically, this area is located in the Papuan Fold and Thrust Belt and the Aure Deformation Zone (Figure 7.1). The Central Range, or Central Highlands, is a 150-km-wide, 3,000-m-high, rugged mountain belt that extends over 1,300 km from Indonesia's Irian Jaya in the west to Milne Bay in the southeast. The Central Range has been formed as a result of collisions between the Pacific and Australian tectonic plates, with movement between these two plates accommodated by four microplates: North Bismarck Plate, South Bismarck Plate, Woodlark Plate and the New Guinea Highlands Block. Crustal deformation and seismicity are concentrated along these boundaries (Wallace et al., 2004; Williamson & Hancock, 2005).

The study area is located in the eastern section of the Papuan Basin, a geological sedimentary basin that covers the southern part of the Papuan mainland. The eastern Papuan Basin comprises sedimentary rock formations up to 4 km thick with Triassic- and Jurassic-age[1] deposits at its base. Sediments of the Papuan Basin underlie the southern plains and are exposed in the adjacent fold-thrust belt in which the Elk-Antelope gas field is located.

The upstream terrestrial Project area from PRL-15 to the coast at Orokolo Bay is located in Seismic Zone 3 based on the zoning provided by the PNG building standards (PNGNSC, 1982) (Figure 7.2). This zone is a moderate seismic hazard zone for building construction in Papua New Guinea. The offshore export pipeline corridor through the Gulf of Papua to Caution Bay is located in Seismic Zone 4, which is a low seismic hazard zone. Irrespective, recent structural and geohazard investigations indicate several active faults in the Project area, presenting moderate to high geohazard risks. There are no volcanoes in the study area. The closest active volcanoes are Crater Mountain and Yelia, which are located 65 km north and 85 km east of PRL-15, respectively (Figure 7.2).

The whole of the Gulf of Papua, where the offshore export pipeline corridor is located, is in the lowest tsunami hazard zone, Zone 3, which is considered to experience a low frequency of tsunamis (PNGNSC, 1982). This low level of concern reflects the fact that no active submarine tectonic trenches or volcanoes exist in the region.

1 Sedimentary rocks in the basin date back more than 250 million years.

TECTONIC DOMAIN MAP OF PAPUA NEW GUINEA

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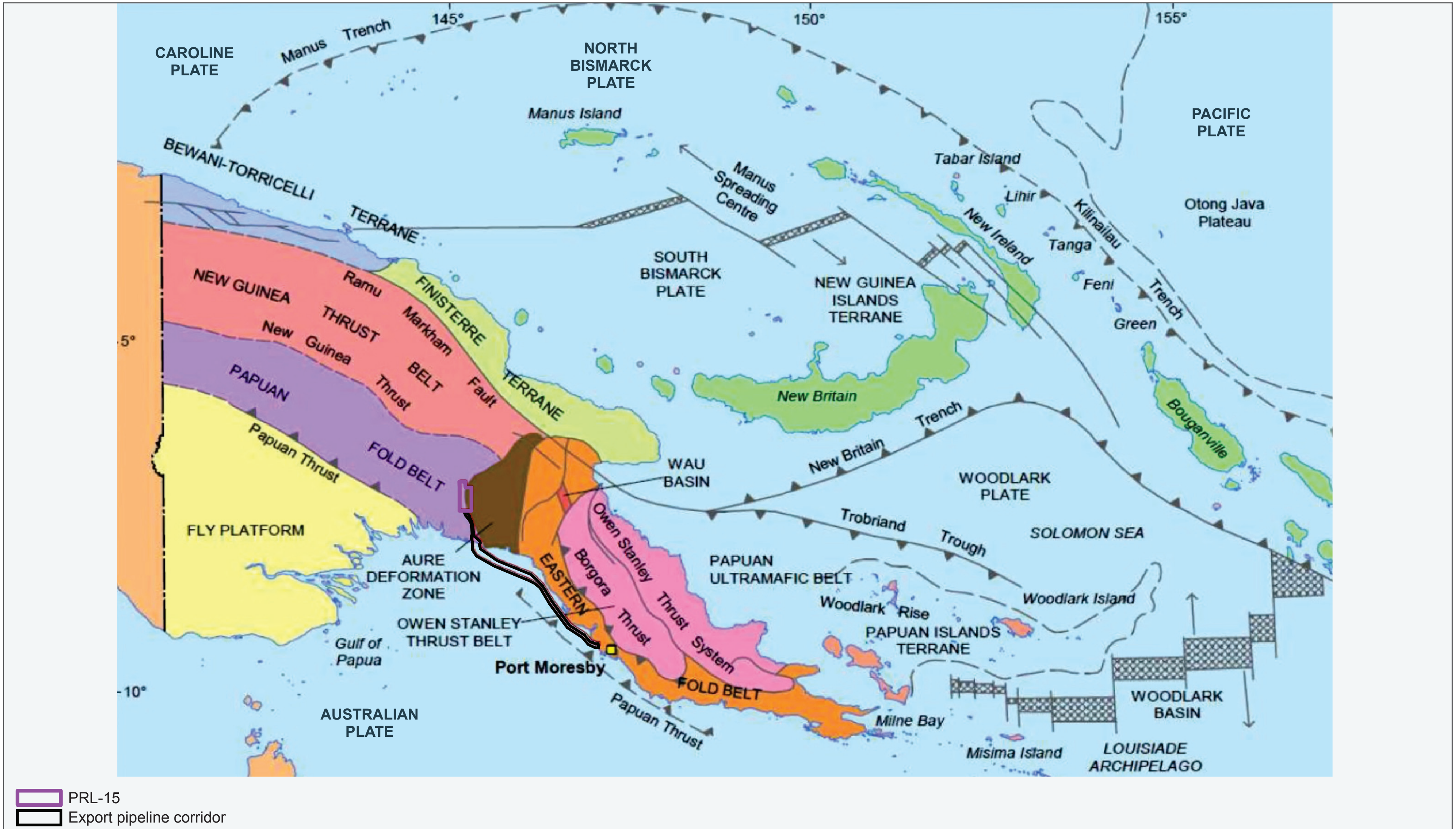
FIGURE 7.1



Source: Adapted from William son and Hancock, 2005.

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SEISMIC ZONES AND HISTORICAL SEISMIC ACTIVITY IN THE PAPUA NEW GUINEA REGION 1900 TO 2012

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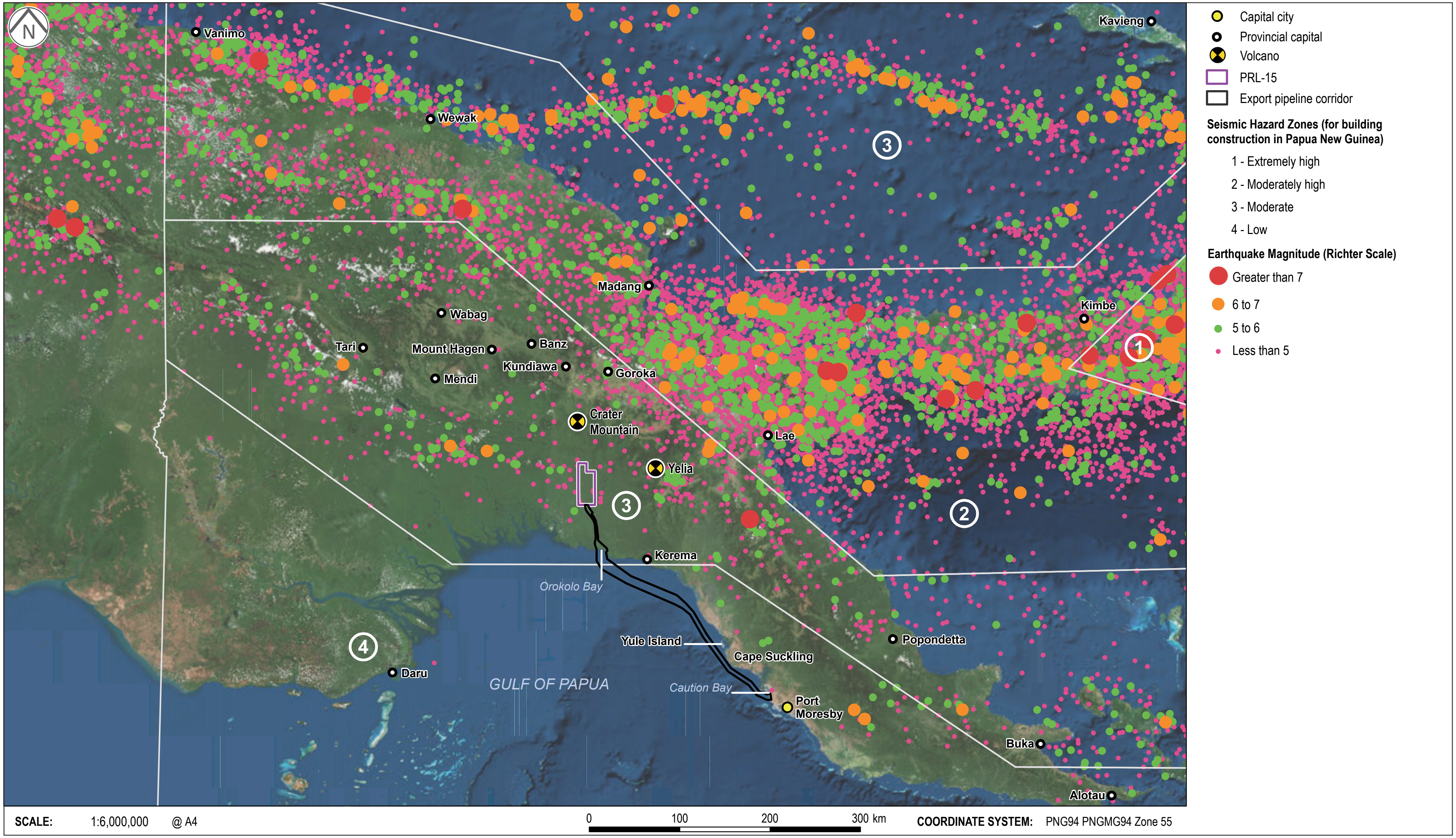
FIGURE 7.2



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7.2.2 Study Overview

Description of the geology, terrain and soils of the study area is based on existing information from previous studies, the scientific literature, and field studies undertaken of sites in PRL-15 and the onshore export pipeline corridor during November 2016. The field survey investigated 27 sites located in and around the proposed upstream components of the Project, including the wellpad areas, the central processing facility (CPF) and associated infrastructure, and the onshore export pipeline corridor. Several ground-truthing assessments were undertaken at these sites including:

- Localized geology assessment.
- Geomorphology and terrain assessment.
- Soil profile excavation and assessment of soil type and characteristics.
- Collection of soil samples from nominated sites for laboratory testing, including particle size, pH, salinity, organic carbon and matter, cation exchange capacity, Emerson aggregate test, total nitrogen and phosphorus, heavy metals, total petroleum hydrocarbons and potential acid sulfate soils.

7.2.3 Geology Baseline Characterization

The geology of the study area is shown in Figure 7.3. Most of PRL-15 and the eastern edge of the export pipeline corridor are dominated by two lithologies:

- Tmup1: mudstone, siltstone, minor sandstone, rare conglomerate and calcarenite and is generally carbonaceous and calcareous in places.
- TQe: lithic sandstone, siltstone, mudstone, minor conglomerate with regressive sequence from shallow marine to continental deposits and coal seams.

In the southwest section of PRL-15, including the proposed CPF area, and the western edge and coastal area of the export pipeline corridor, the dominant lithology is:

- Qa5: gravel, sand, silt, mud, carbonaceous mud, clay, minor peat, alluvial soils, alluvium and littoral deposits.

This lithology also occurs on the alluvial plains of the Purari River and the beach ridges and plains landforms toward the coast, which are further described in Section 7.2.4.

The predominant rock types observed in outcrops in the study area include interbedded mudstones, siltstones, sandstones, conglomerates and limestone (Plate 7.1). Carbonaceous rocks in the form of carbonaceous mudstones and coal occurred as detrital angular, cobble-sized particles in Oyomo Creek in the proposed CPF area.

There are varying levels of structural deformation in PRL-15, from relatively gently dipping strata to strongly faulted and folded materials. Landslides, debris flows, rockfalls (Plate 7.2) and gullying are common geohazards in the ridge and ravine landforms, triggered by large rainfall events. These geohazards can cause significant land movement due to the topography and steeply dipping strata, which have weak, clay-rich rock masses interbedded with strong rock masses.

The deeper stratigraphy of the study area around the gas field is described in Table 7.1, including the deep carbonate geology of the Kapau Limestone in which the target gas reservoir lies. Mudstones, marls and shales of the Orubadi Formation overlie the hydrocarbon resource (Pieters, 1980; GHD, 2015d).

GEOLOGY OF THE STUDY AREA

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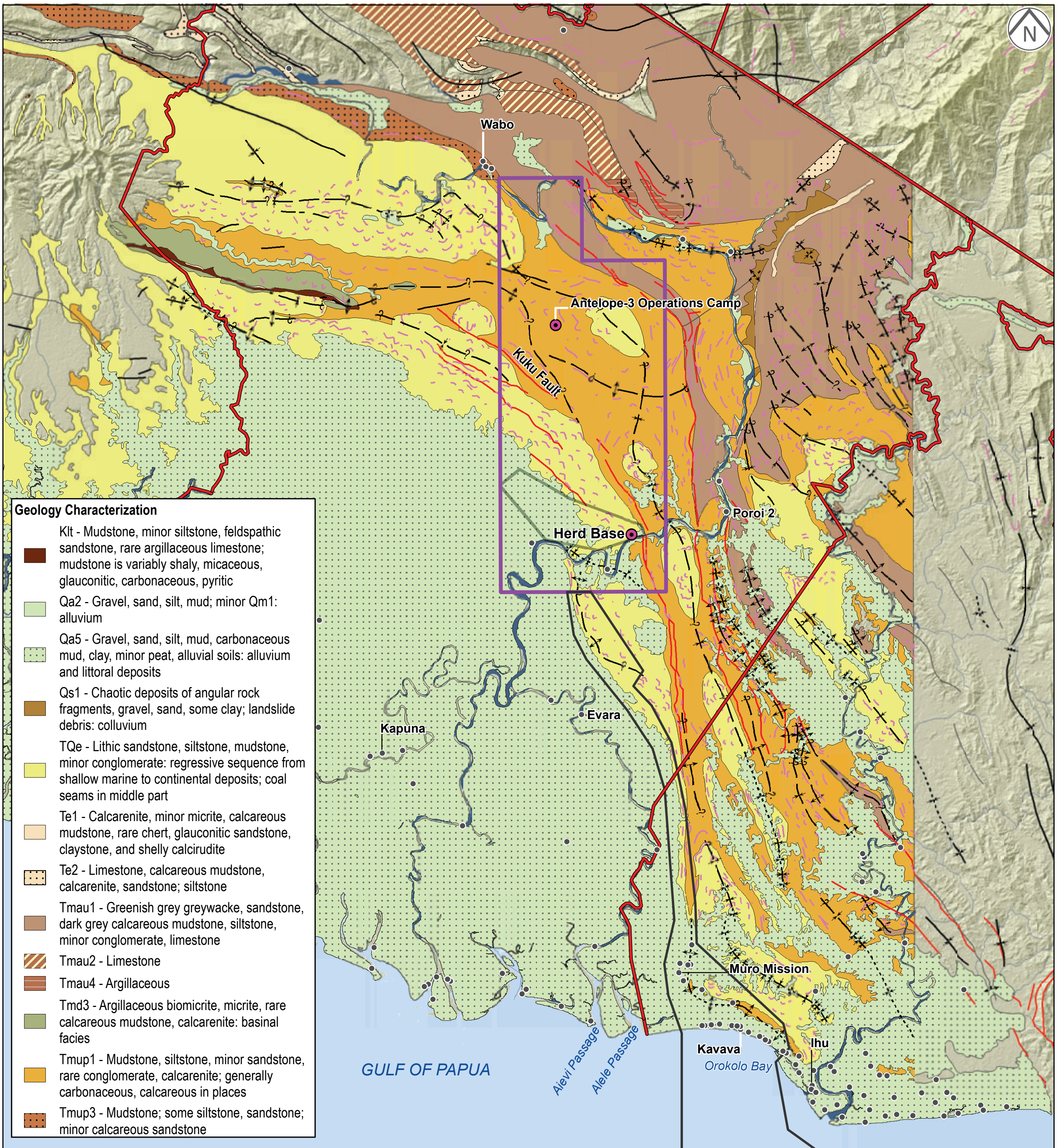
FIGURE 7.3



SCALE: 1:650,000 @ A4 — 0 5 10 15 20 25 km — **COORDINATE SYSTEM:** PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Local level government boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- CPF, logistics base and airstrip area

Geological Structures

- Anticline, accurate
- Anticline, approximate
- Anticline, concealed
- Lineament
- Major fault, lineament
- Overturned anticline, accurate
- Syncline, accurate
- Syncline, approximate
- Syncline, concealed
- Trend-line

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Plate 7.1 – ANT-6 Well Pad Showing Interbedded Siltstone, Sandstone and Fossiliferous Limestone Beds (see Inset)

Photo: SLR Consulting.

Plate 7.2 – Example of a Rockfall on Steep Slopes Near ANT-6

Photo: SLR Consulting.

Table 7.1 – Basic Stratigraphy in the Study Area

Geological Age	Name and Thickness	Description
Holocene	Quaternary Sediments <100 m	Variable depending on parent geology and location in the study area. Accumulations within river valleys and creek lines. Unconsolidated coarse sands and gravels in upper catchments with fine black to dark grey sands and silts in the Purari River basin.
Pliocene to Pleistocene	Era Beds <2,000 m	Sandstone, siltstone and mudstone with rare coal and conglomerate. Commonly carbonaceous. Blue to grey and brown when weathered.
Uppermost Miocene to Pliocene	Orubadi Beds <2,400 m	Mudstone, siltstone, sandstone, minor conglomerate and rare calcarenite and limestone breccia. Blues to grey and brown in more calcareous areas. Fine to medium bedded and occasionally massive.
Upper Oligocene to Lower Miocene	Kapau Limestone >1,000 m	Cream to light brown, mainly thin bedded but occasionally massive limestone. Fossiliferous in places, including fragments of corals, bivalves and gastropods. Reservoir rock, target of gas exploration.

Source: Compiled from Pieters (1980) and GHD (2015d). < = less than; > = more than.

7.2.4 Geomorphology and Terrain Baseline Characterization

7.2.4.1 Ridge and Ravine Landform

The topography of the study area is shown in Figure 7.4. The northern section of PRL-15 is in the foothills of the frontal part of the Papuan Fold and Thrust Belt (see Figure 7.1). The relief in this area is pronounced, with landforms formed by tectonic processes, i.e., ridge and ravines with significant cliffs. These landforms are predominantly determined by their lithologies and structural orientations. Mixed sedimentary rocks form homoclinal (Plate 7.3) or hogback/strike ridge and ravine landforms,[2] with a succession of ridges and valleys orientated north-northwest to south-southeast of the Kuku fault ridge (see Figure 7.3). The landforms are underlain by thickly bedded to massive sandstone and are scarred by numerous slumps, landslides and gullying.

The maximum elevation of the ridge and ravine landform in PRL-15 is about 410 m asl. The ridge and ravine landform continues south at a lower relief (10 to 50 m asl) along the eastern edge of the export pipeline corridor toward the coast.

Plate 7.3 – Homoclinal Ridges Near ANT-3 and ANT-5 Wellpads

Photo: SLR Consulting.

2 The distinction between the homoclinal and hogback/strike landforms is that the dip slopes of the homoclinal ridges generally range from 10° to 25° whereas the hogback/strike ridges have dip slopes generally exceeding 25°.

TOPOGRAPHY AND DRAINAGE OF THE STUDY AREA

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FIGURE 7.4

SCALE: 1:650,000 @ A4 | 0 5 10 15 20 25 km | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Hathor Gorge
- Local level government boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- CPF, logistics base and airstrip area

Elevation (m)

- Below sea level
- 0 to 9
- 10 to 24
- 25 to 49
- 50 to 99
- 100 to 149
- 150 to 199
- 200 to 249
- 250 to 299
- 300 to 399
- 400+

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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7.2.4.2 Composite Meander and Levee Alluvial Landform

The lower Purari River and its delta are formed of a central meander plain, back plains and swamp landforms (Plate 7.4). The meander plains include oxbow lakes, discontinuous levees, point bars, and scroll complexes. The back plains flood frequently and are permanently swampy where drainage is impeded by levees or meander plains. The drainage status varies greatly, depending on local conditions, from poorly to well drained. Relict alluvial plains, probably of Pleistocene age, occur locally between the Purari and Vailala rivers (Löffler, 1974).

The proposed CPF, logistics base and airstrip area and the western edge of the export pipeline corridor are located in the alluvial plain of the Purari River at the foot of the ridge and ravine landform.

Plate 7.4 – Meandering River and Back Plains Landform of the Purari River Delta

Photo: BMT WBM.

7.2.4.3 Recent Littoral Landform

In the southern portion of the export pipeline corridor adjacent to Orokolo Bay, the recent littoral landform consists of beach ridge complexes and beach plains (Plate 7.5). These beach terrain systems comprise recent sediments shaped as long parallel ridges and swales (Löffler, 1974). Villages are present on the back beach area; and tidal marshes, estuaries and lagoons are found in this area. During storm surges, waves sometimes inundate these populated, low-lying areas.

Immediately to the west of this area, the landform is dominated by the main eastern river mouth distributary of the Purari River, which discharges into the Gulf of Papua. The drainage is tidal, with a maze of channels that mainly comprise swamps, marshes and estuaries. Mud banks along the channels support mangrove vegetation (Section 7.7.5.2).

Plate 7.5 – Recent Littoral Landform at Orokolo Bay

Photo: Iain Woxvold.

7.2.5 Soils Baseline Characterization

7.2.5.1 Soil Complexes and Units

Soils surveys found the soil units in the study area to be broadly consistent with soil mapping provided in the PNG Resource Information System (PNGRIS). Entisol and Inceptisol soil orders dominated the study area. These are poorly formed soils with no to limited soil pedological development. In the ridge and ravine areas in PRL-15 and in the eastern edge of the export pipeline corridor, these soils are thought to result from ongoing erosion that has prevented soil from developing over the bedrock parent material. On the alluvial plains in the southwestern parts of PRL-15 and the western edge of the export pipeline corridor and in beach landforms near the coast, soils are poorly formed due to their young age in the depositional profiles.

The inundated tidal flats, swamps and saturated alluvial soils are dominated by Histosol soils, which typically form under saturated conditions and have high organic matter in the upper layers.

Soils in the study area are categorized into four soil complexes[3] comprised of denudational soils (i.e., soils formed from the weathering of the earth's surface) or aggradational soils (i.e., soils formed from the deposition of material). The occurrences of the four soil complexes in the study area are shown in Figure 7.5 and described as follows:

- Soil Complex 1: This denudational soil complex occurs on the ridge and ravine terrain, including the hillslopes, crests, steep valleys and drainage lines located in PRL-15, and on hilly and ridge terrain along most of the eastern side of the export pipeline corridor south of PRL-15. The dominant soils are Entisols, including Lithic Udorthents (fine to coarse textured soils), Dystrudepts (clay soils) and Dystrochrepts (clay loam to clay soils) in the hillslopes and ridges and Sulfaquents (gleyed clays) in the valleys and drainage lines. The soils mapped as Soil Complex 1 in the ridge and ravine terrain are moderate to well drained, have moderate cation exchange capacity and low levels of nutrients and exhibit stable aggregates. These soils are poorly formed with limited to no pedological profiles. High levels of water-induced erosion are evident due to the frequency and intensity of rainfall combined with the sloping landform of the ridge and ravine terrain.
- Soil Complex 2: This aggradational soil complex occurs on the alluvial plains and meander plains in the southwestern corner of PRL-15 and on the flatter terrain below the ridgeline along the western edge of the export pipeline corridor south of PRL-15. The dominant soils are clay loams and clay Inceptisols (alluvial Dystrudepts) and Sulfaquents These soils are moderate to poorly drained, have low to moderate cation exchange capacity depending on the texture in each layer, have low nutrient levels, and exhibit stable aggregates. While these soils are considered stable, there are potential acid issues associated with the disturbance or drainage of the Sulfaquents, with potential acid sulfate soils (PASS)[4] observed on the alluvial plains along the export pipeline approximately 7 km inland from the coast. There are also limitations due to periodic saturation and groundwater within 0.5 m to 1.0 m of the surface where the sandy loams and sandy clay loams overlie the higher clay content subsoils. The field investigations noted many subsistence gardens and tree crops in this soil complex; however, it was observed these required considerable intervention and shaping by villagers to provide drainage and compost mounding to assist plant growth.

3 Soil complexes are mapping units that consider terrain feature, land system and soil unit.
4 Potential acid sulfate soils are soils containing iron sulfides (commonly pyrite) that have the potential to produce sulfuric acid if they are drained or disturbed.

SOIL COMPLEX MAP OF THE STUDY AREA

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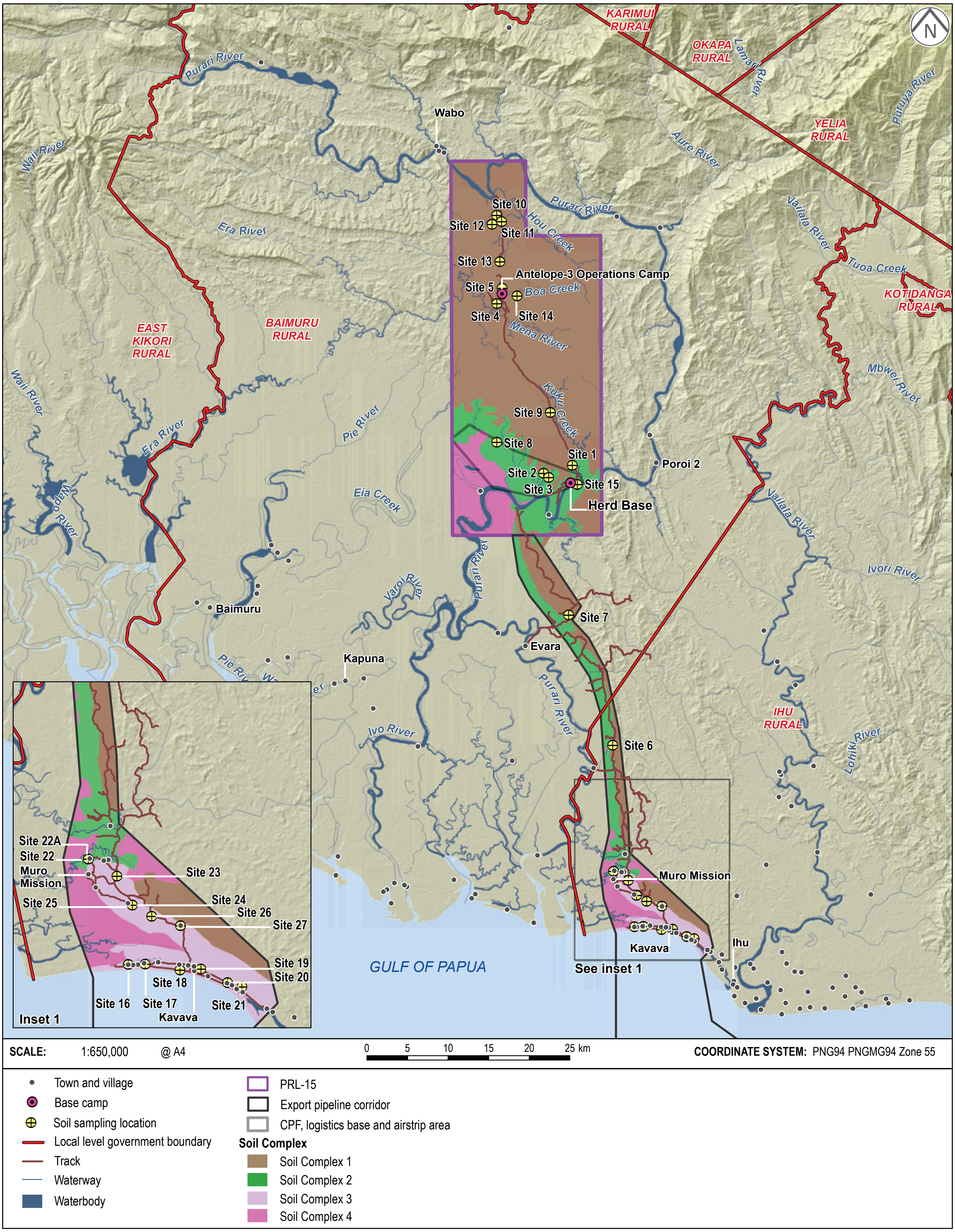
FIGURE 7.5



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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- Soil Complex 3: This aggradational soil complex occurs on the littoral plains, including the beach ridges and beach plains along the coast in the onshore export pipeline corridor. The dominant soils are Psammaquents consisting of weak structured to structureless deep sands and sandy clay loams with high watertables. Some of these soils may also be potentially acid-producing if drained or disturbed. The sandy soils of Soil Complex 3 in the beach ridges and beach plains are typically well drained in the upper layers; however, subsoils are frequently waterlogged due to the low elevation. The soils generally have low cation exchange capacity and very low nutrient levels. These soils are stable if able to form aggregates; however, most soils were found to be sandy with no structure. They have inherent limitations for traditional agriculture, including lack of water-holding capacity within the sandy profiles (although shallow watertables can cause periodic saturation of these layers), salt water ingress, lack of structure, clay and organic matter causing low cation exchange capacity, and potentially high acid levels due to PASS.
- Soil Complex 4: This aggradational soil complex occurs on the inundated plains and swamps including the tidal flats along the coast and Purari River delta in small sections of the onshore export pipeline corridor and on the swampy lowlands in the southwestern corner of PRL-15. The inundated soils of Soil Complex 4 were not sampled due to access constraints, with these soils being largely underwater, and the safety risks due to crocodiles. Given the saturated condition of these soils, they are considered to be Histosols and Hydraquents consisting of inundated organic soils and undifferentiated soft alluvial swamp soils. Histosols are commonly called bogs, moors, peats or mucks. Histosols form in decomposed plant remains that accumulate in water, forest litter, or moss faster than they decay. There is a risk these soils are PASS given their low position in the landscape and their near continuous saturation.

7.2.5.2 Land Capability

The land capability of the study area has been categorized according to the USDA Land Capability Classification (SCS USDA, 1961), an eight-tiered land capability classification system ranging from Class I (soils with few limitations that restrict their use) to Class VIII (i.e., soils with limitations that preclude their use for (commercial) plant production). Soils in the study area are classified as Class VIII in the ridge and ravine terrain and in the frequently flooded alluvial plains and beach landforms. This land capability is essentially unsuitable for broad-scale agriculture or grazing. Only areas within Soil Complex 2, which are the better-drained areas of the alluvial plains, exhibited the possibility of some grazing and tree crops with areas of Class VI land capability evident. All activities associated with subsistence gardening endeavors were observed to rely on high levels of human intervention and inputs, such as creating artificial drainage and compost mounding to provide a suitable growing medium.

Notwithstanding that soil complexes in the study area are categorized as limited in their capability for conventional ‘western’ agriculture, local communities have managed to successfully grow tree crops of sago, coconut, papaya, betel nut and mustard and other food crops, such as potatoes, melons, pineapple, passion fruit and bananas, for many generations.

7.2.5.3 Potential Acid Sulfate Soils

Acid sulfate soils are commonly associated with coastal swamp, mudflat and mangrove environments. These soils contain naturally occurring iron sulfides that are stable in reduced oxygen conditions below the watertable; however, if disturbed and exposed to the atmosphere, oxidation of the sulfides results in the formation of leachates containing sulfuric acid. These leachates, if not managed, may have a localized, adverse impact on vegetation, soil, surface water and groundwater. In the reduced oxygen condition, the soils are regarded as PASS.

Laboratory tests for PASS were performed on 22 samples from nine targeted sites. The results indicate that the study area contains several soil units that may be prone to releasing acid leachate if disturbed or drained and exposed to the atmosphere. With the exception of one site in the southern extent of PRL-15 (site 9, see Figure 7.5), all sites that indicated PASS were located on the alluvial floodplains, beach ridges and beach plains in the lower Purari River delta (sites 18, 19, 22, 22A, 23 and 27, see Figure 7.5), which experience frequent inundation. The site with PASS in PRL-15 (site 9) was located along a saturated drainage line associated with Kuku Creek. The Psammaquents and Sulfaquents of Soil Complexes 2 and 3 typically indicated PASS, while the Sulfaquent of Soil Complex 1 in PRL-15 indicated PASS in the subsoil layers.

While no samples were taken in Soil Complex 4, the presence of PASS in these soils is considered likely based on known physical features of the landform, i.e., saturated soils in coastal margins with a geomorphology developed from the Holocene epoch when sea water levels were higher, bringing sulfates into the present day coastal soils. The majority of coastal soils in the study area are therefore considered likely to be PASS.

7.2.5.4 Contaminants

Laboratory analyses were made of metal concentrations in soil samples collected during the November 2016 survey, and comparisons were made with human health-based screening levels (NEPC, 2013) and US EPA ecological soil screening levels (Eco-SSLs). Metal concentrations were well below the NEPC (2013) health-based screening levels; however, there was wide variation when the analyses results were compared to the US EPA Eco-SSLs with some exceedances for cobalt, copper, lead, manganese, nickel, selenium, tin, vanadium and zinc. Higher concentrations of chromium (106 to 191 mg/kg), selenium (9 to 16 mg/kg), vanadium (321 to 639 mg/kg) and zinc (87 to 178 mg/kg) were measured in samples from sites 23 and 27 inland from the coast in the southern part of the study area (see Figure 7.5) compared to other sites. Whether the source of these metals is related to anthropogenic activities or to natural conditions is not known. These metal concentrations are higher than the average concentration in world soils provided in Alloway (2013) of 42 mg/kg for chromium, 0.7 mg/kg for selenium, 60 mg/kg for vanadium and 62 mg/kg for zinc.

None of the sampling sites showed evidence of hydrocarbon contamination of soil. Total petroleum hydrocarbon (TPH) and benzene, toluene, ethylbenzene and xylene (BTEX) levels in all samples tested were below the limits of reporting and ecological screening levels.

7.3 Hydrology and Meteorology

7.3.1 Regional Context

The hydrology and meteorology study area spans three catchments:

- Purari River.
- Era River.
- Pie River.

These catchments, including the major subcatchments of the Purari River, are shown in Figure 7.6. The Purari River is Papua New Guinea’s third largest river (by catchment size) with a catchment area of 33,730 km^2. The catchment covers a large portion of the central and southern part of mainland Papua New Guinea, with its headwaters including the Erave, Kaugel, Wahgi, Tua, Pio and Aure rivers. The river basin covers a wide geographical range extending from Papua New Guinea’s highest mountain, Mount Wilhelm (4,510 m asl), to the lowlands of the Gulf of Papua. These areas include high montane and lowland forests, densely populated highland valleys, and largely unpopulated low montane and lowland forests through to swamps and coastal mangroves.

The study area is in a high-rainfall, humid tropical environment; however, there is a range of climatic conditions within the basin, including Mount Wilhelm having occasional snow cover (Petr, 1983a). In upland areas, cloud and fog are an important source of moisture for most of the year, with areas subject to the most cloud receiving the most rain.

The Project will occur in the lower part of the Purari River catchment, downstream of Hathor Gorge, which is located approximately 60 km upstream of PRL-15 (Figure 7.6); within PRL-15 and along the onshore export pipeline corridor to the coast at Orokolo Bay. At a catchment-wide scale, the Hathor Gorge rapids represent a significant hydraulic and physical barrier (Haines, 1979). The major tributary Aure River joins the Purari River downstream of Wabo near the village of Subu, approximately 8 km east of PRL-15. The two principal waterways in PRL-15 that form part of the Purari River catchment are Hou and Kuku creeks (see Figure 7.4). Hou Creek drains the northeast part of PRL-15, flows east of the Mena plateau and discharges into the Purari River 10 km downstream of Wabo. Kuku Creek drains the southeastern part of PRL-15 (north of the Purari River) and flows into the Purari River at Herd Base (see Figure 7.4).

Downstream of PRL-15 within the delta, the Purari River splits into the three main distributary channels: the Purari River (eastern channel) and the Urika-Ivo River (central channel), both of which flow directly into the Gulf of Papua; and the Wame-Varoi River (western channel), which flows into the gulf via Port Romilly (see Figure 7.4). These river channels are potential transport routes for the Project.

The waterways of the Era River catchment drain most of the central and western areas of PRL-15, with the upper tributaries Mena River and Boa Creek draining the area of the Elk-Antelope gas field (see Figure 7.6). The Era River flows southwest from PRL-15, discharging into the Gulf of Papua west of Port Romilly.

The only Pie River subcatchment in PRL-15 is Eia Creek (see Figure 7.6 and Figure 7.4). This drains from the central western side of PRL-15, west of a small ridge that separates the subcatchment from the Mena River subcatchment to the northeast. While discharge volumes from Eia Creek are not available, Petr (1983b) identifies the creek as having typically low flow resulting in negligible dilution impact on the Pie River. The Pie River flows into the Gulf of Papua at Port Romilly.

7.3.2 Baseline Characterization

7.3.2.1 Study Overview

Description of the hydrology and meteorology of the study area is based on existing information from previous studies, scientific literature, field studies undertaken in 2016 and 2017 and numeric modeling specifically undertaken for the study area. Modeling included:

- Hydrological model and rainfall frequency analysis for parts of the Purari, Era and Pie river catchments to describe likely flows associated with different rainfall events.
- Hydraulic model (TUFLOW) for subcatchments associated with potential infrastructure locations to ascertain likely flooding extents.
- Catchment model for the Purari River catchment to estimate sediment loads from catchment runoff.

Detailed descriptions of the modeling and findings are presented in Part 2 of Volume 2.

The description of existing meteorology in the study area is mainly based on measured data presented in Petr (1983b) and Evesson (1983). These reports provide data from studies conducted for the Wabo Hydroelectric Scheme Project and from long-term climate records from government regional weather stations, including information presented in McAlpine et al. (1983). While more recent meteorological data has been collected in the study area between 2013 and 2015 from monitoring stations at Wabo, Hou Creek and Herd Base, the datasets for these sites are short and incomplete. As such, they are considered unsuitable for characterizing and describing long-term meteorological patterns in the study area. Description of the more recent data collected at Wabo, Hou Creek and Herd Base is provided in the Upstream Air Quality Baseline Report (Part 19 of Volume 2). Meteorological modeling undertaken as part of the air quality baseline study, documented in that report, has also been used to describe wind patterns in the general area of PRL-15.

7.3.2.2 Climate

Wind Patterns

Two surface pressure systems influence wind and overall climate processes in southern Papua New Guinea (McAlpine et al., 1983):

- Southeast trade winds, which prevail from about May to October.
- Northwest monsoon, which prevails from about December to March.

These wind streams are driven by the positioning of the subtropical high-pressure belt and the Pacific Inter Tropical Convergence Zone (ITCZ) (Evesson, 1983). Between April and October, the ITCZ moves over Papua New Guinea while the subtropical high-pressure belt moves over central Australia. This causes southeast trade winds to develop between the ITCZ and the subtropical high-pressure belt. During the southeast trade wind season, the windward slopes that face southeast and the southern face of elevated ranges experience heavier rainfall compared to leeward slopes.

A transitional period in November is characterized by the development of an equatorial trough (McAlpine et al., 1983). This leads to light variable surface winds, i.e., doldrums. Trade winds continue to blow during this time but have a weakened effect.

Following the November transition, from December to March, the northwest monsoon forms following the southward movement of the ITCZ over Australia. This movement of the ITCZ causes the monsoon line to move southwards over Papua New Guinea and northern Australia (McAlpine et al., 1983). This brings winds from the northwest.

Similar to November, April represents a transition marked by doldrums, following the northward movement of the ITCZ (McAlpine et al., 1983). The length of transition in April is variable, with the start of the southeast trade wind season varying between the start and end of April (Evesson, 1983).

The Purari River catchment is topographically diverse, ranging from sea level to over 4,000 m asl in the Bismarck Range. The majority of the highland valleys in the middle to upper reaches of the catchment occur around 1,000 m asl (McAlpine et al., 1983). As shown schematically in Figure 7.7, the higher topography of the catchment forms barriers to wind movement, inhibiting

CATCHMENT OVERVIEW

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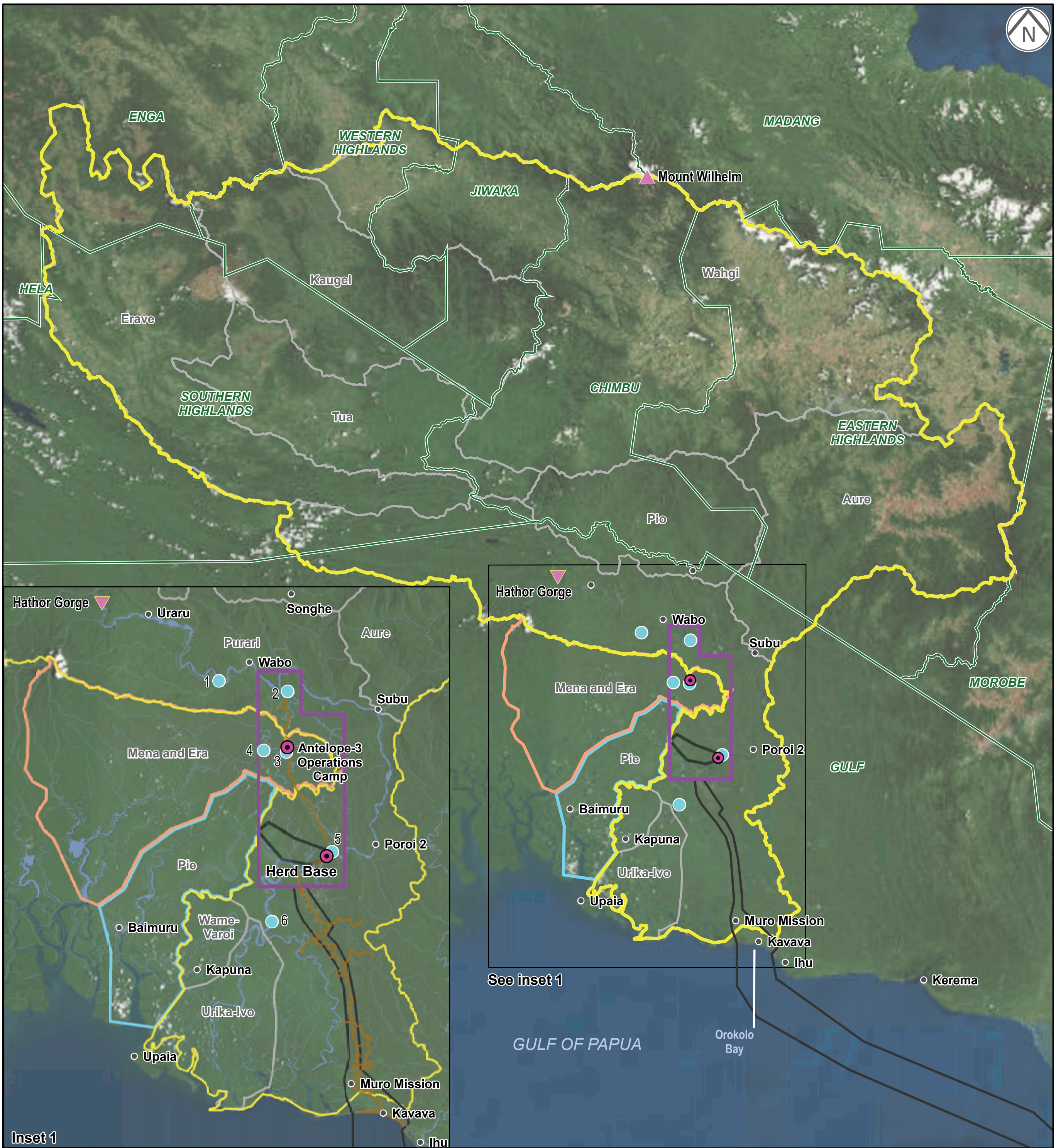
FIGURE 7.6



SCALE: 1:1,750,000 @ A4 | 0 10 20 30 40 50 km | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

Town and village
Base camp
Hathor Gorge
Mount Wilhelm
Reporting location
Province boundary
Tracks
Waterway
Waterbody
PRL-15
Export pipeline corridor
CPF, logistics base and airstrip area

Catchment Boundary
Purari River catchment
Mena and Era catchment
Pie River catchment
Catchment boundary

winds from reaching much of the upper catchment during both southeast trade wind and northwest monsoon seasons.

Annual wind roses for the south of PRL-15 in the area of the proposed CPF and a mid-point along the onshore export pipeline corridor, produced from meteorological modeling of conditions during 2014 and 2015, are presented in Section 10.2.3. These show that the area of the proposed CPF generally experiences low to moderate winds of less than 5 m/s, predominantly from the northeast. The low wind speeds and lack of significant winds from the southeast reflect the topographical barriers to wind movements in the area. Wind patterns and other variables such as temperature and rainfall vary along the export pipeline corridor due to changes in topography and elevation. Modeled wind data shows that this area experiences more varied wind directions than the proposed CPF site, with predominant winds from the northern and southeastern quadrants; and the winds are slightly stronger.

Temperature

Evesson (1983) notes that yearly temperature ranges recorded at individual weather stations in the Purari River catchment are mostly insignificant when compared to diurnal ranges. Temperatures at different locations vary depending on elevation, with minima from 11.6ºC to 22.8ºC and maxima from 22.5ºC to 30ºC. The catchment area downstream of Hathor Gorge generally occurs at an elevation less than 150 m asl; although with some areas up to about 400 m asl, and as such, temperatures from PRL-15 to the coast are expected to be toward the higher end of these ranges. Sea breeze effects near the coast may cause maximum temperatures to be lower in this area.

There is no daily temperature data for PRL-15 or downstream areas; however, McAlpine et al. (1983) has published data for stations in the upper catchment. This shows the following patterns for the catchment, which are considered applicable to PRL-15 and the downstream areas:

- Mean annual temperatures throughout the year do not fluctuate dramatically, with 1 to 2.5ºC of variation between months.
- June through to September are the coolest months of the year.
- There is more variability in minimum temperatures throughout the year than in maximum temperatures.

Rainfall

The topographical diversity of the Purari River catchment is a key driver of spatial variability in rainfall, with most rainfall being associated with convergence (i.e., zone where two prevailing air flows meet and interact) caused by topographical features (Evesson, 1983). In the upper areas of the catchment, the annual average rainfall is 2,000 to 3,000 mm, with the highest rainfall received in the northwest monsoon season. This is shown by rainfall data provided in climatic tables (McAlpine et al., 1983) that are presented in Figure 7.8.

In contrast, lower in the Purari River catchment in PRL-15, rainfall is driven primarily by a low level convergence. This brings high levels of rain throughout the year, with an average annual rainfall at Wabo of 8,900 mm (Evesson, 1983). Significantly higher rainfall occurs during the southeast trade wind season from May to October than during the northwest monsoon from December to March, representing a reverse of the rainfall patterns experienced in upper parts of the catchment. Toward the coast, rainfall is lower and more evenly spread throughout the year (i.e., averaging around 300 mm/month at Kerema) (see Figure 7.8).

TOPOGRAPHICAL BARRIERS

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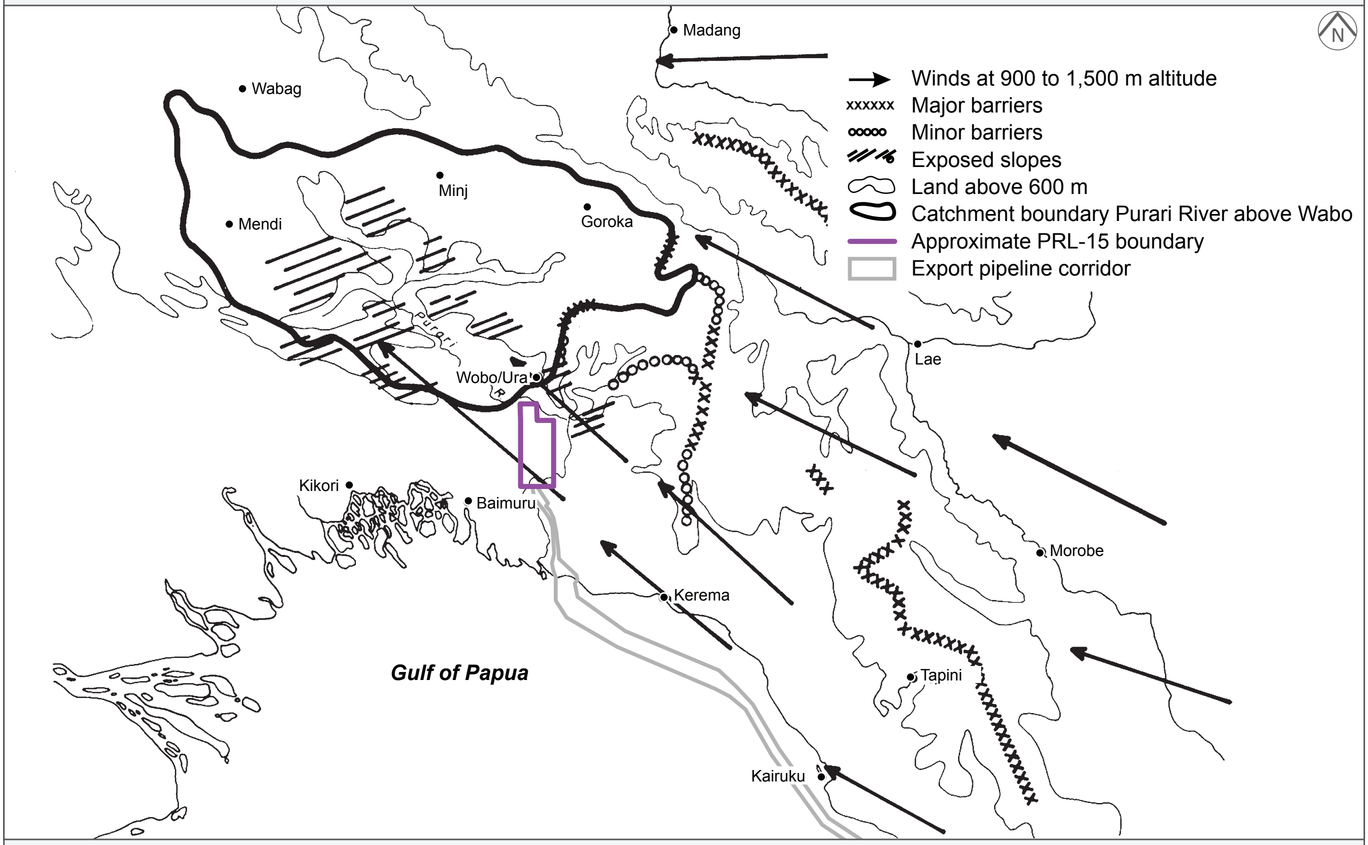
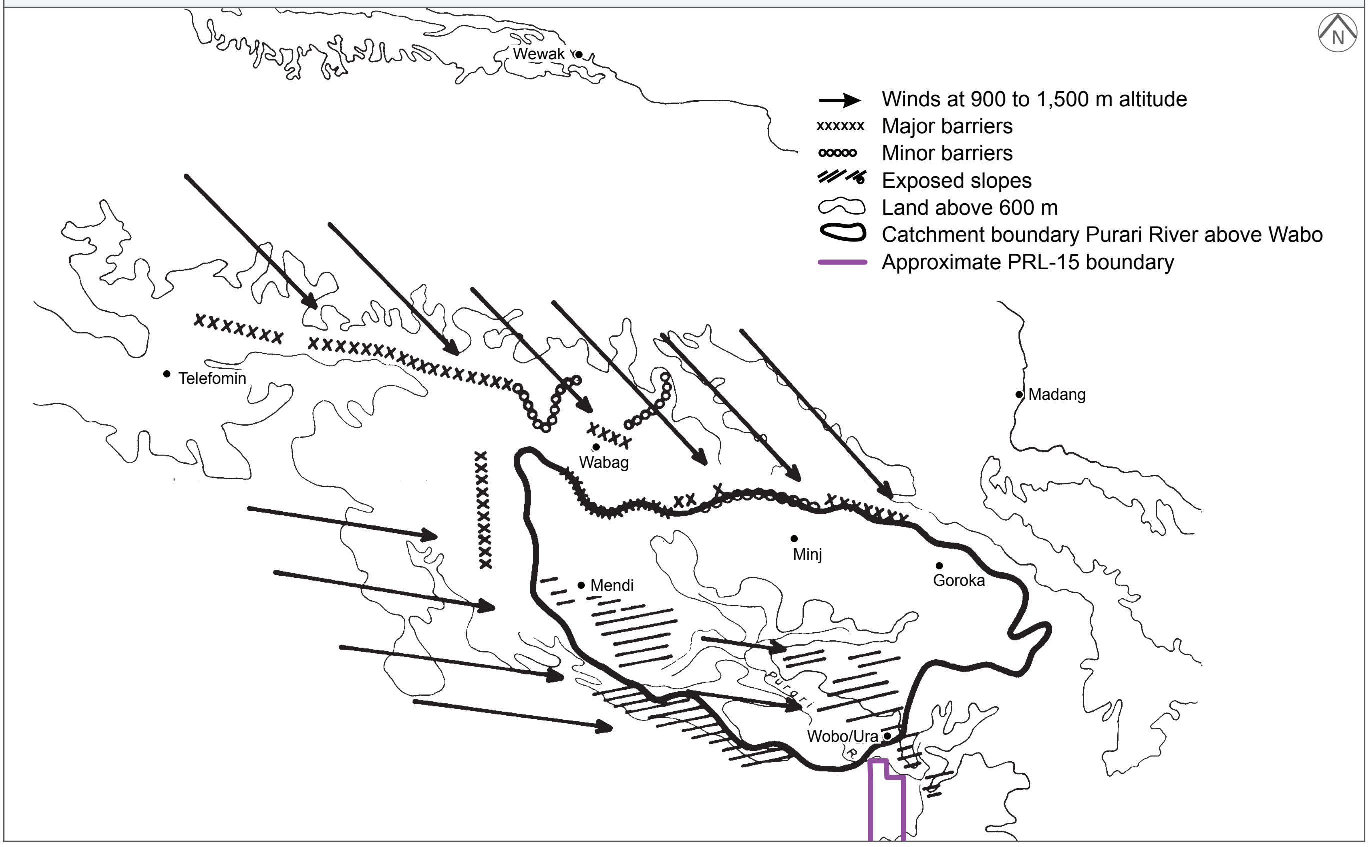
FIGURE 7.7

Southeast Trade Wind Season



Northwest Monsoon Season



Source: Evesson, 1983.

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RAINFALL PATTERNS FOR THE PURARI RIVER CATCHMENT AND ADJACENT AREAS

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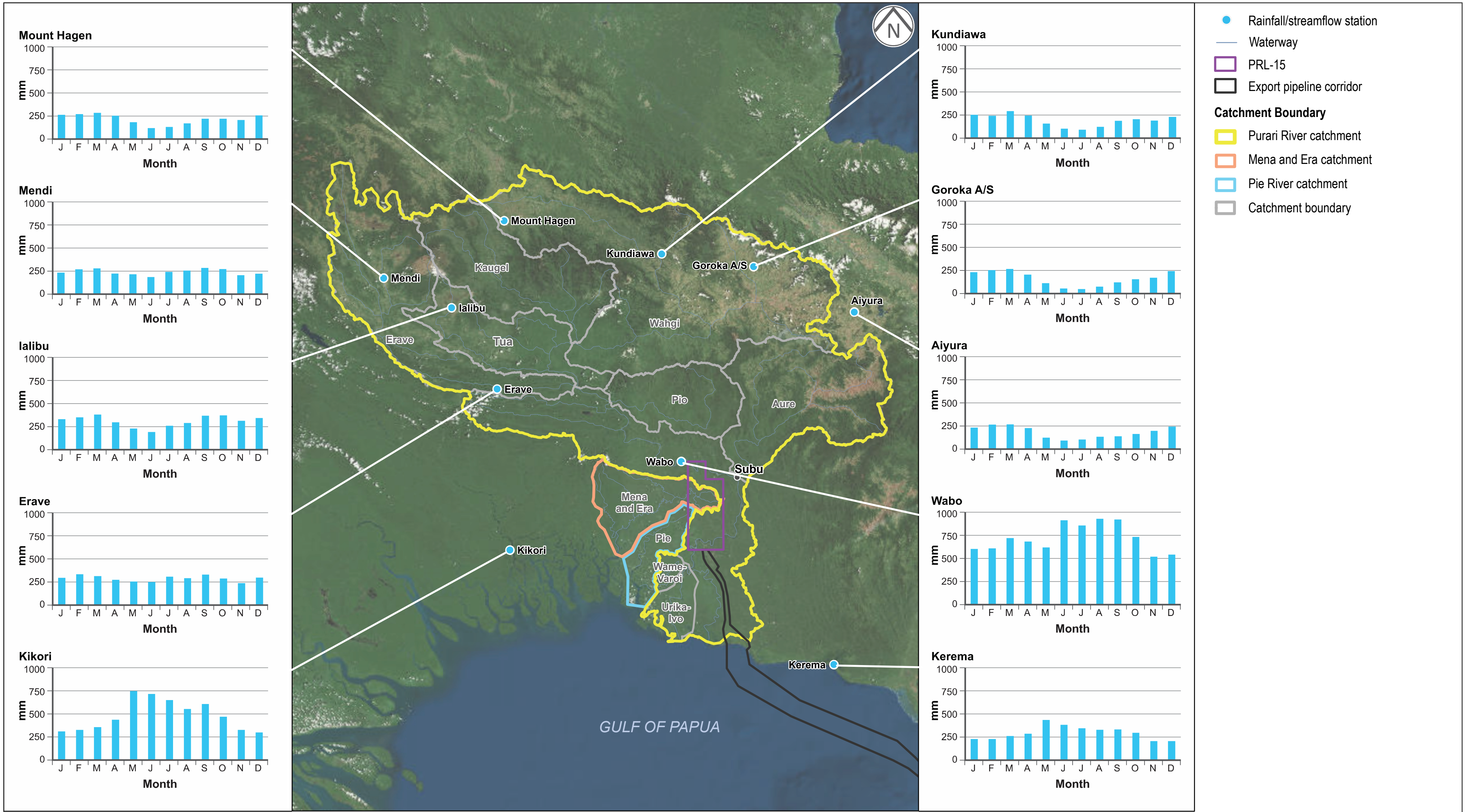
FIGURE 7.8



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The low level convergence that draws rain to the PRL-15 area also occurs over the Pie and Era river catchments. As a result, a similar temporal distribution in rainfall is expected in these catchments. By contrast, rainfall patterns of the Aure River catchment reported by Pickup and Chewings (1983) reflect those for the rest of the Purari River catchment, i.e., with highest rainfall in the northwest monsoon season. This is expected to be the result of topographical barriers preventing southeast trade winds carrying rain from reaching much of the catchment.

Cyclones do not greatly affect rainfall patterns, as the study area is located north of the main cyclone belt (Evesson, 1983).

Evaporation

Evesson (1983) identifies a likely annual evaporation rate at Wabo, which is at an elevation of approximately 40 m asl, of 1,200 mm. This is derived from an extrapolation by McAlpine et al. (1975) of annual evaporation rates at Kuku, which is near Mount Hagen at an elevation of approximately 1,630 m asl in the upper Purari River catchment, where there is five years of United States Class A evaporation pan measurements.[5] However, Evesson (1983) notes that the US Class A pan measurements provide an overestimate of actual evaporation from a water surface. Alternative estimates based on a comparison of net rainfall and flow in the Purari River with expected ground percolation rates indicate that evaporation rates at Wabo are likely to be closer to 1,000 mm/yr.

The available catchment data shows a weak correlation between rainfall patterns and evaporation, with more evaporation tending to occur in the months when rainfall levels are higher. Lower evaporation levels are also experienced at sites lower in the catchment (i.e., Wabo and Kerema) compared to the upper part of the catchment (i.e., Mount Hagen and Goroka).

7.3.2.3 Hydrology

Purari River Bathymetry and Morphology

The Purari River from the mouth to upstream of PRL-15 is a wide, meandering channel cut into sedimentary coastal plains. As a result, the river features significant scour on the outside of bends, forming a deep channel, with shallow sand and mud banks deposited on inside bends. A bathymetric survey in November 2009 showed a semi-continuous channel deeper than 7 m extending along the Purari River from the river mouth (eastern channel) to Herd Base as a result of this scour.

The Purari River morphology is highly variable. Upstream between Herd Base and the Aure River confluence, the river is more confined with less meandering. This has produced a more consistent area of deep channel, with only small areas of shallow banks and bars. Upstream of the Aure River, the river begins to meander again.

Streamflows

Pickup and Chewings (1983) have previously undertaken some hydrologic modeling for the study area, based on instantaneous stream flow data produced for the Wabo Hydropower Project (SMEC-NK, 1977). The mean daily discharge from the Purari River at Wabo from 1961 to 1978 was estimated to be approximately 2,360 m^3/s (203,900 ML/day), with an annual maximum of between 6,290 m^3/s and 10,405 m^3/s and an average minimum of 1,920 m^3/s. The mean daily discharge from the Aure River was estimated to be 307 m^3/s (26,525 ML/day).

River level measurements of the Purari River at Hou Creek and Herd Base between 2013 and 2016 show rapid changes in water levels in the order of meters associated with changing flow

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[5] Standardized evaporation measurements based on a cylinder with a diameter of 120.7 cm and with a depth of 25 cm.

events. These fluctuations occur throughout the year and do not follow a particular seasonal pattern. River level changes measured at Hou Creek appear to be reflected at Herd Base without significant delay, although occasional spikes at Hou Creek are not always reflected at Herd Base.

While Pickup and Chewings (1983) previously described the Purari River hydrology based on hydrologic modeling, comparatively little catchment-specific information is available on the hydrology of the Era and Pie river catchments or the Purari River subcatchments in PRL-15. Catchment modeling, using a deterministic rainfall-runoff modeling approach, was therefore undertaken to provide a comparative assessment of existing conditions of these various catchments and to provide a basis for assessing potential impacts of runoff and sediment loads associated with proposed Project developments. The Unified River Basin Stimulator (URBS) hydrologic model was used to estimate stream flow parameters, including volume, variation, baseflow and duration, for the following six locations in the study area (shown on Figure 7.6):

- Location 1 – representative of Purari River flows upstream of PRL-15.
- Location 2 – representative of Hou Creek flows near its confluence with the Purari River.
- Location 3 – representative of Boa Creek flows near its confluence with the Mena River.
- Location 4 – representative of Mena River flows before its confluence with the Era River.
- Location 5 – representative of Kuku Creek near its confluence with the Purari River.
- Location 6 – representative of Purari River flows downstream of PRL-15.

Figure 7.9 shows modeled average streamflows at these locations. Flows demonstrate obvious seasonality corresponding to rainfall variations. The highest streamflows across the simulated duration (i.e., March 2000 to December 2015) occur during May, June and July at all locations. This period falls within the southeasterly trade wind season when the greatest amount of rainfall is experienced downstream of Wabo. November and December have the lowest streamflows, which is attributed to drier conditions downstream of Wabo during this period. In contrast to the high seasonal variability, there is relatively low inter-annual (i.e., between years) variability in flow regimes, including flooding, and rainfall.

Table 7.2 summarizes the modeled streamflow results for mean daily and mean annual flows. These flows differ from flows described by Pickup and Chewings (1983) due to different data availability and modeling approaches. They do not indicate absolute flow values (i.e., actual instantaneous flows rates) but allow for identification of the relative flow contributions of selected subcatchments to the flow of the Purari River (i.e., Hou and Kuku creeks and Aure River), and for comparison of flows between subcatchments of the Purari and Era rivers (i.e., Hou and Kuku creeks compared to Mena River and Boa Creek).

Table 7.2 – Modeled Existing Streamflow at the Selected Report Locations (Subcatchments)

Location		Modeled Catchment Area (km^2)	Mean Daily Flow (ML/day)	Mean Annual Flow (ML/yr)
1	Purari River upstream of PRL-15	30,700	17,500	6,325,430
2	Hou Creek	136	102	36,791
3	Boa Creek	53	40	14,389
4	Mena River	177	133	48,076
5	Kuku Creek	89	58	20,929
6	Purari River downstream of PRL-15 (including the Aure River subcatchment)	32,920	22,400	8,106,615

Note: 1 ML is equivalent to 1,000,000 L and 1,000 m^3.

DOWNSTREAM FLOW VOLUMES AT REPORTING LOCATIONS

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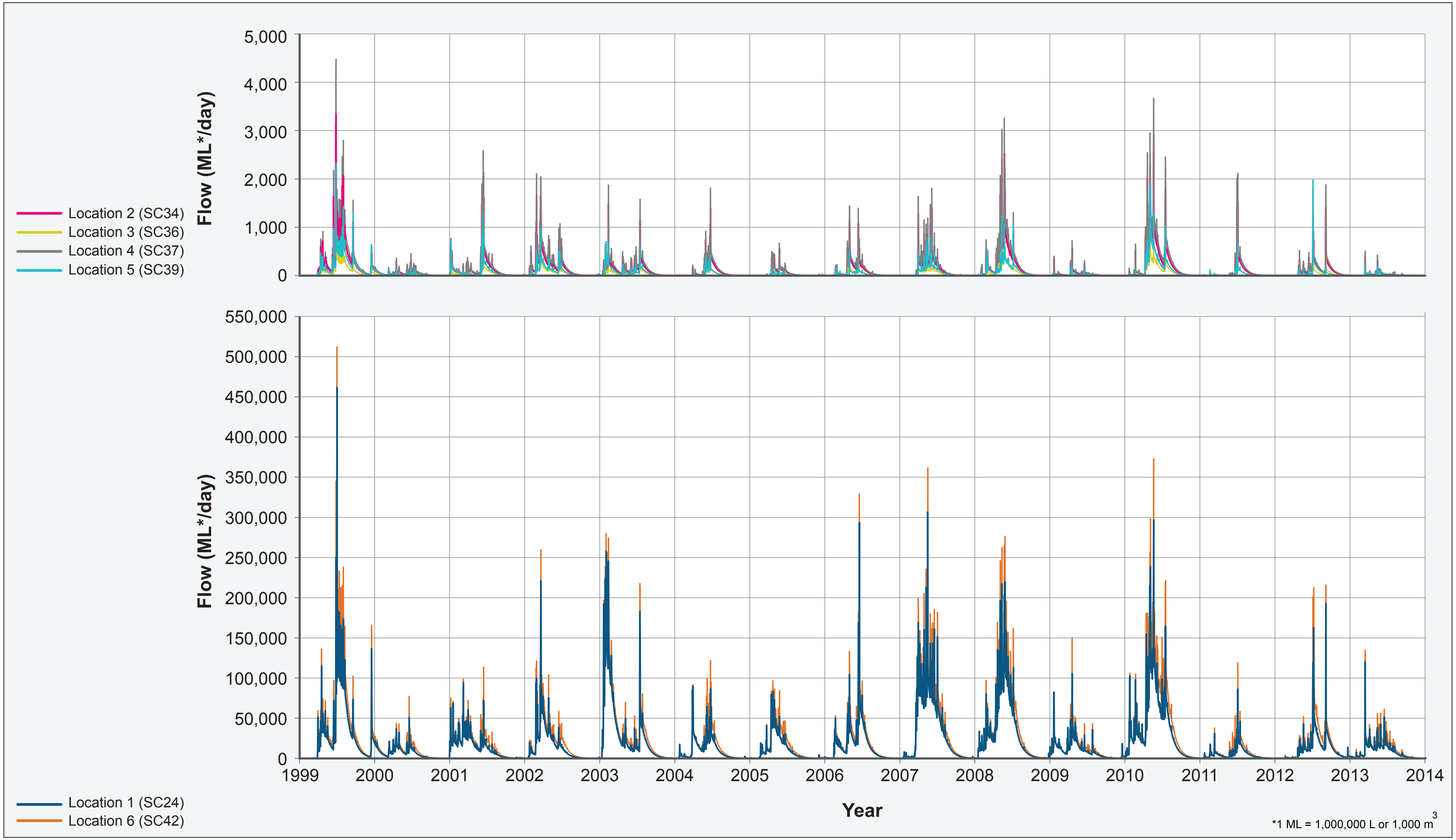
FIGURE 7.9



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The Hou Creek and Kuku Creek subcatchments of the Purari River in PRL-15 (i.e., modeling locations 2 and 5) represent a negligible amount of the total flow in the Purari River, contributing only 3.3% of flow downstream of PRL-15. The increase of 4,900 ML/day in mean daily flow between locations upstream and downstream of PRL-15 is mostly due to inflows from the Aure River.

Flow duration curves, presented in Part 2 in Volume 2 show that there is a large difference between ninetieth and ninety fifth percentile flows at all locations, suggesting the entire system is highly responsive to runoff, particularly as it becomes saturated during prolonged rainfall events.

Flooding

Pickup and Chewings (1983) present a flood frequency curve for the Purari and the Aure rivers, from which the following observations regarding flow events are made:

- Flood variability for both rivers across years is low, due in part to the regularity and length of the wet season, which ensures saturation remains high throughout the year and across years.
- While floods can occur throughout the year in both rivers, flood events in the Purari River at Wabo are generally linked to southeasterly weather patterns that occur from June to September. By contrast, flooding in the Aure River appears to be dominated by northwesterly patterns in February to March.
- Low flow events can occur at any time of the year but are more directly correlated to seasons than to flooding. For both rivers, the lowest flow events in the upper Purari River catchment and in the Aure River catchment tend to occur during the southeasterly season. This is also the season when floods occur on the Purari River downstream of Hathor Gorge. The difference is attributable to the reverse seasonality experienced in the lower part of the catchment compared to the upper catchment (Section 7.3.2.2).

No information is available regarding flooding and low flow events in the Pie and Era river catchments, but these are expected to strongly correlate to the Purari River downstream of Hathor Gorge.

To further understand flood behavior in the study area, TUFLOW hydraulic modeling of 20 subcatchments was undertaken for 10-, 50- and 100-year average recurrence interval (ARI) events (Part 2 of Volume 2). The modeling identified two types of channels/floodplains in the study area:

- Well-defined channels/floodplains with a single main channel within the flood extent, mainly found in smaller tributaries of the upper Era and Purari River catchments in PRL-15. The Purari River from Herd Base to the PRL-15 oxbow wetlands also has these characteristics.
- Poorly defined channels/floodplains with multiple intermingling channels across a wide floodplain, mainly found in the tributaries flowing to the Purari River delta and the PRL-15 oxbow wetlands.

Modeling outputs are provided in Part 2 of Volume 2. For subcatchments with well-defined channels, flood extents tend to be similar for each ARI event as floodwaters are constrained by the channel limits. Flood velocities range from 2.2 to 7.8 m/s. In contrast, flood extents are larger for poorly defined channels/floodplains, but flood velocities tend to be lower, from 1.8 to 3.5 m/s. Stream velocity does not change greatly between 10-, 50- and 100-year ARI events for either type of channels.

The PRL-15 oxbow wetland experiences flood behavior consistent with a poorly defined channel/ floodplain, with widespread, shallow flooding with a low velocity. Wetland inundation from the river occurs in each of the 10-, 50- and 100-year ARI events, with little difference between these.

Although details of inundation of the PRL-15 oxbow wetlands on a more frequent basis is unavailable from the modeling, flows from the Purari River are expected to inundate the oxbow lake within the wetlands on an annual basis. Highly localized rainfall in the area north of the wetlands may also cause backflow events to occur, where water in the oxbow lake overflows into the tie channels and ‘pushes back’ water flow in these channels from the Purari River.

The model simulations for 10-, 50- and 100-year ARI events show flood heights of less than 3 m in the PRL-15 oxbow wetlands, Oyomo Creek and Herd Base, with low flow velocities. Flooding at Herd Base is associated with backflow from Kuku Creek and is confined to areas immediately adjoining the creek. Oyomo Creek has a similar flooding pattern but with a larger extent. Flooding in the PRL-15 oxbow wetlands is very widespread and is deepest in the area between the tie channels, oxbow lake and Purari River.

Sediment Transport and Loads

Sediment transported in the Purari River in the area of PRL-15 predominantly comprises silts and clays, with much of the clay contributed by the Aure River (Pickup, 1983).

Sediment transport rates in the Purari and Aure rivers are closely aligned to rainfall runoff. Pickup (1983) reported up to 57 million tons of sediment is transported in the Purari River at Wabo each year. The Aure River was estimated to deliver an additional 48 million tons downstream of Wabo, making an annual average of around 90 million tons of sediment discharged to the Purari River delta (Pickup, 1983). Based on these results, approximately 50% of the sediment transported in the Purari River downstream of PRL-15 originates from the Aure River.

Catchment modeling of runoff volumes and total suspended solid (TSS) loads was undertaken for the study area at the six locations described in Tables 7.2 and 7.3 and is further described in Part 2 of Volume 2. This modeling indicates that the sediment contribution from the Aure River may be closer to 20%, based on a comparison of loads in the Purari River at locations upstream and downstream of Aure River. The modeling results, presented in Table 7.3, indicate that the mean annual TSS load in the Purari River area is 23 million tons per annum (tpa) upstream of PRL-15 and 29 million tpa downstream of PRL-15. The majority of this 6 million tpa increase in TSS load is due to inflows from the Aure River. The differences in the Pickup (1983) and Part 2 of Volume 2 results are likely due to the different modeling techniques and data limitations and to the inclusion of bedload sediment and TSS in estimates by Pickup (1983).

Table 7.3 – Modeled Total Suspended Solid Loads

Reporting Location		Mean Daily TSS Loads (t/day)	Mean Annual TSS Loads (tpa)
1	Purari River upstream of PRL-15	64,702	23,390,045
2	Hou Creek	67	24,332
3	Boa Creek	14	4,931
4	Mena River	112	40,506
5	Kuku Creek	27	9,771
6	Purari River downstream of PRL-15 (includes the contribution from the Aure River subcatchment)	80,948	29,263,023

Peak TSS loads are predicted to occur between June and September in the Purari, Pie and Era river catchment streams in the vicinity of PRL-15 and to occur between February and March for the Aure River catchment. These periods coincide with peak rainfall, and consequently peak runoff and streamflows, at these times for these areas.

As described above, the dominant contribution to TSS loads in the Purari River downstream of Hathor Gorge comes from the Aure River catchment rather than the Hou Creek and Kuku Creek catchments in PRL-15. Total volumes discharged from the PRL-15 subcatchment are negligible; representing less than 1% of the 6 million tpa difference in TSS loads between modeling location 1 upstream of PRL-15 and location 6 downstream of PRL-15.

7.4 Surface Water and Sediment Quality

7.4.1 Study Overview

Description of surface water and sediment quality focuses on the waterways in the vicinity of PRL-15 and downstream in the Purari River delta. Description of the regional context of these waterways is provided in Section 7.3.1. The study area in PRL-15 includes the Purari River and its tributary streams and the tributary streams of the Era River including Boa Creek and Mena River. Downstream of PRL-15, the study area includes the freshwater streams and estuarine reaches of the Purari River delta. Estuarine areas of the Vaihua River, which flows into Caution Bay, are discussed in Section 7.4.2.3.

The Purari River delta includes both freshwater and estuarine components, with the estuarine boundary delineated by the inland extent of mangrove vegetation, as defined by Shearman (2010) and shown in Figure 7.10. It also includes the three main delta distributaries, the Purari, Urika-Ivo and Wame-Varoi rivers.

Description of the surface water and sediment quality of these waterways considers existing information from previous studies but is mostly based on field studies completed in June and July 2016 and in January and February 2017 (Part 3 of Volume 2).

The surface water quality surveys involved in situ measurements of physicochemical parameters (turbidity, conductivity, salinity, temperature and dissolved oxygen) and collection of surface water grab samples for laboratory analysis of the following parameters:

- Total suspended solids (TSS), major ions (i.e., calcium, magnesium, sodium, potassium, chloride, sulfate and bicarbonate), and total and dissolved organic carbon.
- Nutrients (i.e., ammonia, nitrate/nitrite, total nitrogen, filterable reactive phosphorus and total phosphorus).
- Toxicants (i.e., total and dissolved metals/metalloids, TPH, polycyclic aromatic hydrocarbons (PAH) and BTEX).
- Microbiological water quality (total coliforms).

Water quality instruments were also deployed in the Purari River at Herd Base to continuously measure and log turbidity during the field surveys.

FRESHWATER AND ESTUARINE SURVEY SITES

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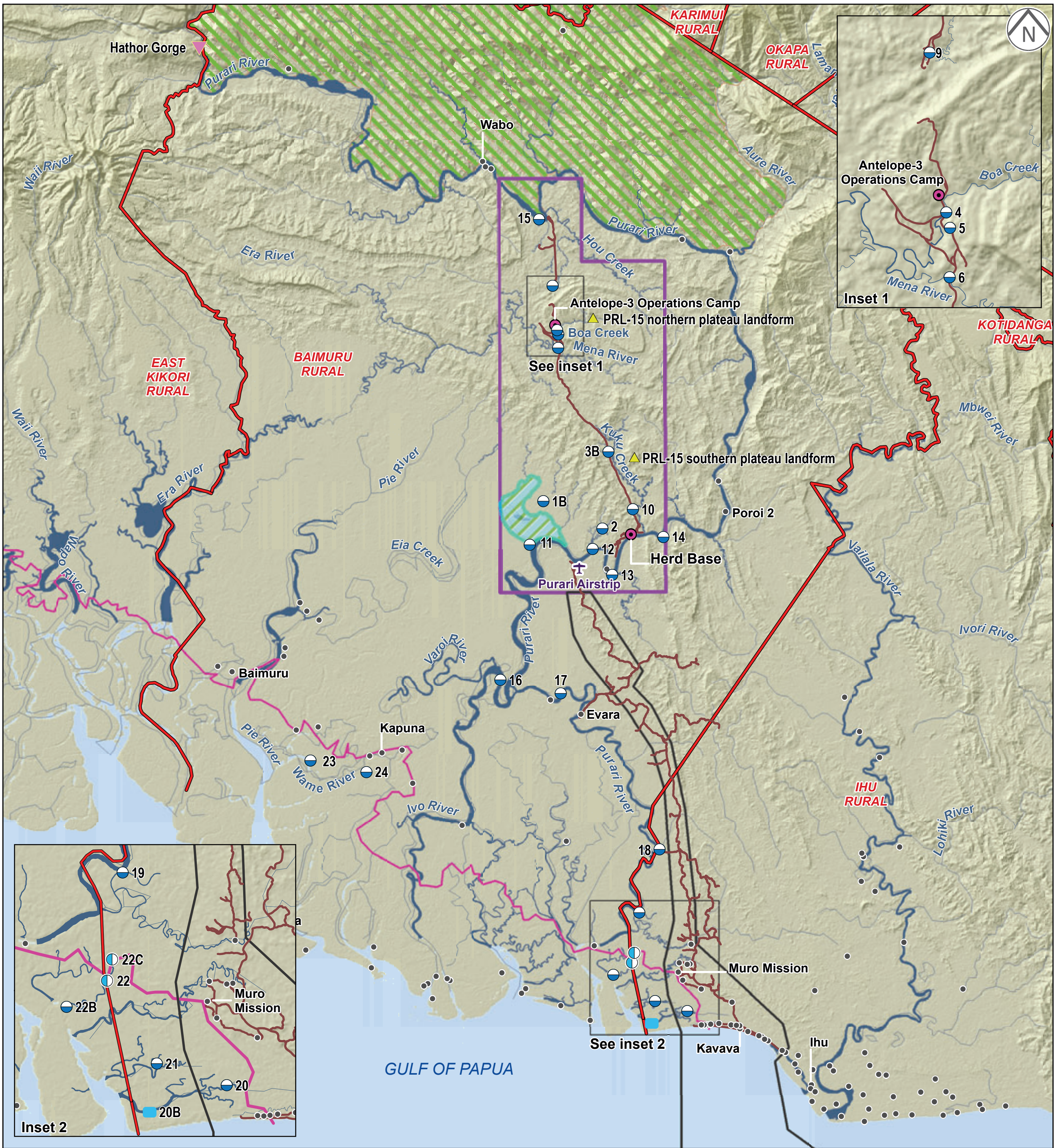
FIGURE 7.10



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0 5 10 15 20 25 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Airstrip
- Hathor Gorge
- Potential sensitive habitat
- Local level government boundary
- Track
- Waterway
- Indicative estuarine freshwater boundary
- Waterbody
- PRL-15
- Export pipeline corridor
- Crater Mountain Wildlife Management Area
- PRL-15 oxbow wetlands

Survey Sites

- Water quality
- Water quality and aquatic biodiversity
- Water quality, sediment quality and aquatic biodiversity

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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To provide a benchmark for assessment, water quality results were compared to the following criteria for protection of aquatic life:[6]

- Schedule 1 of the *Environment (Water Quality Criteria) Regulation 2002*, which provides legally enforceable freshwater and marine water quality criteria in Papua New Guinea.
- Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ, 2000)[7], which provide good international industry practice guidance for water and sediment quality assessment relevant to the region and are applicable to estuarine and freshwater environments.

Suitability for use as drinking water was also assessed considering PNG *Public Health (Drinking Water) Regulation* (PNG PHR) 1984 and the WHO (2011) drinking water guidelines.

Bed sediment samples were collected at all sites for analysis of particle size, total nitrogen and phosphorus, metals/metalloids, TPH, PAH and BTEX. No freshwater or estuarine sediment quality guidelines are provided in the PNG regulations, although the *Marine Pollution (Sea Dumping) Regulation 2013* provides contaminant guidelines for dredged material proposed to be placed at sea. Assessment of results was therefore undertaken considering interim sediment quality guidelines described in ANZECC/ARMCANZ (2000) and revisions to those guidelines described in Simpson et al. (2013).

Detailed water quality and sediment quality results are presented in Part 3 of Volume 2.

7.4.2 Surface Water Baseline Characterization

In describing the study sites in the following sections, distinction has been made between the following areas:

- PRL-15 sites (see Figure 7.10) – freshwater sites occurring in PRL-15 in the Purari River catchment and the Era River catchment, including tributary streams and the Purari River main channel. This includes sites 1B, 2, 3B, 4, 5, 6, 9, 10, 11, 12, 13, 14 and 15.
- Purari River delta sites (see Figure 7.10), including:
  - Freshwater sites occurring in the Purari River main channel from the split of the Purari River into the Purari, Urika-Ivo and Wame-Varoi distributary channels downstream to the indicative estuarine boundary within these channels. This includes sites 16, 17, 18 and 19.
  - Estuarine sites occurring from the indicative estuarine boundary downstream to the coast. This includes sites 20, 20B, 21, 22, 22B, 22C, 23 and 24.
- Vaihua River estuary – estuarine sites of the Vaihua River at Caution Bay, including sites 28 and 29 (Figures 8.11 and 8.21 in Chapter 8).

6 There is an absence of toxicity data specific to estuarine environments upon which guideline values can be based. As a precautionary approach, therefore, where both freshwater and marine guidelines are available, the more stringent of the two was applied for estuarine waters.

7 ANZG (2018) water quality guidelines have recently superseded the ANZECC/ARMCANZ (2000) water quality guidelines, however default trigger guideline values in the new guidelines currently remain the same as described in ANZECC/ARMCANZ (2000).

7.4.2.1 PRL-15

Surface water quality at sites in PRL-15, including tributary streams and the Purari River main channel, is characterized by low electrical conductivity (less than 400 µS/cm), with minimal seasonal variability (Figure 7.11). Stream pH was slightly to moderately alkaline, from pH 7.2 to 8.5, which is likely attributable to the carbonate parent geology in the area. Water was well-oxygenated (i.e., 85 to 120% saturation) at most tributary sites in PRL-15, except for site 11 on Nea Creek in a tie channel to the PRL-15 oxbow wetlands, which had 30% saturation (see Figure 7.11). The low dissolved oxygen level and lower pH (pH 7.2) at this site was most likely due to water outflow from the oxbow wetlands. Such water features typically have low dissolved oxygen levels, low pH and high dissolved organic carbon levels, due to breakdown of organic material. Tannin-stained waters observed entering the Purari River at this location during the field survey also provided evidence of such water in the wetlands.

Turbidity levels in tributary streams of the Purari River in PRL-15 were generally less than 50 nephelometric turbidity units (NTU) and lower than in the main channel; however, there was notable variation (see sites 11 to 15, Figure 7.11). The highest turbidity measured (300 NTU) was at site 12 in the tributary stream at the mouth of Oyomo Creek in the proposed CPF area during the southeast trade wind season survey. This was higher than turbidity in the main channel of the Purari River immediately downstream of this location, where turbidity was 145 NTU. During the northwest monsoon season survey, turbidity in Oyomo Creek (91 NTU) was lower than in the Purari River main channel (263 NTU). In general, turbidity in the Purari River main channel was higher during the northwest monsoon season than during the southeast trade wind season.

Total suspended sediment (TSS) in the Purari River showed the same trend as turbidity, with concentrations from 21 to 428 mg/L (Figure 7.12). This is similar to the findings of Petr (1983c), who reported TSS levels from 29 to 778 mg/L with an average of 254 mg/L. Continuous turbidity measurements undertaken by a fixed instrument in the Purari River at Herd Base during the 2017 northwest monsoon season survey recorded turbidity levels around 200 to 400 NTU, increasing to about 1,000 NTU following rainfall events in the catchment when river flows increased (Figure 7.13).

During both seasons, tributary streams in PRL-15 in the area of the gas field (i.e., sites 4, 5, and 9) had generally low but variable turbidity and TSS levels, with median values of 6 NTU and 7 mg/L, respectively. The highest levels in these tributary streams were measured in the Mena River (site 6) during the southeast trade wind season, when turbidity and TSS levels were 90 NTU and 130 mg/L, respectively. Previous studies reported in GHD (2015a, 2015b, 2015c, 2015d) also found that TSS levels in tributary streams in PRL-15 were usually low (less than 5 mg/L).

All monitoring sites had water with total alkalinity well above 20 mg $CaCO_3$/L and up to 168 mg $CaCO_3$/L, indicating that the waters have good acid-buffering capacity. Major ion analyses show that the waters are calcium and carbonate dominated, reflecting the widespread presence of calcareous rocks in the catchment (Petr, 1983c).

Nutrients and organic carbon were present in generally low concentrations at all sites during both the southeast trade wind and northwest monsoon season surveys. Total nitrogen and phosphorus concentrations in the tributary streams were less than 0.1 to 0.4 mg/L and between 0.02 to 0.15 mg/L, respectively, and were lower than in the main channel of the Purari River where the range was 0.2 to 1.5 mg/L for total nitrogen and 0.04 to 0.4 mg/L for total phosphorus. Ammonia concentrations were similar at all locations and were less than 0.01 to 0.08 mg/L, except at site 11 in the northwest monsoon season where a concentration of 0.83 mg/L was measured. All ammonia results were below water quality guidelines. Nitrate, nitrite and soluble reactive phosphorus concentrations were low (i.e., less than 0.07 mg/L) at all locations.

ELECTRICAL CONDUCTIVITY, DISSOLVED OXYGEN AND TURBIDITY DATA

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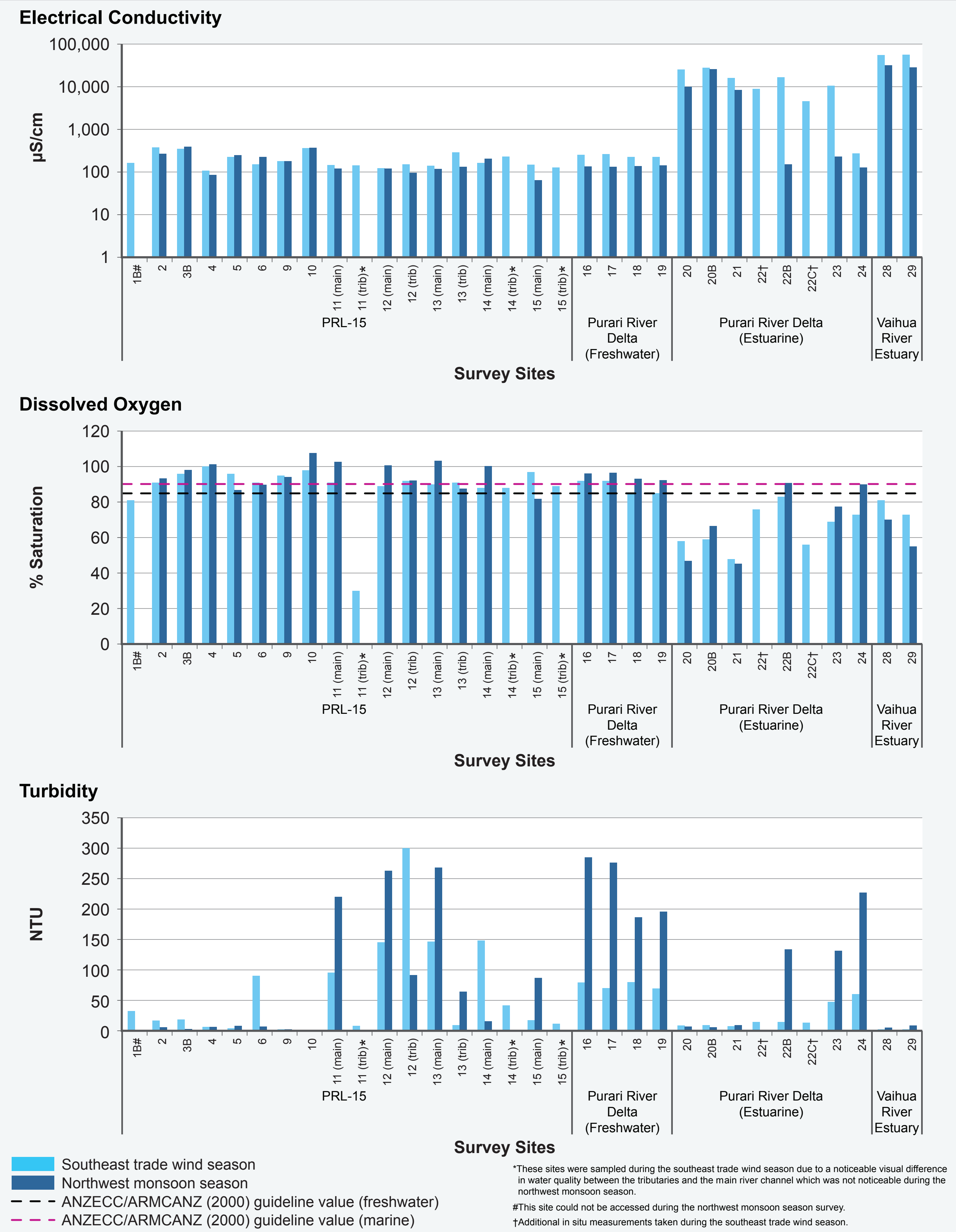
FIGURE 7.11



*These sites were sampled during the southeast trade wind season due to a noticeable visual difference in water quality between the tributaries and the main river channel which was not noticeable during the northwest monsoon season.

#This site could not be accessed during the northwest monsoon season survey.

†Additional in situ measurements taken during the southeast trade wind season.

TOTAL SUSPENDED SOLIDS DATA

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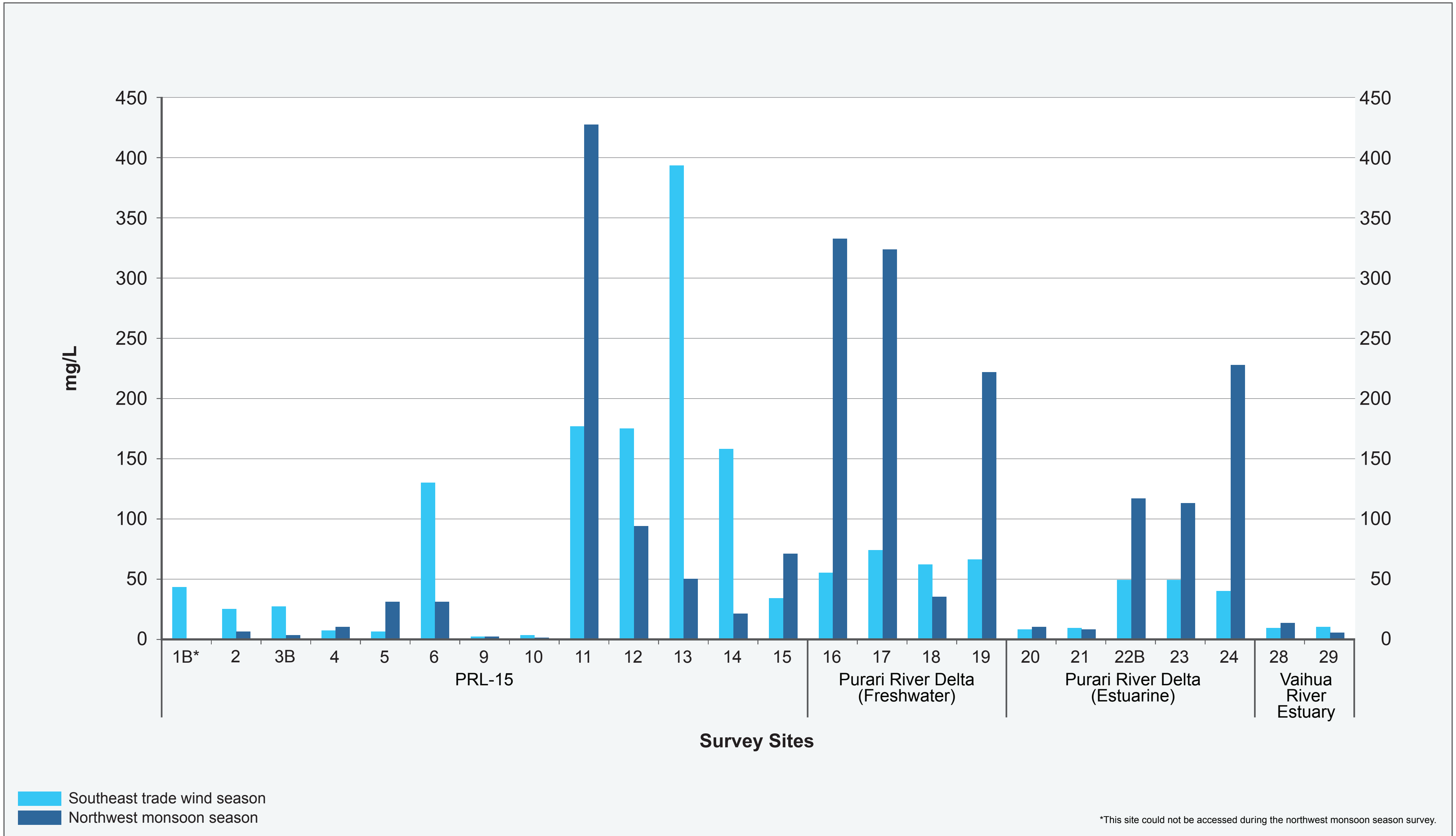
FIGURE 7.12



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TURBIDITY AND WATER DEPTH OF THE PURARI RIVER (HERD BASE)

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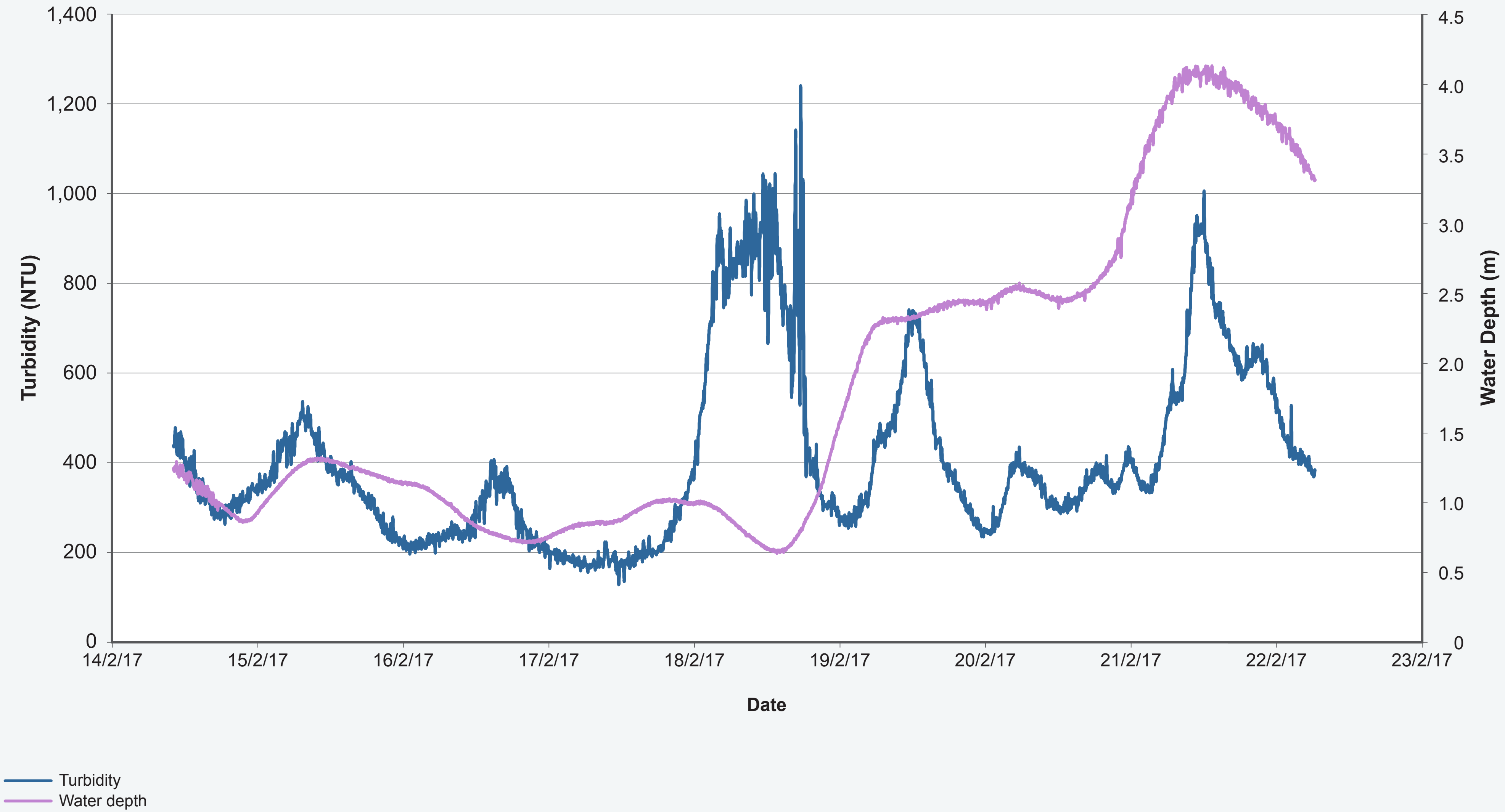
FIGURE 7.13



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Dissolved metal and metalloid concentrations at all sites in tributary streams and the Purari River main channel were also low; most results were below the limit of reporting and were similar between seasons. There were no exceedances of relevant water quality guidelines for protection of aquatic ecosystems or drinking water quality.[8] Total aluminum and iron concentrations were particularly high in the Purari River main channel (i.e., 0.9 to 16.8 mg/L and 1.3 to 21.4 mg/L, respectively), reflecting the elevated levels of suspended sediment present.

Total petroleum hydrocarbon, PAH and BTEX concentrations were below laboratory limits of reporting at all sites during both surveys and less than relevant water quality criteria.

Total coliform levels at all PRL-15 sites during both surveys were greater than 80 colony-forming units (CFUs) per 100 mL. This does not conform with drinking water requirements for protection of human health, which are that coliforms should be less than 3 CFUs/100 mL (PNG PHR) or 0 CFU/100 mL (WHO, 2011). Such exceedances are often observed in waterways in Papua New Guinea with 60% of the population lacking access to sanitation facilities and safe water, particularly in rural areas (WaterAid, 2017). Information on coliform levels in groundwater sources, including community water and sanitation uses and practices, the effects of which are likely contributing to high coliform levels in watercourses in the study area, is provided in Section 7.5.4.

7.4.2.2 Purari River Delta

The freshwater reaches of the Purari River delta include sites 16 to 19 (see Figure 7.10). Electrical conductivity at these sites was 132 to 266 µS/cm, similar to conductivities measured further upstream in PRL-15 (see Figure 6.11), and is consistent with previous results of 115 to 265 µS/cm reported for the lower Purari (Petr, 1983c). Other water quality properties of these freshwater sections of the Purari River delta were also found to be similar to the Purari River main channel upstream in the vicinity of PRL-15 described in Section 7.4.2.1.

The indicative estuarine boundary in the Purari River delta, coincident with the extent of mangrove forest, is shown in Figure 7.10 and includes sites 20 to 24. Electrical conductivity varied between sites and seasons and was around 100 to 28,000 µS/cm; the highest values were at sites closest to the coast due to the marine influence from the Gulf of Papua (see Figure 7.11).

Water column profiling at the estuarine sites showed that water quality was relatively consistent through the water column, indicating minimal stratification when sampled, except one site near the Purari River mouth (site 22B) during the northwest monsoon season survey, which recorded low conductivity (approximately 100 µS/cm) in surface layers and much higher conductivity in bottom water (approximately 20,000 µS/cm). This indicates a salt wedge (i.e., saline marine waters underlying fresh fluvial waters), which is typical of river mouth environments.

Dissolved oxygen concentrations were generally lower (down to 45% oxygen saturation) at the estuarine sites compared to freshwater sites in the Purari River delta (85% to 97% oxygen saturation). Low dissolved oxygen is typical in estuarine waters where degradation of settled detrital material and lack of oxygenation due to water column stratification and poor water mixing depletes oxygen levels.

Estuarine reaches of the Purari River delta had a median TSS concentration of 45 mg/L with a range of 8 to 228 mg/L and a median turbidity of 13 NTU with a range of 5 to 227 NTU. Turbidity

8 The guideline values are applicable to dissolved concentrations. Dissolved zinc at site 4 (9 µg/L) marginally exceeded the ANZECC/ARMCANZ (2000) guideline for aquatic ecosystem protection (8 µg/L); however, the total zinc concentration was less than 5 µg/L, indicating that the filtered dissolved sample may have been contaminated during sampling or analysis.

and TSS levels in the upper reaches of the brackish creeks (sites 20 and 21) were much lower than the sites located in or near main river channels, such as site 22B where turbidity was up to 134 NTU (see Figure 7.11). This is likely to be due to these waters being calmer, allowing solids to settle.

Major ion concentrations in the estuarine reaches were much higher than those in the freshwater reaches, reflecting the influence of seawater, particularly at sites 21 and 22. Alkalinity was quite high, ranging from 66 to 132 mg $CaCO_3$/L, with the highest levels at sites 21 and 22; however, pH was lower than usually observed in marine waters (approximately pH 8), ranging from pH 7.1 to 7.7, and generally lower than measured at freshwater sites in the Purari River delta and further upstream.

Nutrient and organic carbon concentrations in estuarine reaches were within the ranges found at the freshwater sites in the Purari River delta and further upstream in the vicinity of PRL-15, with no trends evident. Chlorophyll levels were low at both freshwater and estuarine sites and were less than or equal to the limit of reporting (2 µg/L).

Dissolved metal and metalloid concentrations at all sites in the Purari River delta were low, with most results being below the limit of reporting. Higher strontium levels observed in estuarine reaches (up to 2.5 mg/L) were a notable exception, which is attributed to it being a major element naturally present in seawater (at concentrations of approximately 8 mg/L). Relevant water quality guidelines for protection of aquatic ecosystems or drinking water were not exceeded. Similar to results for the Purari River main channel in PRL-15, higher total aluminum and iron concentrations observed at some sites (5 to 11 mg/L) reflect the elevated suspended sediment levels present from natural geological sources.

Total petroleum hydrocarbon, PAH and BTEX concentrations were below laboratory limits of reporting at all Purari River delta sites during both surveys and were less than relevant water quality criteria.

Total coliform levels were very high at most Purari River delta sites and did not conform to drinking water requirements for protection of human health that coliforms should be less than 3 CFUs/100mL (PNG PHR) or 0 CFU/100mL (WHO, 2011). Coliform levels also exceeded the PNG Schedule 1 criteria for protection of aquatic life of 200 CFUs/100 mL at all but one site. Total coliforms were highly variable between sites with the highest count of 16,000 CFUs/100 mL occurring at site 24 in the Wame River. Such exceedances, as also noted above for freshwater sites, are often observed in waterways in Papua New Guinea with 60% of the population lacking access to safe water, particularly in rural areas (WaterAid, 2017).

7.4.2.3 Vaihua Estuary

The Vaihua River catchment adjacent to Caution Bay drains a relatively small area and features a low relief and slope.

The Vaihua River at Caution Bay is considered estuarine up to the edge of the salt flats immediately southeast of the existing PNG LNG facilities. The river experiences highest flows between December and March, with only low or intermittent flows in May to October, which leave isolated pools of standing water (CNS, 2009). Most of the tributary streams of the river are ephemeral. As a result, freshwater inputs are negligible during the dry season but high during the wet season, leading to a transition between a ‘negative’ and a ‘positive’ estuary and creating areas of hypersaline wetland in intertidal and supratidal flats (CNS, 2009).

Two sites in the Vaihua River estuary were sampled (sites 28 and 29) during the 2016 and 2017 field surveys. The site locations are shown in Figure 8.11 in Chapter 8.

Electrical conductivity and salinity in the Vaihua River estuary is reflective of a marine environment, with electrical conductivity around 55,000 µS/cm and salinity around 35 parts per thousand. Major ion concentrations were correspondingly high. The pH was from 7.5 to 7.9, slightly below the typical pH for seawater. Turbidity was low from 1.9 to 8.3 NTU, while TSS was 6 mg/L to 14 mg/L. Dissolved oxygen levels were low, from 57% to 81% saturation, and slightly below water quality guidelines for protection of aquatic ecosystems.

Nutrient concentrations were low, usually below laboratory limits of reporting, and similar to or less than concentrations measured in the Purari River delta. Ammonia was an exception with concentrations from 0.08 to 0.16 mg/L, which were slightly higher than concentrations measured in the Purari River delta (0.02 to 0.10 mg/L). Ammonia concentrations were slightly higher in the southeast trade wind season (0.14 to 0.16 mg/L compared to 0.08 to 0.11 mg/L). Total and dissolved organic carbon and chlorophyll levels were similar to those measured in the Purari River delta.

Dissolved metal and metalloid concentrations were low, usually below the limits of reporting and less than water quality guidelines.[9] Similar to estuarine reaches of the Purari River delta, the notable exception was strontium, with concentrations between 5.6 and 8.0 mg/L and higher in the southeast trade wind season. Strontium is a major element naturally present in seawater and may be lower in the northwest monsoon season due to increased freshwater inputs from higher rainfall. Total metal and metalloid concentrations, except aluminum and iron, were generally similar to dissolved concentrations; however, total concentrations of these two metals were not particularly high (less than 0.3 mg/L), reflecting the relatively low TSS levels at the two sites.

Total petroleum hydrocarbon, PAH and BTEX concentrations were below laboratory limits of reporting and less than relevant water quality criteria at all Vaihua River estuary sites during both surveys. Total coliforms were detected at both sampling sites; with 920 CFUs/100 mL measured at site 29 and 7 CFUs/100 mL at site 28 during the 2017 northwest monsoon season survey. Both results were above drinking water requirements for protection of human health that coliforms should be less than 3 CFUs/100mL (PNG PHR) or 0 CFU/100mL (WHO, 2011), while the result from site 29 was also above PNG Schedule 1 criteria of 200 CFUs/100 mL for protection of aquatic life.

7.4.3 Sediment Quality Baseline Characterization

Bed sediment samples were collected during the southeast trade wind season at each of the sampling sites described in Section 7.4.2, except the Vaihua River estuary.[10] Locations of PRL-15 sites[11] and Purari River delta sites are shown in Figure 7.10.

7.4.3.1 PRL-15

The particle size distribution (PSD) results for bed sediment in the vicinity of PRL-15, including tributary streams and the Purari River main channel, indicate that grain size is variable, with some sites consisting of predominantly sand and gravel, while other sites were predominantly silts and clays (Figure 7.14).

9 The guideline values are applicable to dissolved concentrations. Dissolved copper marginally exceeded the ANZECC/ARMCANZ (2000) guideline value at site 29 during the 2017 northwest monsoon season survey; however, the total copper concentration was lower and less than the guideline value, indicating that the filtered dissolved sample was contaminated during sampling or analysis.

10 Intrusive sediment sampling in Caution Bay was unable to be undertaken due to the safety risk from unexploded ordnances, possibly present due to activities during World War II at the nearby Boera battery.

11 Sediment sampling at sites 11 to 15 was undertaken in the Purari River main channel; no sediment sampling was undertaken in the adjacent tributary stream.

SEDIMENT PARTICLE SIZE DISTRIBUTION

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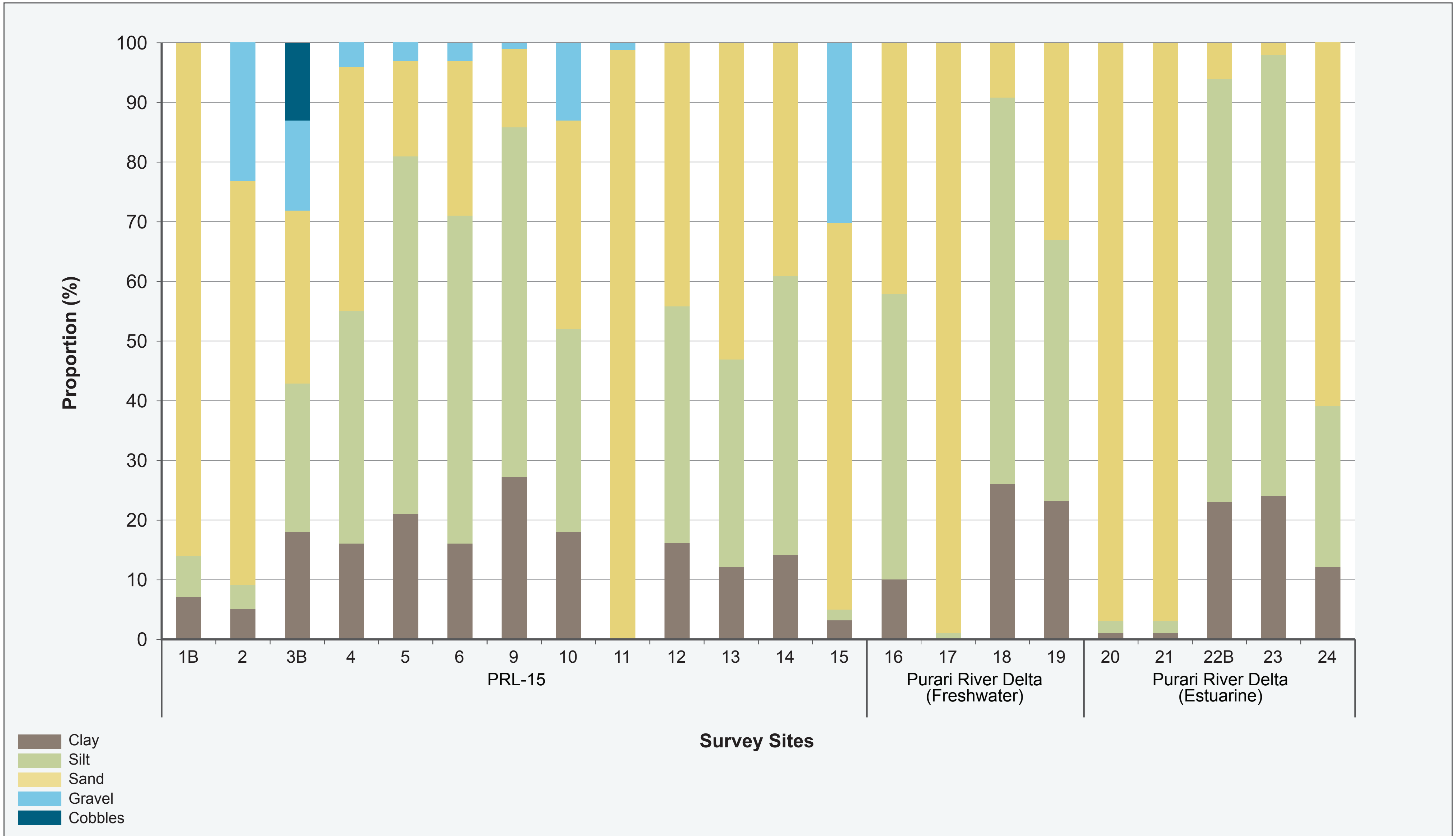
FIGURE 7.14



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In the Purari River main channel in PRL-15, the furthest upstream site (site 15) and the furthest downstream site (site 11) were mostly sand or sand with some gravel respectively, while sites in between (sites 12, 13 and 14) consisted of approximately 50% sands and 50% silts and clays. Coarser bed sediments (i.e., sands) typically occur in high-energy environments, whereas finer sediments (i.e., silts and clays) typically occur in depositional environments and therefore reflect the particular dynamics of the site sampled.

Sites sampled on tributary streams of the Era and Purari rivers in PRL-15 (i.e., sites 4, 5, 6 and 9) have large proportions (55% to 85%) of silts and clays.

Total nitrogen concentrations varied considerably between sites in PRL-15 in tributary streams and the Purari River main channel from 160 to 1,120 mg/kg. Nearly all nitrogen was organically bound, with sites with the highest total nitrogen concentrations also having the highest amounts of total organic matter (up to 3%) and total organic carbon (up to 1.7%). There was less variation in total phosphorus concentrations between sites, with levels from 295 to 885 mg/kg.

Metal and metalloid concentrations in sediment were similar at sites in PRL-15, which included samples from both the main Purari River channel and smaller tributary streams. All concentrations were below sediment quality guideline values, except nickel, which exceeded the guideline value of 21 mg/kg at all sites with values from 31 to 53 mg/kg; however, as found elsewhere in Papua New Guinea and Australia, it is not unusual for natural background nickel concentrations in sediment to exceed this guideline due to the regional geology and climatic conditions.[12] Similar exceedances were found in baseline studies for the PNG LNG Project (Hydrobiology, 2008).

Total petroleum hydrocarbon, PAH and BTEX concentrations at all sites were below the laboratory limits of reporting and less than sediment quality guidelines where available for the various parameters.

7.4.3.2 Purari River Delta

Similar to sites in PRL-15, bed sediment particle size in the Purari River delta – including freshwater main channel and estuarine reaches – is highly variable, with some sites consisting of predominantly sand (sites 17, 20 and 21), while other sites were predominantly silts and clays (sites 18, 19, 22B and 23), with the latter indicating depositional environments (see Figure 7.14).

Also similar to PRL-15, there was considerable variation in total nitrogen concentrations in sediments within the Purari River delta, from 140 to 1,560 mg/kg. As found in PRL-15, this nitrogen was all organically bound; and concentrations were highest in sediments containing higher amounts of organic matter (which was present at levels up to 5%). Total phosphorus levels throughout the Purari River delta were from 482 to 908 mg/kg.

Metal and metalloid concentrations in the Purari River delta, including freshwater main channel and estuarine reaches, were similar between sites and within the ranges determined in sediment from PRL-15. All concentrations were below sediment quality guideline values except nickel, which exceeded the guideline value of 21 mg/kg at all sites with from 29 to 47 mg/kg. Total petroleum hydrocarbon, PAH and BTEX concentrations at all sites within the Purari River delta were below the laboratory limits of reporting.

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12 In high-rainfall tropical environments, soils can become enriched in particular elements due to weathering of the parent rock by rainfall, resulting in removal of more soluble elements, such as calcium and magnesium, and concentrating less soluble elements, such as nickel and cobalt.

7.4.3.3 Vaihua River Estuary

Although no sediment samples were collected in the Vaihua River estuary during the 2016 and 2017 surveys due to safety risks from unexploded ordnances, sampling previously undertaken for the PNG LNG Project (Hydrobiology, 2009) indicates that grain size is variable, with sediment at some sites predominantly comprised of sand and at other sites predominantly comprised of silt. Metal concentrations were below sediment quality guidelines, with the notable exception of nickel, which exceeded the guideline value of 21 mg/kg at three out of four sites, with values from 24 to 48 mg/kg. This is similar to the findings of the 2016 and 2017 surveys of PRL-15 and the Purari River delta discussed above, providing further evidence that nickel is present at naturally elevated levels in the study area. Arsenic also slightly exceeded the sediment quality guideline at one of the four locations sampled in the Vaihua River estuary.

7.5 Groundwater

7.5.1 Regional Context

Groundwater assessment in the study area to date has been limited, and little detail is known about the area’s hydrogeology. The few groundwater access points in the study area comprise the Project’s Herd Base abstraction bores in the southern area of PRL-15 adjacent to the Purari River. No known bores occur in the onshore export pipeline corridor. Groundwater springs are understood to be relatively common in the upper reaches of the study area, particularly during and following the wet season (GHD, 2015d). Hand-dug village wells used for domestic water supply are common in the coastal areas (Part 14 of Volume 2). There is little quantitative data regarding groundwater levels or the water flow or quality from these shallow groundwater features.

Some interpretation of potential deeper groundwater occurrence can be made based on the understanding of the stratigraphy of the study area described previously in Table 7.1. Based on this geological information, four potential hydro-stratigraphic units are likely to be present:

- Perched or shallow groundwater (i.e., minor occurrences of groundwater above regional groundwater) in upper weathered rock material, alluvium or back beach deposits, which is considered to represent the primary source of creek discharge in their upper reaches. In the higher altitude terrain in the northern part of PRL-15, in the gas field area, this groundwater may not be present year round and is unlikely to be laterally continuous. Close to rivers and water bodies, alluvial sediments may support groundwater capable of providing sustainable and valuable groundwater yields to these surface waters. In the lower coastal areas, this groundwater may be very shallow, less than 1 m below ground level (bgl), and is an important water supply for some villages. The perched groundwater is likely to be predominantly controlled by topography.
- Shallow permanent groundwater within sandstones, siltstones, mudstones and minor conglomerates of the Era Beds in certain areas of the study area, with Era Beds largely absent from the northern part of PRL-15 in the gas field area. This groundwater is understood to exist at depths corresponding to the levels of nearby watercourses; hence, beneath ridgelines and high points, depth to groundwater could be greater than 200 m. Groundwater occurrence in this hydro-stratigraphic unit is likely to be variable, with permeability and hydraulic conductivity controlled by sediment variation.
- Formation (interstitial) water is likely to be present at various levels throughout the stratigraphy of the Orubadi Beds. The hydraulic conductivity of this material is likely to be low, and only low volumes of water have been encountered during the drilling of exploration wells; hence, this hydro-stratigraphic unit is not considered to represent an aquifer.

- Deep groundwater, greater than 1,600 m bgl, may be present in the Kapau Limestone that contains the gas reservoir, although only in low quantities, as hydrocarbons occupy pore space in this geology. Exploration drilling to date has shown very little water is associated with gas and condensate. This hydro-stratigraphic unit is considered to be confined by low permeability material of the overlying Orubadi Beds and unconnected to surface water of shallower hydro-stratigraphic units. The volume of water expected in this formation and its status as a hydrocarbon reservoir, means that this hydro-stratigraphic unit is not considered to represent an aquifer.

On the basis of observations and information collected during the field survey, only one of these potential hydro-stratigraphic units that is accessed by the community as a groundwater resource is the perched or shallow groundwater within upper weathered rock material, alluvium or back beach deposits.

7.5.2 Study Overview

Description of the groundwater in the study area is based on existing information available from previous studies, the scientific literature and a field survey undertaken in PRL-15 and the onshore export pipeline corridor in November 2016.

The field survey involved general observations of the surrounding environment in PRL-15 and the onshore export pipeline corridor. Gauging and sampling was also undertaken of groundwater bores at Herd Base and of springs and shallow wells at coastal and inland villages along the onshore export pipeline corridor.

Forty-three sites were observed, gauged, sampled or sighted during the field survey (Figure 7.15). Thirty-one groundwater features (e.g., wells, springs or bores) were observed and documented, while observations of springs, seepages or erosional features were made at 12 additional sites, to inform groundwater conceptualization (see observation sites in Figure 7.15). Of the 31 groundwater features documented, water levels were gauged at 28 sites; in situ water quality measurements were undertaken at 17 sites; and water samples were collected at 16 sites, of which 14 were analyzed for general water quality parameters and contaminants, including metals, hydrocarbons and coliforms.

The suitability of groundwater for use as drinking water was assessed considering PNG PHR and the WHO (2011) drinking water guidelines. Given the close connectivity of surface waters with groundwater, which occurs close to the surface at most of the sampling locations, consideration was also given to Papua New Guinea and international freshwater guidelines for aquatic ecosystem protection (i.e., Schedule 1 of the *PNG Environment (Water Quality Criteria) Regulation 2002*, and ANZECC/ARMCANZ (2000)[13], respectively). These assessment criteria are provided and further described in Part 4 of Volume 2. Based on the review of existing information relating to the study area and field observations, a conceptual understanding of known and likely groundwater conditions in various parts of the study area has been developed and is described in Section 7.5.3. The results from groundwater quality sampling undertaken in the study area in November 2016 are summarized in Section 7.5.4.

13 ANZG (2018) water quality guidelines have recently superseded the ANZECC/ARMCANZ (2000) water quality guidelines, however default trigger guideline values in the new guidelines currently remain the same as described in ANZECC/ARMCANZ (2000).

GROUNDWATER SURVEY SITES

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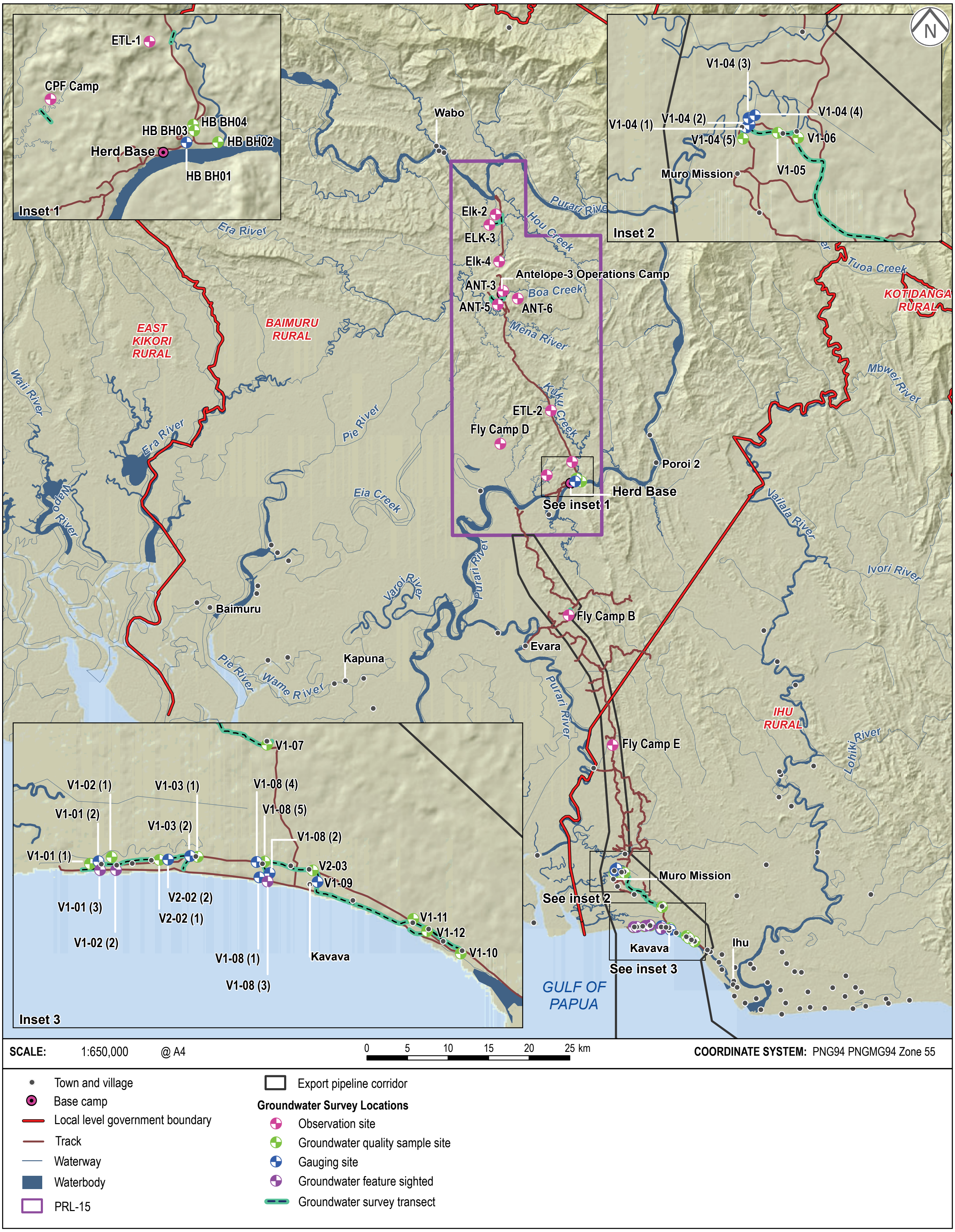
FIGURE 7.15



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

7.5.3 Groundwater Conceptualization

7.5.3.1 PRL-15

The Elk-Antelope gas field area in the north of PRL-15 is characterized by steep slopes and incised valleys and experiences high rainfall. In this area, localized bodies of shallow, unconfined, perched groundwater are thought to be present within superficial sedimentary material, including alluvium, colluvium, landslide debris and weathered material. Where present, this perched groundwater is likely to exist within 10 m of the ground surface. The superficial sedimentary material in this area is thought to have a high capacity to contain and transmit water, releasing it slowly from springs and seeps, and to act as a buffer that sustains stream baseflow for some time after rainfall events. These shallow groundwater systems are thought to be localized (i.e., confined to single valleys), with recharge and discharge areas in close proximity to each other. Since there was little to nil rainfall prior to and during the field survey, limited evidence of this was observed in the field, although this interpretation is supported by multiple examples of spring-type erosion and minor seeps observed within the area.

Permanent groundwater is likely to occur in more extensive alluvial deposits in the major river valleys. This groundwater is likely to be connected to surface water. With the possible exception of sandstones within the Era Beds, the deeper geology is unlikely to support sufficient groundwater to classify aquifers as being present. The Orubadi Beds are dominated by mudstones and siltstones (see Table 7.1), which are likely to have low hydraulic conductivities. This, in addition to the depth to this formation, supports the interpretation that this sedimentary material does not support significant groundwater systems.

The proposed CPF area and Herd Base have low relief when compared to the gas field area, yet it still includes steep slopes and incised valleys. Major surface rivers and streams, including the Purari River and Kuku Creek, are also present. Local shallow, perched groundwater is considered likely in superficial sedimentary materials, as evidenced by seeps and spring type erosion. Similar to the gas field area, these shallow groundwater systems are likely to be localized, with recharge and discharge areas close to each other.

At Herd Base, four groundwater abstraction bores target groundwater from the alluvial material associated with the Purari River and its tributary, Kuku Creek. These bores encounter groundwater between 3 and 6.5 m bgl in fine-grained sand lenses, which are interpreted to be alluvial deposits from historical river channels. Two of the bores have reliably supplied water to Herd Base for several years. The groundwater encountered by these bores is thought to have connectivity with the surface waters of Kuku Creek and the Purari River. Testing of one of the bores has shown that the intersected aquifer is capable of yielding at least 0.8 L/s.

7.5.3.2 Onshore Export Pipeline Corridor

The onshore export pipeline corridor from the Purari River near Herd Base passes through an area topographically similar to PRL-15 with steep slopes and strike ridges, albeit of lower relief, before descending to the coast in the south (see Section 7.2). The weathered sedimentary material overlying competent geology is considered to support a perched groundwater system recharged by local rainfall. Evidence of spring erosion was observed in this area during the field survey. No information regarding deeper groundwater is known in this area; however, the geology of the ridgelines (Orubadi Beds) is dominated by mudstones and siltstones that are not thought to represent aquifer materials.

Villages at the southern end of the onshore export pipeline corridor, inland from the coast, use groundwater for domestic purposes (e.g., drinking water, washing and stock water;

Section 9.5.4.3). The communities of these inland villages often access groundwater from springs (Plate 7.6) and wells, excavated to approximately 2 m deep. These provide reliable year-round water from shallow alluvial sediments, recharged during local rainfall. This groundwater is considered to be laterally extensive and, given the very shallow depths, is likely to support groundwater-dependent ecosystems (freshwater swamps) where such ecosystems occur.

Plate 7.6 – Excavated Inland Village Spring at Kilavi (left) and Traditional Coastal Palm Stump Well at Harevavo (right)

Photos: SLR Consulting.

Villagers on the coastal strip within the onshore export pipeline corridor also use shallow groundwater wells (see Plate 7.6). The wells target shallow, approximately 1 m bgl, freshwater in marine, sandy beach and back beach deposits. The freshwater is likely to lie on top of more saline water in the deeper sediments below. The recharge zone for this freshwater is likely to be very localized, with high levels of infiltration due to the sandy substrate. Surface flows of seawater may inundate wells during major storm events.

7.5.4 Groundwater Quality Baseline Characterization

The groundwater features sampled during the November 2016 field survey included three drilled groundwater supply bores at Herd Base and 14 wells and springs in villages along and inland of the coast in the onshore export pipeline corridor (see Figure 7.15).

The bores sampled at Herd Base are 16.8 to 22.6 m deep, with groundwater levels from 3 to 6.5 m bgl in November 2016. The village wells and springs are 1 to 2.7 m deep, with groundwater levels from 0.05 to 2.1 m bgl.

7.5.4.1 Physicochemical Parameters

In situ measurements were undertaken for various physicochemical parameters, including temperature, pH, electrical conductivity, dissolved oxygen and turbidity.

The groundwater pH was moderately alkaline at pH 8.6 to 9.5, with a median value of pH 9.1. The most alkaline groundwater measurement was at Herd Base. All field pH measurements exceeded the aesthetically-based highest desirable limits of the PNG PHR and the WHO (2011) drinking water guidelines. The high pH is attributed to the carbonate parent geology in the area.

Groundwater electrical conductivity in bores at Herd Base was 765 to 992 µS/cm and is classified in the WHO (2011) drinking water guidelines as representing fair drinking water based on aesthetic considerations, i.e., taste. Groundwater conductivity in the village springs and wells was lower at 75 to 400 µS/cm and was within the range considered to represent good drinking water.

The low conductivities in village wells close to the coast indicate that salt water ingression into the shallow groundwater system has not occurred through either ground intrusion or overland flow (e.g., storm surges).

Groundwater at all locations was well-oxygenated, having greater than 95% oxygen saturation, at all locations, which is high for groundwater. This is attributed to the large area of air-water interface of the shallow wells and springs and the large volumes of standing water precluding conventional purged sampling.

Groundwater turbidity ranged from less than 0.5 to 55 NTU, with an average of 12 NTU. Turbidity at nine locations exceeded the PNG PHR and WHO (2011) aesthetically-based drinking water guideline of 5 NTU.

7.5.4.2 Laboratory Analyses

Water samples were collected at 14 sites during the November 2016 field survey for analysis of the following parameters:

- Major cations and anions, including alkalinity.
- Total suspended solids (TSS).
- Total and dissolved organic carbon.
- Total nitrogen, total phosphorus, nitrate/nitrite, ammonia and orthophosphate.
- Total and dissolved metals (i.e., aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, vanadium, zinc, iron and mercury).
- Total petroleum hydrocarbons (TPH), BTEX and PAH.
- Microbiological water quality (i.e., total coliforms and fecal streptococci (enterococci)).

Detailed analytical results are presented in Part 4 of Volume 2.

Coastal village groundwater was dominated by magnesium and carbonate, with the magnesium likely reflecting marine influences in this area. At the inland villages, the major ion composition of groundwater was similar to surface waters (Part 3 of Volume 2), being calcium-carbonate dominated but with slightly higher chloride concentrations and lower calcium dominance. The similarity of groundwater and surface water at the inland villages suggests a linkage between these systems, with shallow groundwater being very young and readily replenished by rainwater recharge moving through the system. Concentrations of all major ions were below the PNG PHR and WHO (2011) aesthetically-based drinking water criteria at all locations sampled.

Nitrate concentrations in groundwater at all locations were below PNG PHR and WHO (2011) drinking water criteria. Ammonia concentrations exceeded aquatic ecosystem protection criteria as per the *Environment (Water Quality Criteria) Regulation 2002* and ANZECC/ARMCANZ (2000), which are applicable to surface waters, at seven locations; however, concentrations in all samples were less than the aesthetically-based WHO (2011) drinking water guideline of 35 mg/L. The highest ammonia concentration of 2.39 mg/L was measured in groundwater at Herd Base (site HB BH02). The maximum concentration measured in village wells was 0.15 mg/L at site V1-01(1). Natural levels in groundwater are usually below 0.2 mg/L (WHO, 2011). Potential sources of ammonia include cement mortar pipe linings and bacterial, sewage or animal waste pollution (WHO, 2011).

Total iron concentrations in groundwater exceeded the PNG PHR and WHO (2011) aesthetically-based drinking water guidelines at numerous locations. At some locations, this may be attributable to the use of steel drums as well casings (Plate 7.7). Dissolved zinc concentrations were also slightly above ANZECC/ARMCANZ (2000) criteria for freshwater ecosystem protection at five locations; however, concentrations were less than PNG PHR and WHO (2011) drinking water guidelines. The total arsenic concentration measured in the groundwater at Herd Base was equal to the WHO (2011) drinking water guideline but was less than the guideline value at all village springs and wells. Concentrations of all other metals were below the relevant screening criteria.

Plate 7.7 – Well With Steel Drum Used for Casing

Photo: SLR Consulting.

Concentrations of TPHs and PAHs were less than the limits of reporting in all groundwater samples. Concentrations of BTEX were also below reporting limits, except for toluene concentrations in all samples, which were just above the limit of reporting (2 μg/L) but over two orders of magnitude below the WHO (2011) drinking water guideline of 700 μg/L.

The microbiological water quality of the sampled wells and springs was found to be poor, with high coliform counts from 40 to 18,000 CFUs/100mL. This does not conform to either the PNG PHR and WHO (2011) drinking water guideline that coliforms should be less than 3 CFUs/100mL (PNG PHR) or 0 CFUs/100mL (WHO, 2011). This result is, however, not unexpected for Papua New Guinea, where people in rural areas, in particular, lack access to clean drinking water (WaterAid, 2017). All wells and springs at the village sampling locations were relatively open, allowing exposure to biological contamination. Potential sources of microbiological contamination include the well and spring users, direct contact with domestic and wild animals (e.g., animals drinking from water features and bird droppings in the water sources), subsurface migration of sewage-impacted water from pit latrines and informal toileting or windblown detritus. In addition, the well and spring construction method makes many of these structures susceptible to surface water inflows transporting contaminants and seawater inundation during tidal surges. While the village wells are not always the sole source of drinking water, as rainwater tanks are present in most locations, there is increased use of groundwater during extended dry periods and therefore the microbiological quality of water presents a human health concern (Part 16 of Volume 2)

Coliforms were also present in groundwater sampled at Herd Base. This bore has a basic cap at its headworks, and downhole contamination is possible from insects and amphibians that may gain access to the bore. The current water use from the bore is limited to vehicle and workshop washdown, and the water quality is considered suitable for this purpose.

Overall, the results of laboratory analyses on collected samples indicate that, apart from microbiological contamination, groundwater quality in the sampled systems within the study area is relatively good with no evidence of gross chemical contamination. These exceedances of water quality guidelines for chemical analytes are minor and are mostly related to aesthetic considerations, such as taste, to which the communities have likely become accustomed.

7.6 Freshwater and Estuarine Biodiversity

7.6.1 Regional Context

PRL-15 and the Purari River delta fall within the Papuan Gulf Foreland and the Papuan Gulf Coastal Lowlands ecoregions described by Polhemus et al. (2004). These ecoregions encompass the coastal lowlands in the southern part of central New Guinea, including the Purari, Fly, Digul and Kikori rivers. They are characterized by a high degree of endemism clustered around tectonic plates (Abell et al., 2008). The freshwater fauna of the ecoregions also has strong affinities with that of northern Australia, reflecting the recent geological connection between these land masses (Allen, 1991; Abell et al., 2008).

Papua New Guinea has high rainfall and high river discharges; and due to PNG’s mountainous topography, its rivers tend to have high velocities in their upper reaches (Osborne, 1987). The riverine habitat types found in the study area are characteristic and representative of those found elsewhere in Papua New Guinea, i.e., fast-flowing, low-order streams in areas with steep topography, which widen and lose velocity at lower gradients and eventually form large turbid lowland river systems in the lowland environments.

The study area encompasses the Purari River and its tributaries, the tributaries of the Era and Pie rivers and the deltaic plains of the Purari River. The portion of the Purari River catchment in the study area is located downstream of Hathor Gorge (see Figure 7.10). As described in Section 7.3.1, the Hathor Gorge rapids represent a significant hydraulic and physical barrier and are a key control on aquatic fauna distribution patterns in the Purari River catchment (Haines, 1979).

The deltaic plains of the Purari River consist of a broad floodplain containing low-gradient floodplain channels and a range of freshwater wetland systems. The most extensive wetland types are lowland freshwater swamps (forested wetlands) and, to a lesser extent, marshes and lakes. The floodplain wetland types occurring along the Purari River are well represented throughout Papua New Guinea, e.g., in the Sepik River basin, Fly River basin, Kikori River basin and the numerous other river systems listed in Section 7.1 that discharge into the Gulf of Papua.

The Vaihua River estuary at Caution Bay is part of the Papua Peninsula ecoregion defined by Abell et al. (2008). This ecoregion encompasses the Papuan Peninsula and offshore islands including the Trobriand islands, D’Entrecasteaux islands and Louisiade Archipelago along the southeast coast of New Guinea. This ecoregion is also characterized by a high degree of endemism clustered around tectonic plates (Abell et al., 2008). The Papuan Peninsula ecoregion overlaps with the South Papuan Peninsula Foreland (Area 30) ecoregion, as defined by Polhemus et al. (2004).

7.6.2 Aquatic Habitats Baseline Characterization

7.6.2.1 Study Overview

Description of the existing freshwater and estuarine biodiversity in the study area is based on information from previous studies, the scientific literature and targeted field surveys of the study area. These surveys were undertaken in conjunction with the surface water and sediment quality surveys described in Section 7.4 and were completed in June and July 2016 and January and February 2017 (Part 5 of Volume 2). Sampling was undertaken at the same sites as the surface water and sediment quality (see Figure 7.10).

The baseline characterization focused on the following:

- Description of different aquatic habitat types and features in the study area, including rivers, tributary streams and wetlands.
- Characterization of spatial and temporal patterns in the structure of fish and macroinvertebrate assemblages of the study area including benthic macroinvertebrates in estuarine areas.
- Identification of species listed as Threatened under the International Union for Conservation of Nature (IUCN) Red List, species listed as threatened or protected by the *Fauna (Protection and Control) Act 1996*, or species and habitats potentially relevant to a critical habitat assessment.
- Quantification of contaminants (i.e., metals, metalloids and PAHs) in aquatic biota.

Haines (1983) identified the following five key freshwater and estuarine habitat types in the study area:

- High- to moderate-gradient tributary streams.
- Low-gradient slow- to moderate-flowing tributary systems.
- Unconfined turbid major river systems and floodplain stream mouths.
- Freshwater floodplain wetlands and oxbow lagoons.
- Estuarine wetlands.

These are analogous to habitat types defined by Polhemus and Allen (2006). Further detail regarding the characteristics of each of these habitats is provided in Part 2 of Volume 2. The occurrence of each of these habitats in the study area is discussed in the following sections.

Estuarine areas of the Vaihua River are included in this section due to the close connectivity with the Caution Bay marine environment (Section 8.5), which is included in the upstream Project area at the southern end of the offshore export pipeline corridor.

7.6.2.2 PRL-15

High- to moderate-gradient tributary streams occur in steep valleys within PRL-15 in the vicinity of the gas field. These streams have confined or partially confined channels; clear, swift-flowing waters; substrate comprising predominantly bedrock, boulders and cobbles; and an absence of trailing vegetation and macrophytes. High- to moderate-gradient tributary streams that were surveyed in PRL-15 included sites 3B, 4, 5, 6, 9 and 10, which were located in tributary streams of the Era and Purari rivers (see Figure 7.10 and Plate 7.8). The riparian zone generally comprises intact, continuous lowland forest that forms a dense canopy over narrow streams.

Low-gradient slow- to moderate-flowing tributary streams were identified to occur in the southern region of PRL-15, with such locations including sites 1B (see Figure 7.10), located in an unnamed creek upstream of Herd Base, and site 2 (see Figure 7.10), located in Oyomo Creek near the proposed CPF area (Plate 7.9). These are a transitional zone between the swift-flowing, clear-water environments that characterize the high- to moderate-gradient tributary streams and the slow-flowing, unconfined turbid major river systems. They have substrates dominated by gravel, pebbles and sand; the common occurrence of gravel and sand bars; and hydraulic habitats including riffles, glides and runs with occasional pools. They usually have low turbidity, although this is temporally variable and turbidity is higher in lower reaches. Woody debris, leaf litter, trailing vegetation and trailing roots are abundant, providing a high level of microhabitat complexity. Riparian vegetation is continuous lowland or alluvial forest, while aquatic macrophytes are absent, which is likely due to channel scour and shading by riparian vegetation.

Plate 7.8 – Example of High- to Moderate-Gradient Tributary Stream in PRL-15 at Site 4 (Boa Creek)

Photo: BMT WBM.

Plate 7.9 – Example of Low-Gradient Slow- to Moderate-Flowing Tributary Stream in PRL-15 at Site 1B

Photo: BMT WBM.

The Purari River below Hathor Gorge (see Figure 7.10) is classed as an unconfined turbid major river system. In places, the river consists of multiple braided channels that are highly unstable and subject to shifts in position. The river can also form a continuous meandering channel that is also unstable, migrating over time (see Plate 7.4, Section 7.2.4.3). Downstream of Herd Base, the river has an extensive floodplain and in-channel sediment deposits. The river is highly turbid, is up to 11 m deep in areas, and comprises a continuous run hydraulic habitat (Plate 7.10). Substrates vary depending on channel form and include gravel, sands and muds. Riparian vegetation consists of continuous forests but is semi-continuous to patchy adjacent to villages and gardens.

Plate 7.10 – Highly Turbid Purari River (Unconfined Turbid Major River System)

Photo: TEP PNG.

The tributary streams near their confluence with the Purari River, including sites 11, 12, 13, 14 and 15, are classed as floodplain stream mouths (e.g., Plate 7.11). The mouths of floodplain streams are strongly influenced by the Purari River and have similar physical/hydraulic habitat characteristics. Extensive sand and cobble bars are present at most river mouth sites, which are dynamic features that vary in response to flow conditions (e.g., sites 12 and 14).

Plate 7.11 – Confluence of Nea Creek to PRL-15 Oxbow Wetlands Tie Channel and the Purari River, Site 11

Photo: BMT WBM.

The Purari River has an extensive floodplain containing palustrine wetlands (swamps), flooded forests and oxbow lakes. The degree of inundation by overbank flooding of these wetland types varies seasonally in response to flooding of the Purari River. Freshwater floodplain wetlands and oxbow lagoons occur in the southwest of PRL-15, with vegetation including mixed swamp forests, herbaceous swamps and swamp woodlands. Further detail regarding the flora composition is provided in Section 7.7.

The PRL-15 oxbow wetlands (Plate 7.12) are located in the southwest of PRL-15 approximately 18 km downstream of Herd Base (see Figure 7.10). Such oxbow lakes form where meander bends have been separated from the main channel. The PRL-15 oxbow wetlands may connect with the main channel of the Purari River during periods of high flow via the Nea Creek tie channel (see Plate 7.11). Aerial observations of the PRL-15 oxbow wetlands indicate submerged grasses and aquatic macrophytes occur along the littoral margins, with herbaceous swamp and swamp woodland vegetation dominating the surrounding area.

Plate 7.12 – PRL-15 Oxbow Wetlands

Photo: BMT WBM.

7.6.2.3 Purari River Delta

Downstream of Herd Base, the Purari River and other major distributaries within the delta, including the Urika-Ivo and Wame-Varoi rivers, are classified as unconfined turbid major river systems with an extensive floodplain (Plate 7.13).

Plate 7.13 – Unconfined Turbid Major River Systems, Wame-Varoi River

Photo: ERIAS Group.

The floodplain has large areas of floodplain forest containing palustrine wetlands and small off-river waterbodies (classed as freshwater floodplain wetlands and oxbow lakes). Section 7.7 describes the floristic characteristics of these wetlands, which include mixed swamp forests, herbaceous swamps and swamp woodlands. The low gradient of the Purari River has resulted in a gradual transition from forest to sago and nipa palms through tidal freshwater swamp forest to mangrove vegetation on the coast.

The Purari River delta estuary, including the Urika-Ivo and Wame-Varoi rivers, forms the transitional zone between freshwater environments and the Gulf of Papua. These major distributaries are up to 6 m deep and hundreds of meters wide and have low sinuosity with mid-channel bars and islands. The distributaries and secondary and side channels that comprise the estuary are heavily influenced by freshwater inputs from the Purari River and small subcatchments feeding directly into the estuarine zone.

Estuarine wetlands are found in the southern extent of the Purari River delta and primarily comprise mangrove forests (Plate 7.14). This habitat is tidally influenced despite the large freshwater inputs from the Purari River. The small estuarine creeks surveyed (sites 20, 21 and 22) were narrow (10 to 40 m) and deep (3 to 10 m). The upper reaches of these creeks were poorly flushed, with high organic loads, resulting in low dissolved oxygen concentrations less than 60% saturation. Point bars and silt deposits were observed at most creek confluences throughout the delta.

Plate 7.14 – Purari River Delta Estuarine Wetlands – Mangroves (*Sonneratia lanceolata)* on Shallow Bank

Photo: BMT WBM.

Based on observations from the current study and consistent with previous studies by Cragg (1983), the mangrove species *Sonneratia* dominates low-energy environments (i.e., inside bends) within the estuary while *Avicennia* and *Sonneratia* species are most abundant in more coastal environments. Mangrove communities are interspersed with freshwater species, particularly in more landward locations. *Nypa fruticans* is dominant in higher-energy environments, including creeks and along the Purari River main channel to the freshwater/estuarine boundary (Plate 7.15). A high diversity of mangrove communities occur along more quiescent creek margins in the lower estuarine areas, with species of *Sonneratia, Rhizophora, Xylocarpus, Avicennia, Ceriops*, *Bruguiera* and *Nypa* observed. The flora found in the Purari River delta is further described in Section 7.7.

Plate 7.15 – Purari River Delta Estuarine Wetlands – Nipa Palm (*Nypa fruticans*) Along Steeper Banks

Photo: BMT WBM.

The floodplain wetland types occurring along the Purari River are well represented throughout Papua New Guinea, including the Sepik River basin, Fly River basin and the numerous other river systems including the Kikori, Turama, and Vailala rivers that discharge into the Gulf of Papua.

7.6.2.4 Vaihua River Estuary

The Vaihua River estuary at Caution Bay is another example of an estuarine wetland with mangrove forests as the primary vegetation type (Plate 7.16). Mangroves are found along much of the coastline in Caution Bay and within the Vaihua River estuary. Saltmarshes and salt flats are found on the landward margin beyond the mangrove forests.

Plate 7.16 – Mangroves in the Vaihua River Estuary, Caution Bay

Photo: BMT WBM.

CNS (2008) previously noted the spotted red mangrove (*Rhizophora stylosa*), the dominant species in the area, to occur between 300 and 900 m from the waters edge to the beginning of the salt flats and accounts for over 90% of all mangrove individuals present. Other species observed in the area include the grey mangrove (*Avicennia marina*), club mangrove (*Aegialitis* *annulata*) and yellow mangrove (*Ceriops* sp.) (CNS, 2008). The survey undertaken in 2016 also found that *R. stylosa* is the dominant species in the Vaihua River estuary close to Caution Bay but is absent further inland at Site 29. Other species of *Rhizophora* and *Bruguiera*, the yellow mangrove (*Ceriops tagal*) and the myrtle mangrove (*Osbornia octodonta*) were also recorded in the Vaihua River estuary during the 2016 and 2017 survey.

7.6.3 Aquatic Fauna Baseline Characterization

This section provides information on aquatic macroinvertebrates, fish and crustaceans in the study area. Section 7.7.6 describes aquatic herpetofauna (i.e., turtles, crocodiles and frogs).

7.6.3.1 Aquatic Macroinvertebrates

Freshwater Environments (PRL-15 and Upper Purari River Delta)

Surveys of aquatic macroinvertebrate assemblages were conducted during the 2016 southeast trade wind season and 2017 northwest monsoon season in riffle, edge and pool hydraulic habitats.

Sixty-three aquatic macroinvertebrate families were identified during the surveys across both seasons. Assemblages across both survey periods were numerically dominated by mayfly (Ephemeroptera) families (Baetidae, Caenidae and Leptophlebiidae), which together accounted for 34% of the catch. Other abundant taxa were copepods, which accounted for approximately 19% of the catch; Hemiptera (true bugs), which accounted for over 17% of the catch; and non-biting midges from the subfamily Chironominae, representing approximately 17% of the catch. Other common fauna, occurring in lower abundance, were decapods (freshwater shrimp and prawns), Oligochaeta (worms) and Plecoptera (stoneflies).

Previous surveys in PRL-15 (DES, 2008, 2010) also found mayflies (Ephemeroptera) from the family Baetidae to be the most common macroinvertebrate. Atyidae shrimps were also widespread and abundant, while Caenidae mayflies and Philopotamidea caddisflies were widespread but not as abundant as Baetidae.

The following two endemic aquatic insect species, which Polhemus et al. (2004) found are restricted to the Papuan Gulf Coastal Lowlands ecoregion, are also expected to occur:

- The waterstrider *Ciliometra setosa* (family Gerridae).
- The waterstrider *Iobates ivimka* (family Gerridae).

The habitat requirements of these species are not well documented but are expected to mostly encompass quiescent freshwater environments (e.g., floodplain wetlands, backwaters and slow-flowing streams).

Estuarine Environments (Lower Purari River Delta)

Sampling at sites in the lower Purari River delta in 2016 identified 21 benthic macroinvertebrate taxa from at least 11 families. These comprised representatives from a range of common estuarine fauna groups, including mollusks, crustaceans (excluding macrocrustaceans) and polychaete worms. Polychaete worms were the dominant benthic macroinvertebrates, with species from the families Spionidae and Capitellidae accounting for approximately 70% of the total abundance. Bivalve mollusks accounted for around 8% of the total catch, while crustaceans, other than prawns, and gastropods accounted for 3% and 1% of the catch respectively.

Taxonomic richness and abundance varied greatly among sites, with poorly flushed environments in the upper reaches of brackish creeks having particularly depauperate assemblages. This observation is consistent with upper estuarine environments elsewhere that have fluctuating salinity levels, have low dissolved oxygen levels and are poorly flushed and, as such, typically have low benthic macroinvertebrate species richness and abundance (Saenger et al., 1988; Alongi 1990).

Estuarine Environments (Vaihua River Estuary)

Although no sediment samples were collected in the Vaihua River estuary during the 2016 and 2017 surveys due to safety risks from unexploded ordnances, previous studies (Hydrobiology, 2008b) identified 17 major taxa, including 41 families. The most abundant families or taxa included Oligochaeta (Naididae), Polychaeta (Amphinomidae, Spionidae), Ostracoda and Cumacea (Leuconidae). Polychaeta and Spionidae were also found to be abundant in the lower Purari River delta.

Polhemus et al. (2004) identified five freshwater invertebrate species as endemic to the South Papuan Peninsula Foreland ecoregion. These are the Gerridae (water striders) *Ciliometra femorata* and *Ptilomera breddini* and the Naucoridae (creeping water bugs) *Aptinocoris fenneri*, *A. sogeri* and *Cavocoris ismayi*. The ecology and salinity tolerance of these insect species is poorly known, but they are most likely found only in freshwater habitats. Sampling by Hydrobiology (2008b) did not identify any of these species in the Vaihua River estuary. On this basis, the Vaihua River estuary is unlikely to represent an important habitat for any of these endemic freshwater insects.

7.6.3.2 Fish and Macrocrustaceans

PRL-15 and the Purari River Delta

A total of 1,123 individual fish were recorded from 31 families represented by 61 species during the sampling undertaken in the 2016 and 2017 surveys. An additional 14 species from nine additional families were identified in villager fish catches. Ariidae (ariid catfish) was the most specious family, represented by 12 species, while Eleotridae and Gobiidae were represented by six and five species respectively. The remaining 28 fish families were represented by only one to three species.

Six fish species comprised 58% of the catch: Goldie River rainbowfish (*Melanotaenia goldiei*), estuarine glass perchlet (*Ambassis macracanthus*), greenback mullet (*Liza subviridis*), spoon-snouted catfish (*Nedystoma novaeguineae*, formerly known as *Doiichthys novaeguineae*), nursery fish (*Kurtus gulliveri*) and freshwater anchovy (*Thryssa scratchleyi*) (Table 7.4). Thirteen of the remaining species each accounted for between 1% and 4% of the catch, while the remaining 42 species comprised less than 1% each.

With regards to macrocrustaceans, 1,151 individuals were recorded from seven families in the 2016 and 2017 surveys. This included river prawns (Palaemonidae), shrimps (Atyidae) and mud crabs (*Scylla serrate*) in estuarine areas. The results showed that the study area supports a rich and abundant macrocrustacean fauna. A full list of species recorded and the numbers caught in the various habitats is provided in Part 5 of Volume 2.

The highest species diversity was recorded in the estuarine areas of the Purari River delta (39 species). In comparison, 15 species were recorded in the freshwater reaches of the Purari River delta, 18 species in the Purari River at tributary mouths and 24 species in the clear-water tributaries within PRL-15. Fish assemblages in the Purari River delta were dominated by species that are tolerant of fast-flowing and turbid conditions. The most abundant species in the Purari River delta, at both freshwater and estuarine locations, were estuarine glass perchlet (*Ambassis macrocanthus*), spoon-snouted catfish (*Nedystoma novaeguineae*) and greenback mullet (*Liza subviridis*).

Table 7.4 – Numerically Dominant Fish Species in the 2016 and 2017 Surveys

Species	% of Catch	Occurrence	Photo
Goldie River rainbowfish *(Melanotaenia goldiei)*	18%	Exclusively in tributary streams. Dominant fish species at most tributary creek sites.	
Estuarine glass perchlet *(Ambassis macracanthus)*	10%	Present in the Purari River delta in freshwater and estuarine waters.	
Greenback mullet *(Liza subviridis)*	9%	Present in the Purari River delta in freshwater and estuarine waters.	
Spoon-snouted catfish (*Nedystoma novaeguineae*)	8%	Present in the Purari River delta in freshwater and estuarine waters.	
Nursery fish (*Kurtus gulliveri*)	7%	Present in the Purari River delta in freshwater and estuarine waters.	
Freshwater anchovy *(Thryssa scratchleyi*)	6%	Present in the Purari River delta in freshwater and estuarine waters, and the upper reaches of the Purari River main channel (near PRL-15).	

Photos: BMT WBM.

In the clear-water tributaries, the most abundant species were from the families Palaemonidae (freshwater prawns), Eleotridae (gudgeons), Gobiidae (gobies), Terapontidae (grunters) and Melanotaeniidae (rainbowfishes). Species of *Macrobrachium* prawns were the most abundant fauna in the clear-water tributaries.

The majority of fish species identified during the 2016 and 2017 surveys are able to occur across both estuarine and freshwater environments or occur only as estuarine specialists, while very few freshwater specialists were identified. This is consistent with Haines (1979) and Allen (1991), who found that the majority of fish species in the lower Purari River are of marine origin and occur across both estuarine and freshwater environments.

Most species recorded were widespread in the study area. The exceptions were one species of goby (*Awaous* sp.) (site 10), the Bengal eel (*Ophisternon bengalense*) (site 2) and freshwater crabs from the family Hymenosomatidae (site 5) that were recorded at only one location in tributary streams in PRL-15. *Awaous* species have been recorded elsewhere in southern New Guinea and northeastern Australia so are not limited in their distribution to the study area. Bengal eels have a widespread distribution but are infrequently reportedly, and the Hymenosomatidae crabs are found in other regions in Papua New Guinea and around Australia.

No introduced (non-native) species were caught during the surveys; however, a common carp (*Cyprinus carpio*) was incidentally observed in the fish catch of local villagers in the Purari River delta area near site 18 (see Figure 7.10 and Plate 7.17). Introduced species are further discussed in Section 7.6.5.

All freshwater and estuarine fauna determined likely to occur in the study area are listed in Part 5 of Volume 2, based on the 2016 and 2017 surveys, previous observations and inference from distribution and habitat information. Threatened or sensitive aquatic fauna species are described in Section 7.6.4.1.

Plate 7.17 – Common Carp (*Cyprinus carpio*) Caught by Local Villagers (Lali Village, near Site 18)

Photo: BMT WBM.

Vaihua River Estuary, Caution Bay

Thirty fish species and five macrocrustacean species have previously been recorded in the Vaihua River estuary and surrounding catchment (Hydrobiology, 2008b). These are described in Part 5 of Volume 2. One fish species not previously observed, the seven-spot archerfish (*Toxotes chatareus*), was recorded during the survey undertaken in 2017. Schools of mullet (Mugilidae), garfish (Hemiraamphidae) and baitfish were also observed during the 2017 survey. The fish observed were primarily juveniles of marine species and were observed close to the mangroves.

Sediment sampling for macroinvertebrate species was not undertaken during the 2016 or 2017 surveys due to risks from unexploded ordnances.

7.6.4 Sensitive Species, Ecosystems and Habitat Features

7.6.4.1 Sensitive Species

Table 7.5 identifies 14 sensitive aquatic species occurring in the freshwater and estuarine study area, considers the likelihood of occurrence of the species and categorizes the species as one or more of the following:

- Species listed under the *Fauna (Protection and Control) Act 1966*.
- Trade-restricted under the Convention on the International Trade in Endangered Species (CITES) of Wild Fauna and Flora or the *International Trade (Fauna and Flora) Act 1979*.
- Species with a 'Threatened' status under the IUCN Red List of Threatened Species.
- Endemic or restricted-range species.
- Migratory and congregatory species.

Alien and native invasive species are not considered sensitive fauna, even where they occur in one of the above categories. This reflects the negative impact such species have on the ecosystem.

Further details on the listed categories and the process of classifying species are provided in Part 5 of Volume 2.

In summary, the following groups of sensitive species are either known, likely, or considered possible to occur in the study area:[14]

- Three Critically Endangered species, consisting of two sawfish species (*Pristis pristis* and *P. zijsron*) and one river shark (*Glyphis garricki*).
- One mangrove species (*Bruguiera hainesii*). Ono et al. (2016) consider *B. hainesii* to be a hybrid between *B. cylindrica* and *B. gymnorhiza*. Hybrids are not assessed under the IUCN Red List of Threatened Species and it is therefore not considered further here.
- Two Endangered species, the narrow sawfish (*Anoxypristis cuspidata*) (Plate 7.18) and speartooth shark (*Glyphis glyphis*).
- Four Vulnerable species, consisting of two ray species (*Glaucostegus typus*, *Urogymnus granulatus*) and two dolphin species (*Sousa sahulensis*, *Orcaella heinsohni).*
- One Near Threatened species, the bull shark (*Carcharhinus leucas*).
- Two aquatic insect species (waterstriders – *Ciliometra setosa* and *Iobates ivimka*) not considered Threatened on the IUCN Red List but identified as endemic to the Papuan Gulf Coastal Lowlands ecoregion by Polhemus et al. (2004).

Further description of the sensitive species listed in Table 7.5 is provided in Part 5 of Volume 2.

14 The following changes have been made to the IUCN rankings of recorded or potentially occurring species since undertaking the freshwater and estuarine biodiversity baseline study (based on the 2018 IUCN Red List): the orange-spotted grouper (*Epinephelus coioides*) has had its status downgraded from Near Threatened to Least Concern, and the Australian snubfin dolphin (*Orcaella heinsohni*) has had its status upgraded from Near Threatened to Vulnerable. There are no changes to nationally Protected status.

Table 7.5 – Sensitive Freshwater and Estuarine Species Potentially Present in the Study Area

Species Name	Common Name	IUCN*	CITES #	Other	Occurrence within Biotopes†						
					1	2	3	4	5	6	7
Bruguiera hainesii	Haines orange mangrove	CR	-	-	Does not occur	Does not occur	Does not occur	Does not occur	Does not occur	Known	Does not occur
Pristis pristis	Longtooth sawfish	CR	I	Migratory	Unlikely	Unlikely	Likely	Likely	Likely	Likely	Likely
Pristis zijsron	Green sawfish	CR	I	-	Does not occur	Does not occur	Does not occur	Possible	Does not occur	Possible	Does not occur
Anoxypristis cuspidata	Narrow sawfish	EN	I	Migratory	Does not occur	Does not occur	Does not occur	Possible	Does not occur	Possible	Does not occur
Glyphis glyphis	Speartooth shark	EN	-	-	Unlikely	Unlikely	Likely	Likely	Possible	Likely	Possible
Glyphis garricki	Northern river shark	CR	-	-	Unlikely	Unlikely	Likely	Likely	Possible	Likely	Possible
Carcharhinus leucas	Bull shark	NT	-	-	Unlikely	Unlikely	Likely	Likely	Likely	Likely	Likely
Glaucostegus typus	Giant shovelnose ray	V	-	-	Unlikely	Unlikely	Possible	Likely	Possible	Likely	Possible
Urogymnus granulatus	Mangrove whipray	V	-	-	Unlikely	Unlikely	Unlikely	Likely	Unlikely	Likely	Unlikely
Orcaella heinsohni	Australian snubfin dolphin	V	I	Migratory	Unlikely	Unlikely	Possible	Likely	Does not occur	Likely	Unlikely
Sousa sahulensis	Australian humpback dolphin	V	I	Migratory	Unlikely	Unlikely	Possible	Likely	Does not occur	Likely	Unlikely
Ciliometra setosa	Water strider	-	-	Considered to be endemic and range restricted	Likely	Unlikely	Unlikely	Does not occur	Likely	Does not occur	Likely
Iobates ivimka	Water strider	-	-	Considered to be endemic and range restricted	Likely	Unlikely	Unlikely	Does not occur	Likely	Does not occur	Likely

* IUCN, where CR – Critically Endangered; EN – Endangered; V – Vulnerable; NT – Near Threatened.
# CITES, where I refers to CITES Appendix I (species threatened with extinction).
† Biotopes are (1) tributary streams (high- to moderate-gradient), (2) tributary streams (low-gradient), (3) freshwater reaches of unconfined turbid major river systems, (4) estuarine reaches of unconfined turbid major river systems, (5) floodplain wetlands, (6) estuarine wetlands, and (7) oxbow wetlands and off-river waterbodies.

Plate 7.18 – Narrow Sawfish (*Anoxypristis cuspidata*) Observed in Villager Catch at Orokolo Bay

Photo: Ken Aplin.

7.6.4.2 Sensitive Ecosystems and Habitat Features

As described in Section 7.6.2, the study area contains a mosaic of upland, lowland and coastal landscapes and encompasses a wide diversity of aquatic biotope types, including tributary streams, floodplain and estuarine wetlands, and large river systems. These habitat features can be important in that they have unique aquatic biotope features in a regional or greater context, provide habitat for a high diversity of aquatic species or particular threatened species, or are areas that may promote species endemism.

The sensitivity rating of the various habitat types that occur in the study area is categorized in Table 7.6 and is based on an assessment of their vulnerability (i.e., the likelihood of a value being lost) and irreplaceability (i.e., the spatial limitation of a value). Further description of the method and criteria used in this assessment is provided in Part 5 of Volume 2[15].

Table 7.6 – Sensitivity Rating of Freshwater and Estuarine Habitats

Aquatic Habitat	Sensitivity Rating	Comments/Applicable Criteria
High- to moderate-gradient tributary streams	Low	Habitat type does not support specific life cycle functions of species with moderate, high or extreme vulnerability and is not considered to be unique.
Low-gradient slow- to moderate-flowing rivers and backwaters of large rivers	Low	Habitat type does not support specific life cycle functions of species with moderate, high or extreme vulnerability and is not considered to be unique.
Unconfined turbid major river systems (including the Purari, Urika-Ivo and Wame-Varoi rivers)	Moderate	Area potentially used by species with extreme vulnerability (*Pristis* and *Glyphis* spp.) for activities other than those critical to the life cycle of the species. Note: As the species occurrence in this habitat is currently unconfirmed, the sensitivity rating is moderate rather than high.
Freshwater floodplain wetlands on deltaic plains	Moderate	Area potentially used by species with moderate, high or extreme sensitivity (*Pristis pristis*, *Glyphis* spp. and *Glaucostegus typus*) for activities other than those critical to the life cycle of the species. Note: As the use of this habitat by these species is currently unconfirmed, the sensitivity rating is moderate rather than high or extreme.

15 Sensitivity is redefined in Chapter 11 consistent with ratings in Chapter 3. The different rating terminology used in baseline reflects the approach at the time the baseline was undertaken.

Table 7.6 – Sensitivity Rating of Freshwater and Estuarine Habitats (cont'd)

Aquatic Habitat	Sensitivity Rating	Comments/Applicable Criteria
Estuarine wetlands	High	Area used by species with moderate, high and extreme vulnerability (*Pristis pristis* and *G. typus*) that is critical to life cycle functions (i.e., spawning and nursery areas for a range of fish species).
B. hainesii stands	Extreme	Area supports species with extreme vulnerability.
Oxbow lakes (including the PRL-15 oxbow wetlands) and off-river water bodies	High	Area potentially supports unique assemblages of aquatic species and is a unique landscape feature within the lower Purari River catchment. Note: As it is uncertain whether oxbows actually support unique assemblages, the sensitivity rating of this habitat is high rather than extreme.
Mouth or delta of large river systems	Moderate	These areas represent a potential congregation point for various aquatic species that are able to move between marine and freshwater systems, including as part of life-cycle migrations. They have been given a moderate sensitivity rating because there are no distinctive migration routes of any species within the study area.
Plateaus	High	Area potentially supports unique assemblages of species due to isolation or discontinuity. Note: As it is uncertain whether plateaus actually support unique assemblages, the sensitivity rating of this habitat is high rather than extreme.
Crater Mountain Wildlife Management Area	High	Protected area.

The more sensitive environments of the study area include the estuarine wetlands and mangroves, which are used as nursery and spawning areas for a range of fish species. The mangrove forests of the Purari River catchment, together with the Kikori River and Omati River mangrove system, represent the largest contiguous mangrove forest system in Papua New Guinea and are among the largest in the Asia-Pacific region. These mangrove forests have among the highest number of mangrove species in the world, including the Critically Endangered *Bruguiera hainesii* (see Section 7.6.4.1).

Habitat areas potentially used by threatened species include turbid main river channels and floodplain wetlands. The main channel of the Purari River (including the Urika-Ivo and Wame-Varoi rivers) and large, semi-confined turbid tributaries in the Purari River delta provide suitable habitat for threatened river sharks (*Glyphis garricki* and *G. glyphis*), rays (*Glaucostegus typus*), sawfish (*Pristis pristis*) and dolphins (*Orcaella heinsohni* and *Sousa sahulensis*).

The freshwater wetlands, including the PRL-15 oxbow wetlands, also provide potential habitat for endemic aquatic insect species (*Ciliometra setosa* and *Iobates iyimka*). The western floodplain of the Purari River contains a wide diversity of wetland types, including palustrine (swamps), lacustrine (oxbow lake) and lotic (running stream) systems. Some of these wetland environments may contain peat wetlands. These are highly sensitive environments that support specialist aquatic fauna species that are adapted to the unique water chemistry of low pH, low nutrient levels and low turbidity. The distribution and extent of peat wetlands in Papua New Guinea is not well known, and it is therefore unknown whether they are well represented at a regional or national scale.

PRL-15 plateau catchments occurring north and south of PRL-15 (see Figure 7.10) support waterways that are separated from lowland environments by waterfalls. Isolation over geological timescales is a key driver of speciation, and such environments can represent centers of local endemism. Thus, endemic species or other features of evolutionary significance could occur on these plateaus.

7.6.5 Introduced and Invasive Species

While not recorded during the freshwater and estuarine surveys, an aquatic weed species, the water hyacinth (*Eichhornia crassipes*), was noted during the terrestrial biodiversity surveys in Nea Creek, in the PRL-15 oxbow wetlands and at the Purari Airstrip (see Section 7.7.6.6 for other weed species identified in the study area).

Other aquatic weed species are known to occur in Papua New Guinea and, although not recorded, may be present in the study area. These include the giant salvina (*Salvina molesta*) and water cabbage (*Pistia stratiotes*). In addition, hydrilla (*Hydrilla verticillata*) is considered to pose a potential future threat in Papua New Guinea (Orapa, 2006).

No introduced or invasive alien fish species were captured during the 2016 and 2017 field surveys, but some species have been identified as occurring in the study area from consultations with local villagers. A common carp (*Cyprinus carpio*) was observed in one fish catch, and anecdotal evidence from local fishermen suggests this species and tilapia (*Oreochromis mossambica*) are found in lacustrine environments such as the PRL-15 oxbow wetlands. DES (2010) also reported these two species to be present in the PRL-15 oxbow wetlands. Tilapia is also known to occur in the Vaihua River catchment, having been previously recorded approximately 2.5 km northwest of the Vaihua River estuary (Hydrobiology, 2008b).

Small-bodied Poeciliidae invasive species such as the mosquitofish (*Gambusia affinis*) and guppy (*Poecilia reticulata*) are not known in the Purari River but could occur, especially in slower flowing streams and floodplain environments. The mosquitofish (*Gambusia affinis*) is of most concern. The mosquitofish (*Gambusia affinis*) was introduced to Papua New Guinea to control mosquito populations. It has now become an established invasive species and has been reported to compete with small surface-feeding native species, such as fish and frogs, for food resources. There are records for this species in Lake Kutubu about 200 km northwest of Wabo, but there is little existing information on the population status of this species in the study area.

Other introduced fish species known to occur in the Purari River upstream of Hathor Gorge (see Figure 7.10) include snakeheads (*Channa striata*), walking catfish (*Clarias batrachus*) and climbing perch (*Anabas testudineus*), all of which compete or prey upon native fauna (Haines, 1983). Furthermore, rainbow trout *(Oncorhynchus mykiss),* brown trout *(Salmo trutta),* green swordtails *(Xiphophorus helleri*), blue panchax (*Aplocheilus panchax*) and gourami (*Trichogaster pectoralis* or *Trichogaster trichopterus*) are present in Papua New Guinea (Polhemus et al., 2004) and could in time colonize study area waterways.

7.6.6 Metals and Polycyclic Aromatic Hydrocarbons in Aquatic Fauna

Tissue samples were taken of selected freshwater and estuarine fish (i.e., 97 individuals of 17 species from 12 sites) and *Macrobrachium* prawn species (hind body tissue and cephalothorax (head) of 51 individuals from 11 sites) caught during the 2016 and 2017 surveys for laboratory analysis of metals, metalloids and PAHs. The results are presented and described in Part 5 of Volume 2 and provide information on current concentrations in various species in the study area against which future comparisons can be made.

Metal and metalloid concentrations were compared to international food standards for benchmarking. This includes maximum levels for contaminants permitted in foods, based on the consideration of risk to human consumers assuming a certain dietary intake, that have been developed by Food Standards Australia New Zealand (FSANZ) (ANZFA, 2015), the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) (FAO/WHO, 2006) and the United States Food and Drug Administration (USFDA) (USFDA, 2000). Comparison was also undertaken with generally expected levels (GELs) provided by FSANZ (ANZFA, 2001), which represent ninetieth percentile metal concentration that have been measured in Australian fish and shellfish. The GELs do not, therefore, represent a guideline for assessing the health risk associated with consuming fish and shellfish; however, the GELs do provide a benchmark for typical contaminant levels in fish and shellfish.

Biota take up contaminants, such as metals, metalloids and hydrocarbons, from their surrounding environment to a varying extent. The degree of uptake in aquatic fauna tissues depends on the pollutant type, body part, fauna species and its contaminant excretion rate and trophic level, and the physicochemical properties of the waters. For this reason, there is not always a strong correlation between contaminant levels in biota and the ambient environment where the specimen is captured, particularly for mobile species.

Metals and metalloids were detected in aquatic biota, with copper, lead and zinc concentrations in individual specimens often greater than GELs. Copper and lead concentrations in prawns exceeded GELs at most sites and were typically higher in the cephalothorax than the hind body tissues. The health-based USFDA Guidance Level for lead was also exceeded in one prawn at site 15 in the Purari River near Wabo in 2016. The cephalothorax contains most of a prawn’s organs and represents a site of metal processing and storage, hence higher metal concentrations occur in this body part.

Exceedances of GELs in fish tissue for copper and zinc occurred at most sites for most fish species. Furthermore, lead concentrations in one specimen of *Nedystoma novaeguineae* at site 22b in the Purari River delta estuary in 2016 and one specimen of *Valamugil buchanani* at site 14 in the Purari River upstream of Herd Base in 2017 exceeded the health-based FAO/WHO (2006) CODEX food standard. All other metal or metalloid concentrations were below guideline values or guideline values were not available. No other studies to date have examined metal and metalloid pathways in aquatic biota tissues in the study area.

Polycyclic aromatic hydrocarbon concentrations in all aquatic biota specimens were below detection limits.

7.7 Terrestrial Biodiversity

The information in this section has been drawn and synthesized from the Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2) and the Upstream Deforestation Baseline Report (Part 7 of Volume 2). More detailed information, including full field data results, is contained in those baseline reports and supporting annexes. Information on natural resource use is provided in Chapter 9.

7.7.1 Study Overview

The purpose of the terrestrial biodiversity study was to characterize the terrestrial biodiversity values of the Project area. This was undertaken at the three different scales of biological organization:

- Regional level – values associated with the national and broader regional biodiversity setting at a scale larger than that of the study area landscape.

- Ecosystems, habitats and focal sites – values include the composition and conservation value of the study area and its component landscape features, including ecosystems, protected areas, and 'focal sites',[16] and detailed vegetation mapping.
- Species level – values include the results of the baseline studies, with summaries for conservation-listed species, scientifically undescribed species, endemic and restricted-range[17] species, migratory and congregatory species, and invasive alien species. Seven major taxonomic groups were selected for focus at the species level: vascular plants, non-volant (non-flying) mammals, bats, birds, reptiles, amphibians and insects (represented by odonates). The individual taxonomic group studies are reported as Annex 1 (A to D) to Annex 6 in Part 6 of Volume 2. The vegetation and flora supporting studies include four individual studies on flora (A), vegetation communities and condition (B), weeds (C) and forestry (logging activities) (D). In addition, a separate deforestation baseline modeling study (Part 7 of Volume 2) has contributed to an analysis of anthropogenic effects on forests in the Project area.

Field surveys were undertaken for vegetation, flora and fauna over two seasons in 2016, i.e., the northwest monsoon season and the southeast trade wind season, at 14 sites (Figure 7.16), 13 of which were entirely within the Project area of influence (PAOI). Part 23 of Volume 2 has further information on field surveys.

The information presented in this section draws on the results of these field surveys, the review of existing data sources and expert opinion. These forms of assessment were supplemented with information provided by local community representatives, some of whom were assigned to assist with the terrestrial biodiversity field surveys.

7.7.2 Study Area

The upstream terrestrial biodiversity study area (hereafter 'study area') encompasses and expands on the ecosystems and habitats present in the upstream PAOI and is considered likely to support viable populations of most or all resident species whose distributions overlap Project components. Its boundaries are based on physical landscape features that influence the composition and distribution of terrestrial biotic communities, such as landform, substrate, elevation and watersheds. Figure 7.17 shows the study area. Covering approximately 7,292 km^2, it is bounded:

- In the north by the 500-m contour.
- In the west, from north to south, by the volcanic landforms of Mount Favenc, by the Era and Pie rivers and by Port Romilly.
- In the east, from north to south, by the Aure Scarp and the Vailala River.
- In the south by the Gulf Province coast, extended offshore to include intertidal habitats (e.g., mudflats) as determined by recent aerial and satellite imagery.

16 Various localized terrain and habitat features upon which multiple species or multiple individuals of one or more species are ecologically dependent.

17 Restricted-range species are defined as those that occur over an area less than 50,000 km^2.

TERRESTRIAL BIODIVERSITY SURVEY SITES

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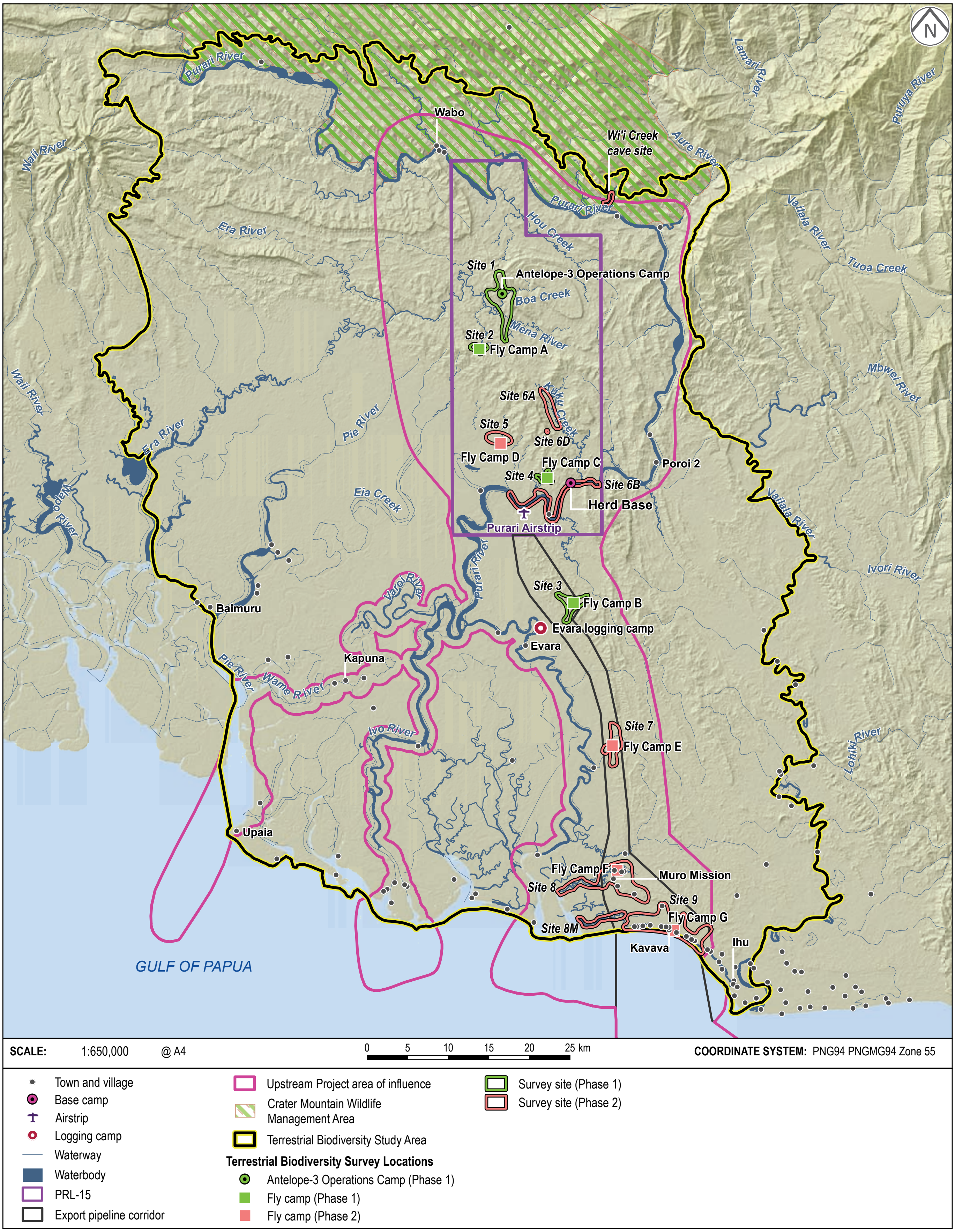
FIGURE 7.16



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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TERRESTRIAL BIODIVERSITY STUDY AREA, ECOLOGICAL ZONES AND MAJOR CATCHMENTS

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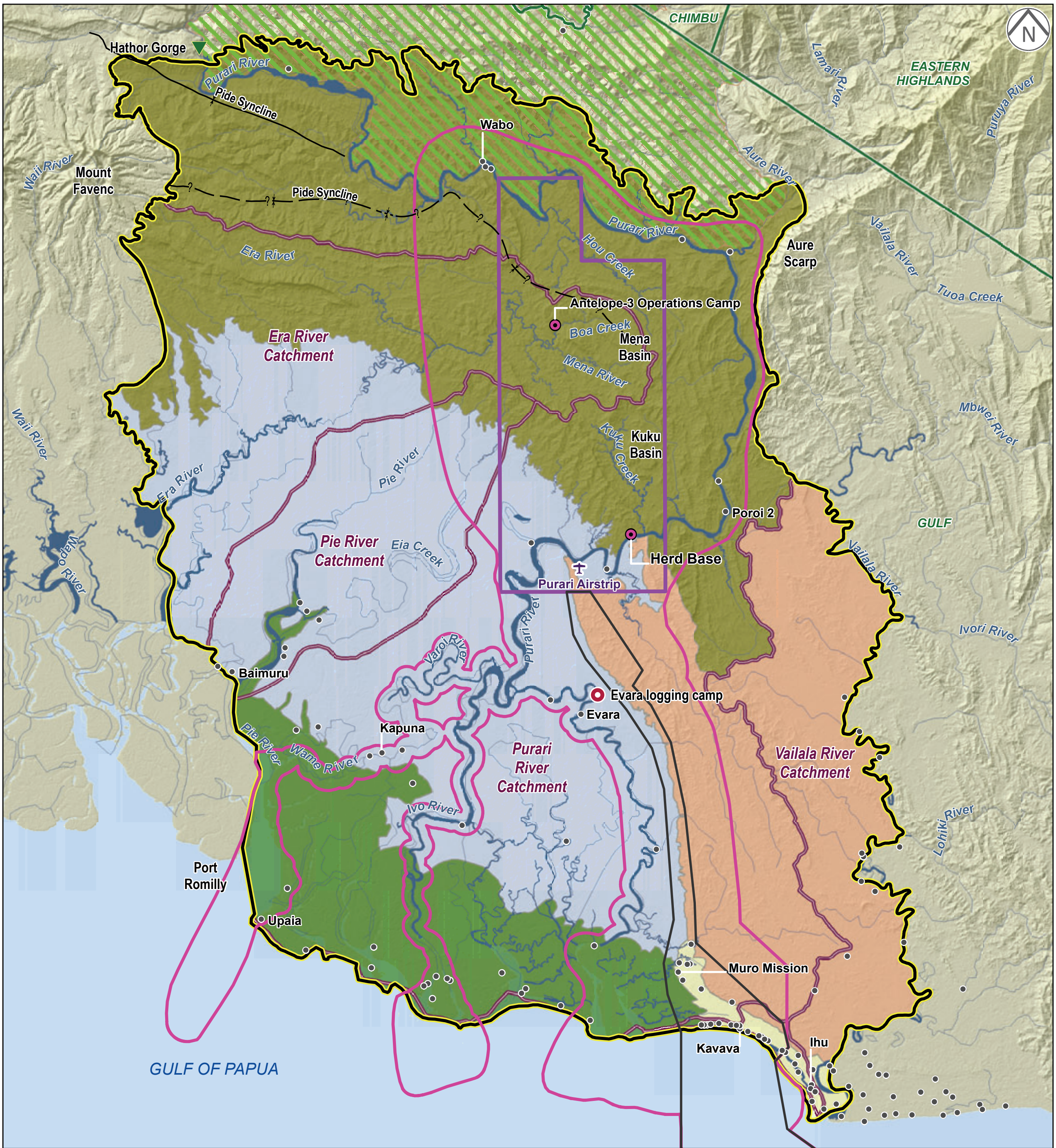
FIGURE 7.17



SCALE: 1:650,000 @ A4

0 5 10 15 20 25 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

Town and village	PRL-15	**Geological Structures**	Southeast Coast
Base camp	Export pipeline corridor	Syncline, accurate	Southeast Hills
Airstrip	Upstream Project area of influence	Syncline, approximate	
Logging camp	Crater Mountain Wildlife Management Area	Syncline, concealed	
Hathor Gorge	Catchment boundaries	**Ecological Zones**	
Province boundary	Terrestrial Biodiversity Study Area	Delta Swamps and Plains	
Waterway		Mangroves	
Waterbody		Middle Purari Hills	

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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The study area covers more than 21% of the land surface of Gulf Province, spans an elevational range of 600 m from sea level to the Kereru Range and encompasses a wide variety of terrestrial vegetation types and coastal marine and freshwater ecosystems occurring across five major catchments (see Figure 7.17), notably including the middle and lower reaches of the Purari River, Papua New Guinea’s third largest watercourse (Petr, 1983a).

7.7.3 Ecological Zones

The study area is divided into five ecological zones, defined primarily according to landform and vegetation, catchment boundaries or areas of marine tidal influence (see Figure 7.17). Each ecological zone is expected to support a distinct assemblage of terrestrial flora and fauna, although boundaries are notional with populations of most species spanning zonal borders. The physiographic features important in shaping the biological environments of the ecological zones are summarized in Table 7.7.

7.7.4 Regional and Biogeographic Setting

7.7.4.1 Regional Biodiversity Setting

New Guinea[18] is among the most biologically diverse and endemically rich regions on Earth (Olson & Dinerstein, 1998; Brooks et al., 2006; Jenkins et al., 2013; Mittermeier et al., 1997; Wikramanayake et al., 2002). It supports the third largest block of unbroken tropical rainforest in the world and the largest tract of primary rainforest remaining in the Asia-Pacific region (Beehler, 2007; Bryan & Shearman, 2015). Its forests support more than 5% of the world’s plant and animal species on less than 1% of its land surface (Faith et al., 2001). As a result, the area of New Guinea within which the study area is located has featured in multiple global biodiversity priority assessments that identified various high-level values.

7.7.4.2 Biogeographic Regions

The study area is located at the eastern end of New Guinea’s Southern Lowlands region, within which smaller biogeographic regions are recognized. The arrangement of these smaller biogeographic regions, both within and beyond the study area, differs among major taxonomic groups. Those relevant to the study area are outlined in Table 7.8 and the elevations of the regional area are shown in Figure 7.18.

7.7.4.3 Protected Areas and Proposed World Heritage Sites

Two protected areas are declared under the *Fauna (Protection and Control) Act 1966* in the vicinity of the study area, and one proposed world heritage site is under consideration by the United Nations Educational, Scientific and Cultural Organization (UNESCO). These are outlined in Table 7.9 and shown in Figure 7.18.

18 Refers to mainland New Guinea, the eastern half of which forms part of Papua New Guinea.

Table 7.7 – Ecological Zones within the Upstream Terrestrial Biodiversity Study Area

Ecological Zone	Description	Area (km²) (Percentage (%))			
		Study Area Total	Upstream PAOI	PRL-15	Export Pipeline Corridor
Middle Purari Hills	♦ Uplifted erosional landforms – an extensive area of low relief, even-peak foothills that extend north across a 30 to 40 km expanse from the head of the Purari River delta to the 500-m contour of New Guinea's central cordillera*, the northern boundary of the study area (see Figure 7.18). ♦ Elevation ranges from approximately 40 m asl to more than 600 m asl; primarily lies below 300 m asl. ♦ Geology is dominated by Tertiary sandstones and mudstones. Surface limestone occurs in limited areas outside of PRL-15, in the west along the Kereru Range and in the extreme north (Bain & MacKenzie, 1974; Pieters, 1980).	2,655.99 (36.4%)	596.34 (33.2%)	595.55 (77.0%)	0 (0%)
Southeast Hills	♦ Uplifted erosional landforms that lie between the Purari and Vailala rivers, south of the Middle Purari Hills and north of the Southeast Coast, and drain into the: – Delta Swamps and Plains ecological zone (Purari River catchment), or – Vailala River (Vailala River catchment). ♦ Geology and topography are similar to those of the Middle Purari Hills although no major limestones are present (Ruxton, 1969a; Pieters, 1980; Bryan & Shearman, 2008). ♦ Contains large areas of alluvial plains and back swamps interspersed among the ridge system. ♦ Elevation ranges from less than 10 m asl on the floodplains to more than 350 m asl on the ridge separating the Vailala River and Purari River catchments (see Figure 7.4); primarily lies below 200 m asl.	1,291.80 (17.7%)	397.33 (22.1%)	20.58 (2.7%)	89.34 (43.9%)
Delta Swamps and Plains	♦ Recent alluvial landform supporting a variety of freshwater swamp and alluvial forest habitats. Levee banks produced by regular flood deposits border the main distributaries and slope gently away into the backwater swamps (Bryan & Shearman, 2008). ♦ Composed of sediments (mud, silt, sand and gravel) deposited by the Purari, Pie and Era rivers (Pieters, 1980; Thom & Wright, 1983). ♦ Elevation ranges from less than 5 m asl to more than 60 m asl on a few isolated foothills near the base of the Middle Purari Hills; primarily lies below 25 m asl. ♦ Together with the Mangroves ecological zone it comprises the easternmost component of a much larger depositional system that stretches west and south along the Gulf of Papua to include the deltaic systems of the Kikori, Turama and Fly rivers (Thom & Wright, 1983).	2,411.81 (33.1%)	571.50 (31.8%)	157.40 (20.3%)	52.30 (25.7%)

Table 7.7 – Ecological Zones within the Upstream Terrestrial Biodiversity Study Area (cont'd)

Ecological Zone	Description	Area (km²) (Percentage (%))			
		Study Area Total	**Upstream PAOI**	**PRL-15**	**Export Pipeline Corridor**
Mangroves	♦ Recent alluvial landform under marine tidal influence. ♦ Forms the eastern part of the largest area of mangroves in Papua New Guinea, stretching west along the coast for approximately 150 km to the mouth of the Omati River (Percival & Womersley, 1975; Saulei & Beehler, 1993). ♦ Deltaic front is morphologically dynamic in response to active river dynamics, tidal flows, wave action and sediment deposition (Ruxton, 1969a; Thom & Wright, 1983; Shearman et al., 2013).	855.57 (11.7%)	170.72 (9.5%)	0 (0%)	17.16 (8.4%)
Southeast Coast	♦ An aggrading series of sub-parallel beach ridges and intervening swales and plains comprising recent littoral sands (Ruxton, 1969b; Ruxton et al., 1969; Bryan & Shearman, 2008). ♦ Also includes some minor mangrove and swamp areas.	77.62 (1.1%)	61.59 (3.4%)	0 (0%)	44.70 (22.0%)
Total		**7,292.79**	**1,797.48**	**773.53**	**203.50**

* Lands north of the study area rise much more abruptly, attaining heights of 1,000 m within a distance of 5 km.

Table 7.8 – Biogeographic Regions Relevant to the Study Area

Region Name	Relevant Taxonomic Group	Identified/ Defined by	Location/Description	General Overlap with Study Area
Kikori-Purari	Warm-blooded vertebrates (mammals and birds)	Beehler, 1993	This region is contained in the Gulf Province lowlands (below 500 m asl) and extends from the Turama River east to the Vailala River. The Lakekamu Basin east of the study area is outside of this biogeographic region.	Study area is contained entirely within the region.
Gulf Lowlands	Lower vertebrates (fish and herpetofauna) and terrestrial insects	Allison, 1993; Miller, 1993	Lowlands spanning the Gulf of Papua, from the Fly River (Western Province) east across Gulf Province to near Hall Sound (Central Province). Includes the Lakekamu Basin.	Includes the southern part of the study area, north to approximately the southern boundary of the Middle Purari Hills ecological zone.
Eastern Highlands			Approximately follows the southern boundary of the Middle Purari Hills ecological zone and extends north to montane environments above 3,000 m asl.	Includes the northern part of the study area.
Papuan Gulf Coastal Lowlands	Aquatic insects*	Polhemus et al., 2004	Includes the southern coastal lowlands below 50 m asl from the Kikori River delta east to Kerema.	Includes the southern part of the study area, including the Delta Swamps and Plains, Mangroves and Southeast Coast ecological zones and parts of the Southeast Hills ecological zone.
Papuan Gulf Foreland			Comprises the basins of the Kikori, Purari, Vailala and Lakekamu rivers at elevations between 50 and 1,200 m asl.	Includes the northern part of the study area, including the Middle Purari Hills and parts of the Southeast Hills ecological zones.

* Including odonates (dragonflies/damselflies), an insect group with both aquatic (larva) and terrestrial (adult) life stages.

Table 7.9 – Protected Areas and Proposed World Heritage Sites Relevant to the Study Area

Name	Location/Description	Study Area Locality
Crater Mountain Wildlife Management Area (WMA)	Comprises approximately 2,700 km^2 of northern central Gulf Province and parts of Chimbu Province and Eastern Highlands Province to elevations over 3,100 m asl.	Northern extremity of the study area overlaps the southern portion of this WMA.
Neiru (Aird Hills) WMA	Covers approximately 25 km^2 of the Kikori River catchment lowlands, located west of the study area within 50 km of its southwestern boundary.	No overlap with the study area.
Kikori River Basin/Great Papuan Plateau proposed World Heritage site	Covers more than 20,000 km^2 and over 6% of PNG's land mass. The site extends more than 300 km northwest from the Purari River delta to encompass Mount Bosavi, the Great Papuan Plateau and parts of the Southern Fold Mountains. Its southeastern boundary lies approximately 15 km from the study area at its closest point in the Purari River delta.	No overlap with the study area.

REGIONAL SETTING OF THE TERRESTRIAL BIODIVERSITY STUDY AREA

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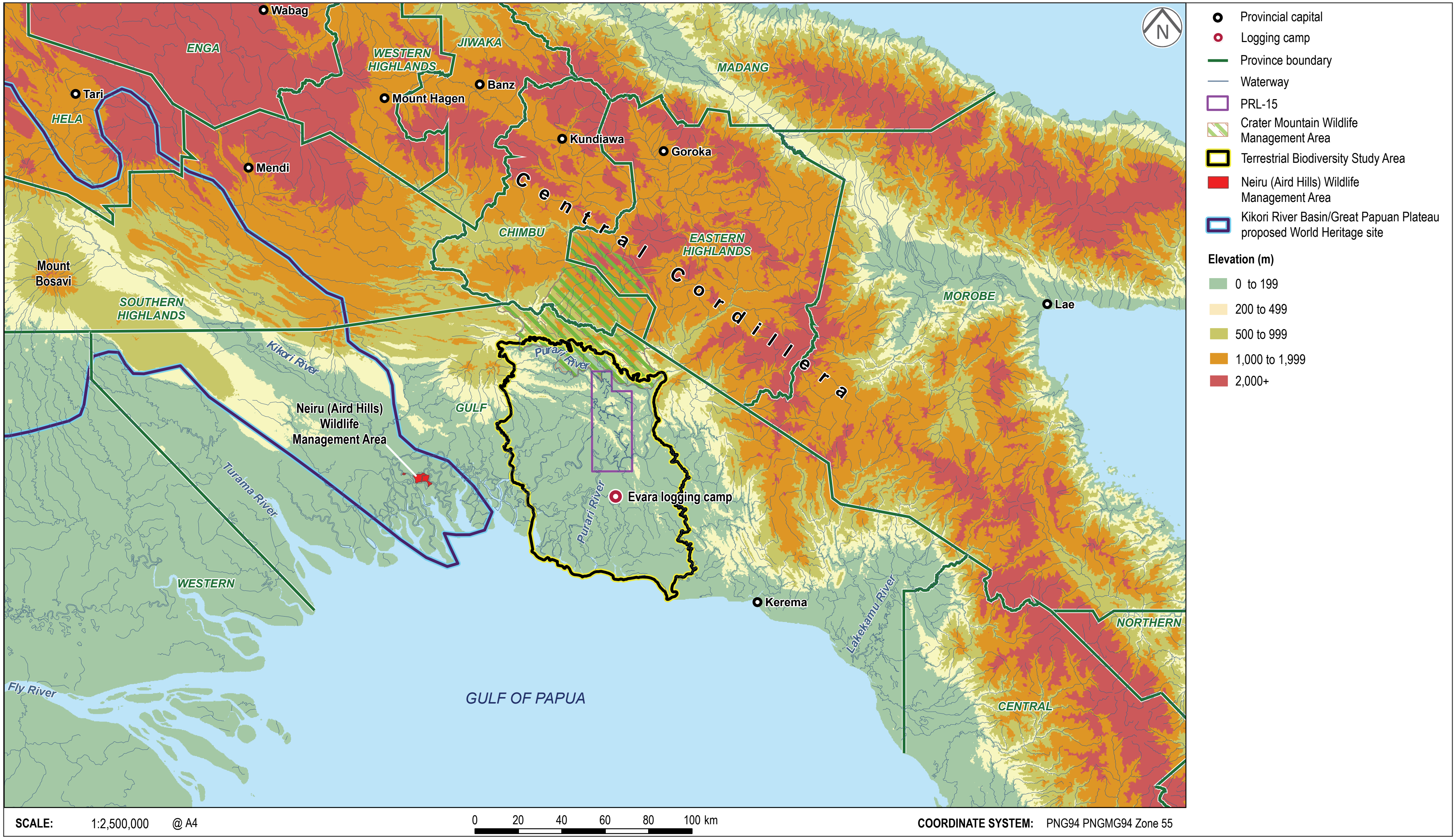
FIGURE 7.18



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7.7.5 Vegetation

7.7.5.1 Approach

The following sections describe vegetation communities present in the study area. Natural vegetation types are first described (Section 7.7.5.2), followed by overlying patterns of anthropogenic disturbance within the study area (Section 7.7.5.3) and description of the vegetation types and condition present in key Project areas (Section 7.7.5.4).

The classification of natural vegetation types is based on the Forest Inventory Mapping System (FIMS) dataset (Hammermaster & Saunders, 1995a, 1995b). The FIMS vegetation maps were revised to improve resolution and accuracy in key Project component areas in the PAOI and along the coastal boundary of the study area through examination of recent aerial or satellite imagery, LIDAR digital elevation modeling, and ground and aerial surveys. Outside of these areas, vegetation mapping at the FIMS scale was accepted as reasonable; and no further refinement was undertaken.

Two types of anthropogenic disturbance to natural vegetation are distinguished:

- Degradation – degraded vegetation retains a natural species composition, although altered in structure or proportional floristic composition. It has been mapped in this study as natural vegetation and includes areas of post-logging secondary forest.
- Loss – habitat loss results from the removal of natural vegetation or its replacement with predominantly non-native plant communities, including gardens and agroforestry. Vegetation loss is recorded here in two ways:
  1. As converted land under the Land use (O) and Urban areas (U) FIMS types.
  2. In areas of vegetation loss that are too small to be mapped at the FIMS scale, as numeric disturbance codes appended to the vegetation mapping units: from 4 (40% intact) to 9 (90% intact). Disturbance codes are displayed in the detailed vegetation maps shown in Figures 7.19 and 7.20. The vegetation types associated with the FIMS codes are shown in Table 7.10.

Recent vegetation losses, additional to those mapped under FIMS (original and revised) as converted lands, were identified based on areas of non-vegetation mapped as roads and bare ground under the Upstream Deforestation Baseline Report (Part 7 of Volume 2).

Overlay maps of post-logging secondary forest were prepared by combining harvested areas mapped under the Upstream Deforestation Baseline Report (Part 7 of Volume 2) and areas of secondary forest digitized from the PNG Forest Observatory website (& Shearman, 2015b). Logged areas in PRL-15 and the export pipeline corridor were verified and adjusted as required, based on visual assessment of aerial or satellite imagery and ground-truthing from flora and fauna surveys.

7.7.5.2 Vegetation Types

The study area land surface is covered almost entirely in natural vegetation (98.9%), including primary and secondary forest types. Five broad vegetation groups (BVGs) are identified within the study area, based on vegetation structure and floristics and on landform affiliations (following Paijmans (1976) and Hammermaster & Saunders (1995a)): hill forest, alluvial forest, freshwater swamp vegetation, mangroves and littoral forest. In the study area, landform, topography and geology are the principal determinants of vegetation community structure;[19] and as a result, these

19 Climate and elevation have limited effect at the study area scale.

VEGETATION AND ANTHROPOGENIC DISTURBANCE IN THE PRL-15 AREA

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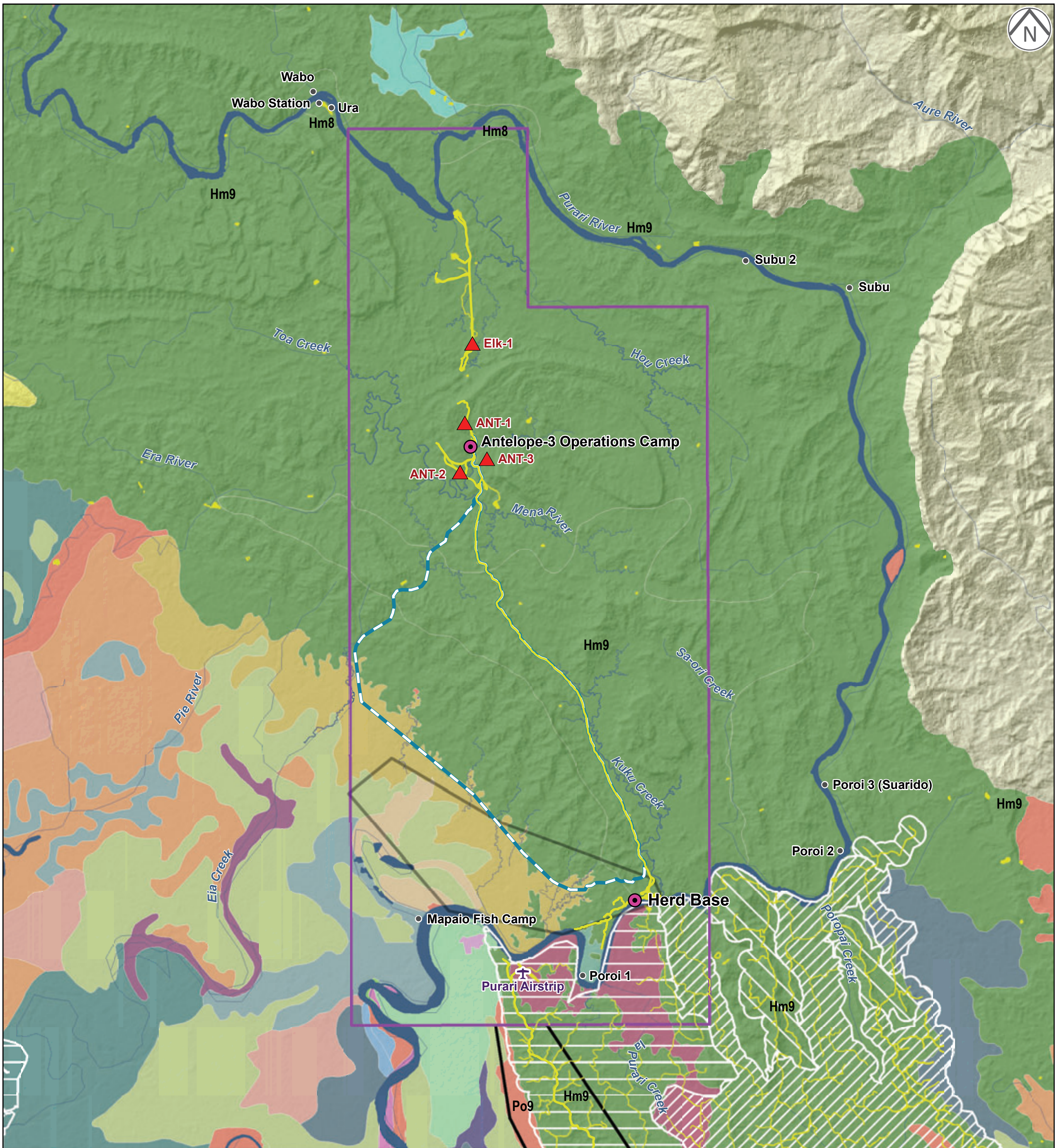
FIGURE 7.19



SCALE: 1:300,000 @ A4

0 2 4 6 8 10 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Airstrip
- Wellpad
- Waterway
- PRL-15
- Export pipeline corridor
- CPF, logistics base and airstrip area
- Trunkline corridor
- Tracks, logging roads and cleared land

Post-logging Secondary Forest

- 2002
- 2015
- 2015+

Vegetation Type

- Hm
- Hm/Hs
- Pl
- Pl/Fsw
- Po
- Po/Fsw
- Po/Fsw/Hm
- Ps
- Fri
- Fsw
- FswC
- Fsw/Wsw
- Wsw
- Wsw/Fsw
- Wsw/Gsw
- Wsw/Hsw
- Gsw/Wsw
- Gri
- Hsw
- Hsw/Gsw
- Hsw/Wsw

Disturbance Code

Hm9*

* *A numeric disturbance code is appended to the vegetation mapping unit. The higher the code, the more intact the vegetation (e.g., 4 = 40% intact). Where there is no code, the vegetation can be assumed to have little disturbance (more than 90% intact).*

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VEGETATION AND ANTHROPOGENIC DISTURBANCE IN THE EXPORT PIPELINE CORRIDOR AND RIVER TRANSPORT ROUTE AREAS

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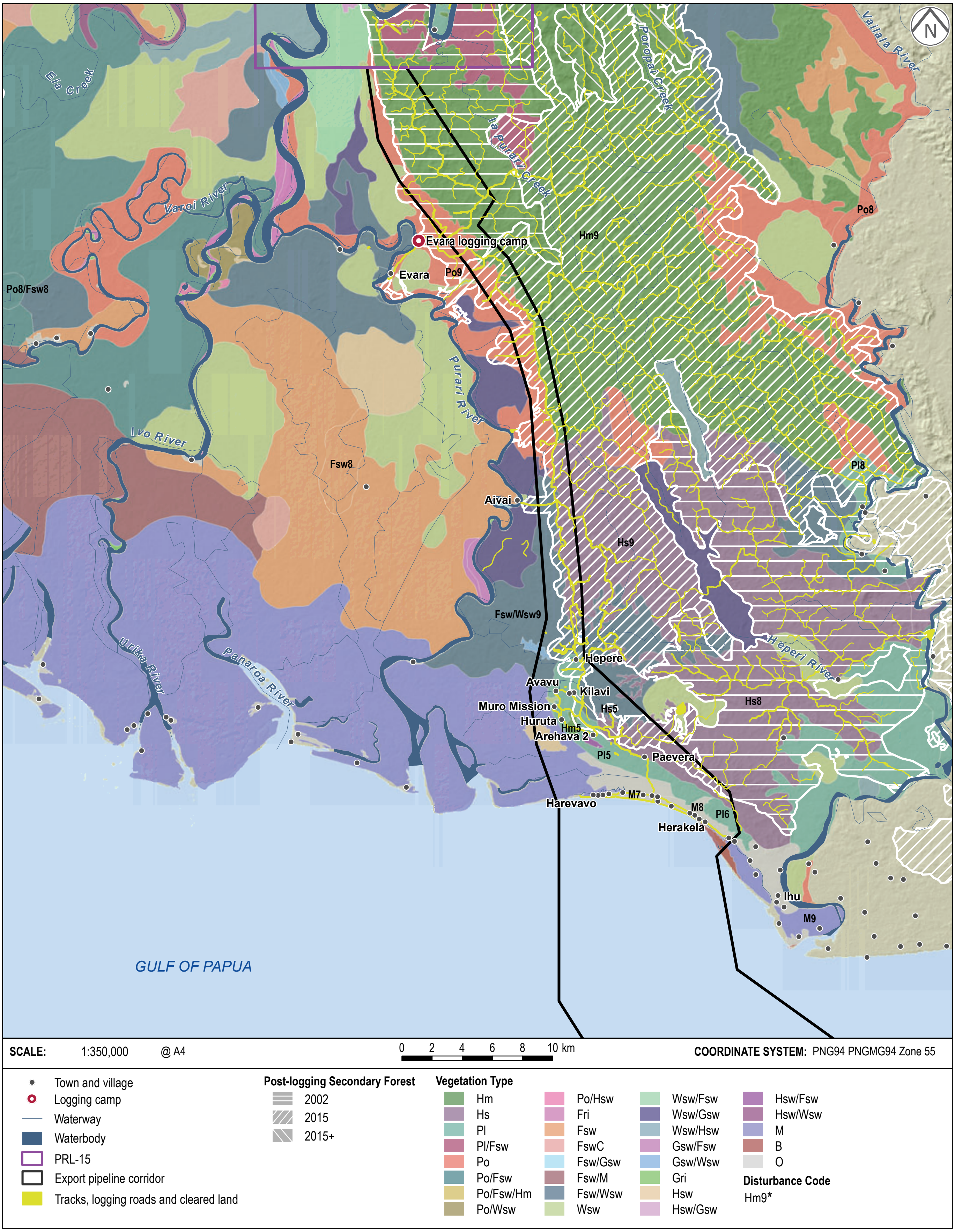
FIGURE 7.20



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

* A numeric disturbance code is appended to the vegetation mapping unit. The higher the code, the more intact the vegetation (e.g., 4 = 40% intact). Where there is no code, the vegetation can be assumed to have little disturbance (more than 90% intact).

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BVGs each occupy a distinct physical environment, linked to the ecological zones, which are also defined principally according to landform and vegetation (see Section 7.7.3). The BVGs are summarized in the following points and shown in Figure 7.21, and their proportions in the study area and each ecological zone are shown in Figure 7.22:

- Hill forest – this BVG is the natural vegetation type occurring on all areas of hill terrain in the study area, which are predominantly uplifted landforms of the Middle Purari Hills and Southeast Hills ecological zones. It is the most widespread BVG, covering more than 3,400 km^2 and 48.7% of the study area land surface in its various forms. Hill forest is floristically rich, and its structure varies with terrain and substrate. Relatively fertile and stable soils in the study area support forest 25 to 30 m tall with emergent trees to 40 m. On low nutrient or unstable, shallow soils the hill forest reaches 20 to 30 m tall with fewer emergents.
- Alluvial forest – occurs on recent depositional landforms in areas well drained or subject to periodic inundation, on the Delta Swamps and Plains, and also in the Southeast Hills and the Southeast Coast ecological zones. Alluvial forest often occurs as a dominant type (50% to 80% of the mapping unit) in complexes with other BVGs, most commonly freshwater swamp vegetation types. In its various forms, including complexes, it covers more than 1,160 km^2 (16.6%) of the study area. It is tall and floristically rich. Forest structure is variable, with drainage and soils among the dominant abiotic factors. Canopies are often open with numerous gaps and with a dense understory rich in saplings, palms, pandanus , gingers, lianes and epiphytes.
- Freshwater swamp vegetation – this is the second most widespread BVG within the study area, covering nearly 1,800 km^2 and 25.6% of its land surface in its various forms. It occurs in areas subject to frequent or permanent flooding. It is most widespread on the composite levee plains of the Delta Swamps and Plains and interior margins of the Mangroves ecological zones, predominantly on the poorly drained back plains spanning the vast interfluvial areas behind riverine levee banks, with other major occurrences in the Purari River and Vailala River catchments in the Southeast Hills and, to a lesser extent, the Southeast Coast ecological zones.

  Freshwater swamp vegetation within the study area encompasses five distinct base vegetation types, each occupying a discrete environment defined by variation in the depth, movement or periodicity of inundation. These grade into one another and into adjacent alluvial forest and mangrove vegetation through a variety of complex forms, as relatively minor changes in topography influence local hydrological and overlying vegetation patterns in a low relief environment.
- Mangroves – the mangrove ecosystem (mangal) is a community of salt-tolerant plant species growing in coastal, estuarine and riverine areas that are subject to periodic tidal inundation and protected from heavy wave action (Giri et al., 2011). Plant diversity in mangrove forest is low compared to non-saline lowland rainforest ecosystems. Mangroves cover 603.6 km^2 of the study area, 97.9% of which occur within the Mangroves ecological zone, with minor occurrences in the Southeast Coast (11.6 km^2) and the Delta Swamps and Plains (1.1 km^2) ecological zones.

BROAD VEGETATION GROUPS OF THE STUDY AREA

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FIGURE 7.21

SCALE: 1:650,000 @ A4 | 0 5 10 15 20 25 km | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Province boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- Terrestrial Biodiversity Study Area
- Ecological zones
- Catchment boundaries

Broad Vegetation Groups

- Littoral forest
- Converted lands
- Freshwater swamp vegetation
- Hill forest
- Mangroves
- Alluvial forest

Largely represents the terrestrial biodiversity baseline survey area.
Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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PROPORTION OF BROAD VEGETATION GROUPSAND CONVERTED LANDS IN THE STUDY AREA AND ECOLOGICAL ZONES

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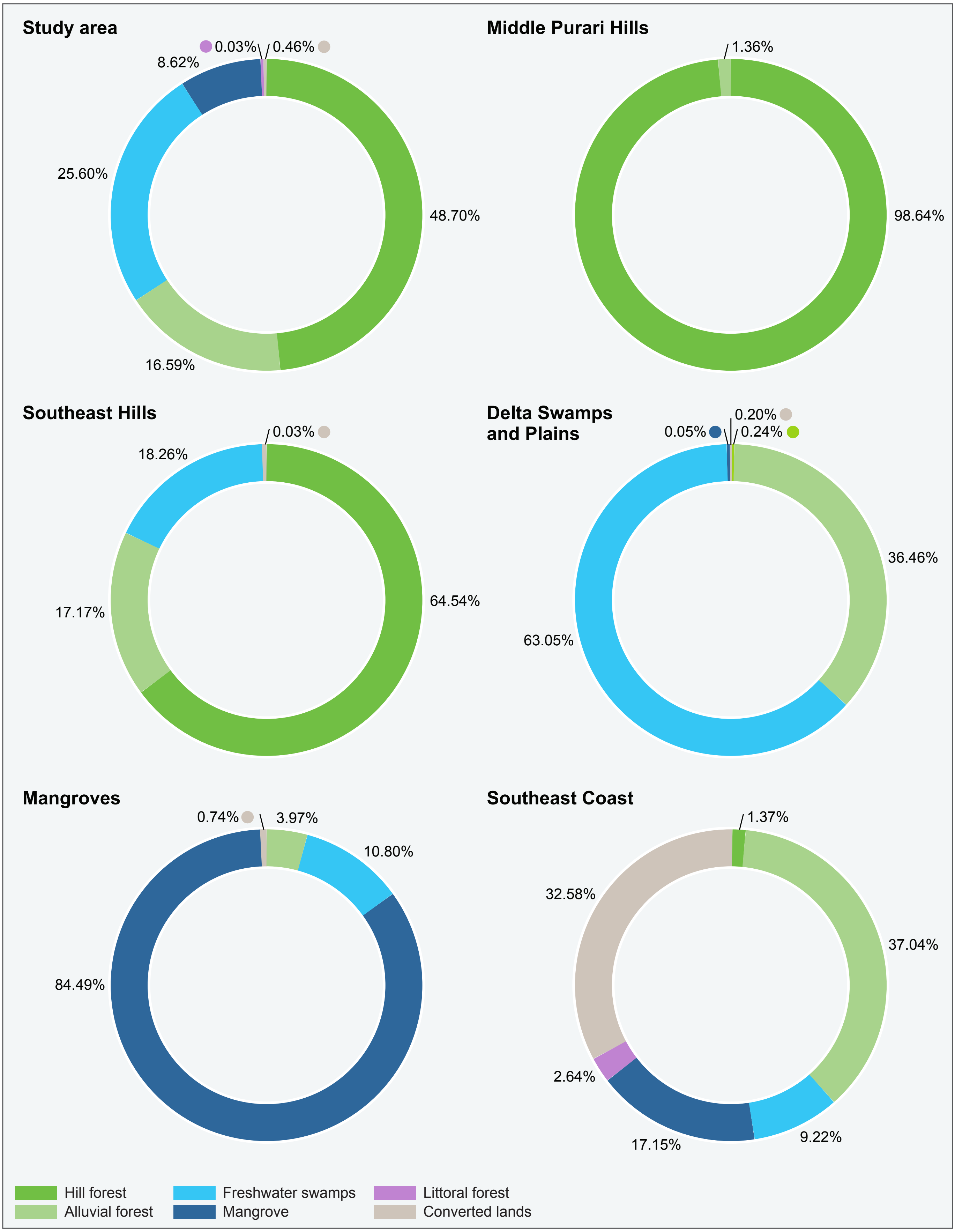
FIGURE 7.22



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- Littoral forest – this vegetation grows on dry sandy beach ridges and plains and comprises a succession of vegetation types. The only mapped occurrences of this BVG in the study area are found in 1.8 km^2 of coastal habitats (e.g., beach ridges and plains) in the Southeast Coast ecological zone.

Within these environments, further variations in terrain, soils, flooding and tidal regimes influence the distribution, structure and floristics of the component natural vegetation types. At this level, 32 FIMS-coded natural vegetation types are recognized within the five BVGs, plus two land cover types denoting areas where the original vegetation has been converted for anthropogenic land use (converted lands) (Table 7.10; Figure 7.23).

Table 7.10 – Vegetation Types Within the Study Area and Each Project Component Area

Broad Vegetation Group/ Vegetation Type	FIMS Code	Study Area		Project Component Area		
		Area (km^2)	Cover (%)	PRL-15*	Export Pipeline Corridor	Riverways
Hill forest BVG		***3,409.79***	***48.70***			
Hill forest	Hm	3,013.61	43.04	X	X	–
Hill forest, *Araucaria* noted	Hm.Ar	19.24	0.27	–	–	–
Small crowned hill forest	Hs	321.08	4.59	–	X	–
Hill forest/Small crowned hill forest	Hm/Hs	55.86	0.80	–	–	–
Alluvial forest BVG		***1,161.94***	***16.59***			
Alluvial forest	Pl	113.05	1.61	X	X	
Alluvial forest/Swamp forest	Pl/Fsw	35.40	0.51	X		
Open alluvial forest	Po	334.46	4.78	X	X	X
Open alluvial forest/Swamp forest	Po/Fsw	441.24	6.30	–	–	X
Open alluvial forest/Swamp forest/Hill forest	Po/Fsw/Hm	78.77	1.12	X	–	–
Open alluvial forest/Swamp forest/Mangrove	Po/Fsw/M	101.38	1.45	–	–	–
Open alluvial forest/Herbaceous swamp	Po/Hsw	0.85	0.01	–	–	X
Open alluvial forest/Swamp woodland	Po/Wsw	8.64	0.12	–	–	X
Small crowned alluvial forest	Ps	39.61	0.57	–	–	–
Riverine seral forest	Fri	8.54	0.12	X	–	X
Freshwater swamp vegetation BVG		***1,792.43***	***25.60***			
Swamp forest	Fsw	642.83	9.18	–	–	X
Swamp forest with *Campnosperma*	FswC	89.10	1.27	X	–	–
Swamp forest/Swamp grassland	Fsw/Gsw	0.33	0.01	–	–	X
Swamp forest/Mangrove	Fsw/M	121.75	1.74	–	–	X
Swamp forest/Swamp woodland	Fsw/Wsw	260.60	3.72	X	X	X
Swamp woodland	Wsw	423.07	6.04	X	X	X
Swamp woodland/Swamp forest	Wsw/Fsw	34.57	0.49	X	–	X
Swamp woodland/Swamp grassland	Wsw/Gsw	67.20	0.96	X	X	X

Table 7.10 – Vegetation Types Within the Study Area and Each Project Component Area (cont'd)

Broad Vegetation Group/ Vegetation Type	FIMS Code	Study Area		Project Component Area		
		Area (km²)	Cover (%)	PRL-15*	Export Pipeline Corridor	Riverways
Freshwater swamp vegetation BVG		***1,792.43***	***25.60***			
Swamp woodland/Herbaceous swamp	Wsw/Hsw	77.83	1.11	X	–	–
Swamp grassland/Swamp forest	Gsw/Fsw	3.38	0.05	–	–	X
Swamp grassland/Swamp woodland	Gsw/Wsw	3.82	0.06	X	X	–
Riverine successional grassland	Gri	2.05	0.03	X	–	X
Herbaceous swamp	Hsw	47.67	0.68	X	X	X
Herbaceous swamp/Swamp grassland	Hsw/Gsw	0.75	0.01	X	–	–
Herbaceous swamp/Swamp forest	Hsw/Fsw	0.53	0.01	–	X	–
Herbaceous swamp/Swamp woodland	Hsw/Wsw	16.95	0.24	–	–	–
Mangroves BVG		***603.63***	***8.62***			
Mangrove	M	603.63	8.62	–	X	X
Littoral forest BVG		***1.78***	***0.03***			
Littoral forest	B	1.78	0.03		X	
Converted lands		***32.17***	***0.46***			
Land use	O	30.07	0.43	–	X	X
Urban areas	U	2.10	0.03			
Other losses#	*n/a*	***44.23***	***0.63***			
Total Land Area		**7,001.74**	**100.00**			
Total Natural Vegetation Cover		**6,924.99**	**98.90**			

* PRL-15 is used here to represent the area of production, processing and related facilities.
# Areas of non-vegetation mapped as roads and bare ground under the Upstream Deforestation Baseline Report (Part 7 of Volume 2). Mapped separately from the vegetation mapping, they are subtracted independently from the total natural vegetation cover, but not the total land area, to calculate the proportion of the study area supporting natural vegetation.

7.7.5.3 Anthropogenic Disturbance

Habitat Loss

Mapped areas of habitat loss amount to approximately 1.1% of the study area land surface. Approximately 32 km^2 of converted lands are identified as Land use (O) and Urban areas (U) (see Table 7.10) and primarily occur along the relatively settled coastal strip of the Southeast Coast ecological zone, with some additional areas around villages along the coast in the Mangroves ecological zone and along major waterways on the Delta Swamps and Plains ecological zone. An additional 44.2 km2 of cleared land was recorded under the deforestation study (Part 7 of Volume 2) and 96% is attributed to clearance for logging roads and associated infrastructure, with additional minor contributions associated with subsistence agriculture (1.9%) and petroleum sector activities (1.5%), the latter mostly within PRL-15.

Between 2000 and 2014, approximately 3,139 ha (0.72%) of forest area were lost from the deforestation study area, which is within the eastern 63% of the study area. Rates of forest loss were faster between 2000 and 2007 than between 2007 and 2014 (Table 7.11). The greater forest

VEGETATION TYPES WITHIN THE STUDY AREA

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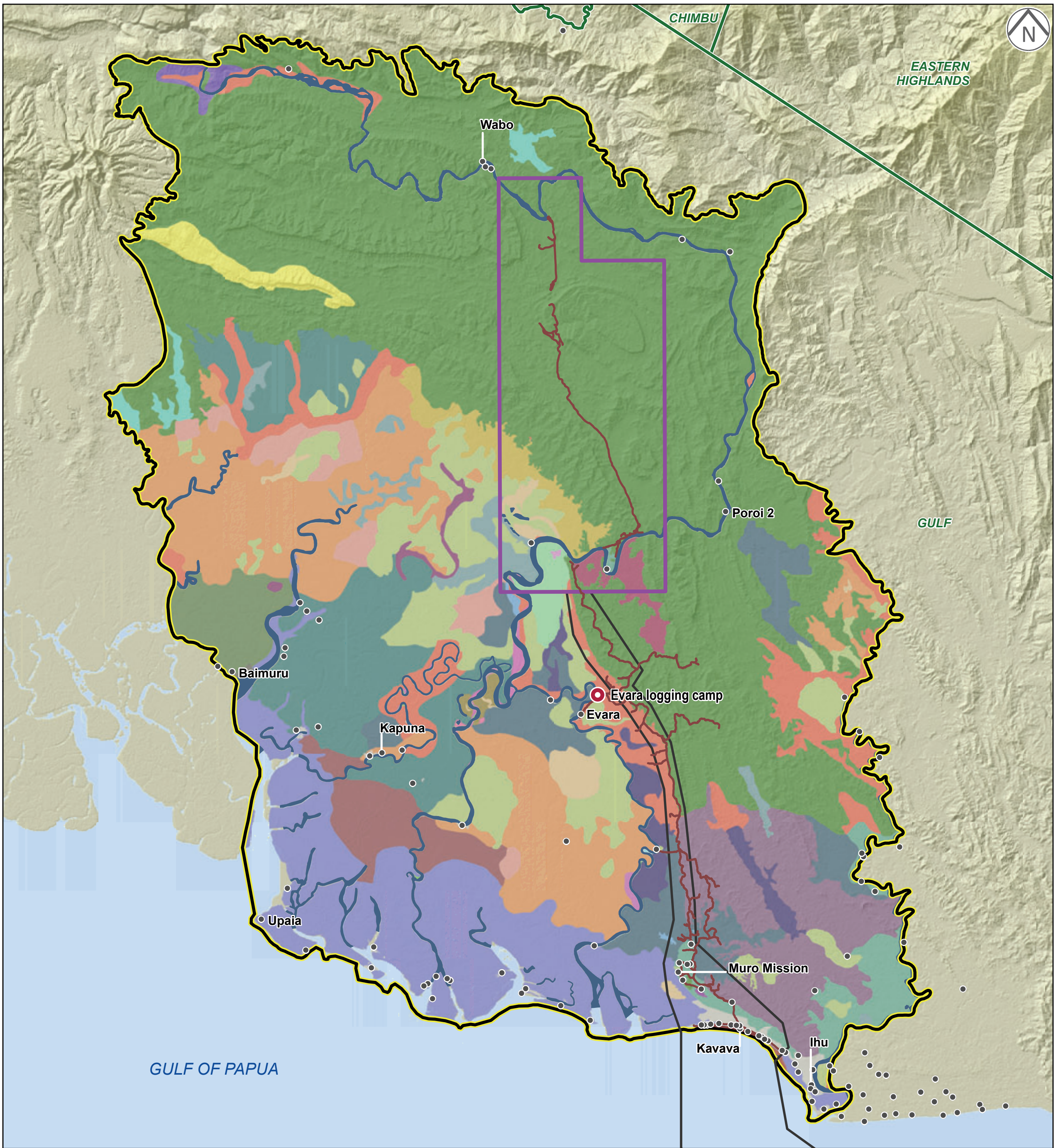
FIGURE 7.23



SCALE: 1:650,000 @ A4 — 0 5 10 15 20 25 km — COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Logging camp
- Province boundary
- Track
- Waterbody
- PRL-15
- Export pipeline corridor
- Terrestrial Biodiversity Study Area

Vegetation Type

Hm, HmAr, Hs, Hm/Hs, Pl, Pl/Fsw, Po, Po/Fsw, Po/Fsw/Hm, Po/Fsw/M, Po/Hsw, Po/Wsw, Ps, Fri, Fsw, FswC, Fsw/Gsw, Fsw/M, Fsw/Wsw, Wsw, Wsw/Fsw, Wsw/Gsw, Wsw/Hsw, Gsw/Fsw, Gsw/Wsw, Gri, Hsw, Hsw/Gsw, Hsw/Fsw, Hsw/Wsw, M, B, O, U

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

losses between 2000 and 2007 were shown to relate to the development of logging tracks and infrastructure in the lower and more accessible terrains of Vailala Block (Blk) 3 at the south and east ends of the export pipeline corridor. Fewer roads and less infrastructure appeared to be developed in the northeast portion of the block between 2007 and 2014.

Table 7.11 – 2000 to 2014 Land Use and Change

Period	Changed Area (ha)			Net Period Change (%)	Annual Change Rate (%)
	Forest to Non-forest	Non-forest to Forest	Net Period Change		
2000 to 2007	2,152	190	1,962	0.45	0.06
2007 to 2014	1,177	0	1,177	0.27	0.04
2000 to 2014	**3,329**	**190**	**3,139**	**0.72**	**0.05**

Degradation Through Commercial Forestry

Commercial forestry is the largest industrial land use activity to have operated within the study area. Seven logging concessions overlap more than 75% of the study area (Figure 7.24), of which percentage approximately 70% is considered commercially viable production forest. Four concessions are currently licensed, two of which are presently active (i.e., Vailala Blk 3 and East Kikori). To date, approximately 1,300 km^2 of forest have been logged in the study area, nearly one quarter of the total area under concession.

Hill forest and alluvial forest are the main production forest types. Approximately 1,125 km^2 of these forest types have been logged, including most of the forest in the Southeast Hills ecological zone and parts of the Middle Purari Hills and Delta Swamps and Plains ecological zones (see Figure 7.24). In Project component areas, around 50 km^2 of forest have been harvested in the southeast corner of PRL-15 and approximately 116 km^2 along nearly the entire length of the export pipeline corridor (see Figure 7.24 and Plate 7.19). The regenerating forest is variable in age, with some logging occurring prior to 2002 (e.g., areas within the export pipeline corridor north of the active Evara logging camp) and other areas logged within the last two to three years (e.g., in the northeast, between Poroi 1 and Poroi 2 villages (see Figure 7.19), and in the southeast between Kilavi and Arehava 2 villages (see Figure 7.20)).

The majority of the unlogged hill and alluvial forest occurs within the Middle Purari Hills or in the Delta Swamps and Plains ecological zones, respectively.

Plate 7.19 – Commercial Logging Activities in the Export Pipeline Corridor

Photo: ERIAS Group.

LOGGING CONCESSIONS AND POST-LOGGING SECONDARY FOREST WITHIN BROAD VEGETATION GROUPS

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FIGURE 7.24

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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In addition to forestry concessions, Special Agricultural and Business Leases (SABLs) provide a mechanism for converting forest to agricultural land use. See also Section 9.8.3 for a discussion on SABLs under land tenure.

Local Resource Extraction

Small-scale timber harvesting is practiced throughout Papua New Guinea to meet local community requirements, including raw material for houses, fencing, canoes and firewood. Of the forests observed during biodiversity baseline surveys, those most affected by local timber extraction are the alluvial forests in the settled Southeast Coast ecological zone. Amid widespread land conversion in this area, patches of remnant alluvial forest are retained by local landowners, sometimes to the exclusion of industrial logging interests, to provide a continuing supply of natural resources.

The commercially valuable non-timber forest product eaglewood (*Gyrinops caudata* and *Aquilaria filarial*) is present in the study area and was recorded in logged hill forest at terrestrial biodiversity Site 3), although, there is no evidence of local harvesting of this product.

7.7.5.4 Vegetation Condition in the Project Component Areas

The total calculated area of habitat loss is an underestimate of the actual amount of natural vegetation that has been removed from within the study area. In many instances this is because converted land occurs in mosaic form with areas of natural vegetation or because of the deficiencies in remote sensing methods. In these areas, the presence of habitat loss is registered in a numeric disturbance code[20] (see Figures 7.19 and 7.20).

For the study area, disturbance codes were revised where the existing FIMs codes under-represented the percentage of canopy disturbance visible from LIDAR imagery and aerial survey. This was mostly applied to areas subjected to logging, particularly in hill forest areas throughout the export pipeline corridor, and to areas of increased subsistence agriculture activities toward the coast. The disturbance codes that were applied to logging areas were based on observations of canopy disturbance from the LIDAR imagery and aerial survey, but the same codes were applied to forest where roads were present in otherwise intact forest such as PRL-15. Thus, the disturbance codes do not necessarily reflect the level of disturbance to the internal forest structure and ground, which are likely to show higher levels of disturbance compared to canopy disturbance because of the relatively rapid canopy closure that occurs within 10 years after logging. The information in Figures 7.19 and 7.20 exemplifies this situation; both show a disturbance code of 9 for the undisturbed forest in PRL-15 and also for heavily logged forest south of the Purari River in Vailala Blk 3. This is because the logged forests in Vailala Blk 3 retain a reasonably intact canopy that conceals the heavily disturbed understory. Table 7.10 describes the vegetation types shown in Figures 7.19 and 7.20.

Production, Processing and Related Facilities

Most of the Hill forest (Hm) in PRL-15 remains in its natural state (Plate 7.20). The forests north of the Purari River have not been commercially logged; and while Pawaian residents pass through

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20 Forest condition is inherent in the FIMS disturbance codes, which reflect the overall level of forest canopy disturbance for a polygon. Where forest remains but has been subjected to anthropogenic disturbance, a disturbance code is provided from 1 to 9 where 9 indicates 90% of the canopy is intact. The degree of disturbance is defined in four categories:

- Slight disturbance 8 to 9 (for this study, it includes the presence of roads through otherwise intact forest).
- Moderate disturbance 6 to 7.
- Heavy disturbance 4 to 5.
- Very heavy disturbance greater than 4.

the area, anthropogenic disturbance is low and the forests do not support villages. Most forest loss or degradation in the area is attributable to earlier Project exploration phases through the construction and operation of roads or tracks, wellpads and isolated camp facilities. As a result (as explained earlier), the disturbance code 9 is applied to the vegetation type (i.e., Hm9) (see Figure 7.19 and Plate 7.20).

In the southwest portion of PRL-15, south of the large areas of Hill forest (Hm), is a northwest to southeast complex of Open alluvial forest/Swamp forest/Hill forest (Po/Fsw/Hm) that covers the central parts of the CPF, logistics base and airstrip area. Further southwest, freshwater swamp vegetation and associated complexes occur, including around the PRL-15 oxbow wetlands north of the Purari River (Plate 7.21). These extend north to meet the Po/Fsw/Hm complex and cover the western half of the CPF, logistics base and airstrip area (see Figure 7.19).

Plate 7.20 – Well-structured Hill Forest (Hm) on Aure Bed Sediments of the Mena Basin in PRL-15

Photo: Iain Woxvold.

Plate 7.21 – Freshwater Swamp Vegetation Around the PRL-15 Oxbow Wetlands

Photo: Iain Woxvold.

A small area of unlogged Alluvial forest (Pl) is present in PRL-15 on the northern bank of the Purari River around Poroi 1 village. While the canopy is largely intact, some conversion and resource harvesting is expected from the local residents.

In contrast, south of the Purari River in the Vailala Blk 3 logging concession, almost all of the Alluvial forest/Swamp forest (Pl/Fsw) complex and most of the Hill forest (Hm) has been intensively logged.

Onshore Export Pipeline Corridor

Lying within the Vailala Blk 3 concession, much of the Hill forest (Hm) and Alluvial forest (Pl) in the export pipeline corridor and surrounding areas to the east have been subjected to intensive logging (see Figures 7.19 and 7.20).

In the areas of Hill forest (Hm) in the export pipeline corridor, secondary forest dominates with only small areas of primary forest remaining along some drainage lines and in areas of steep terrain unsuitable for logging (Plate 7.22). In addition, almost all of the Small crowned hill forest (Hs) has been intensively logged, including most of that in the export pipeline corridor (see Figures 7.19 and 7.20), with only remnant pockets of primary forest remaining (Plate 7.23).

Plate 7.22 – Logged Hill Forest (Hm)

Photo: Iain Woxvold.

Plate 7.23 – Remnant Primary Small Crowned Hill Forest (Hs)

Photo: Iain Woxvold.

Open alluvial forest (Po) occurs in the northern half of the export pipeline corridor, along approximately 30 km of the eastern rim of the Delta Swamps and Plains ecological zone. All accessible areas of merchantable forest appear to have been logged; however, examples of primary Open alluvial forest (Po) were present away from logging roads (Plate 7.24).

In the southern half of the export pipeline corridor (see Figure 7.20), Swamp forest/Swamp woodland (Fsw/Wsw) (Plate 7.25) extends south from near Aivai village for approximately 16 km to the northern part of the populated Southeast Coast ecological zone, along with areas extending further east of Hepere village. Much of this area is mapped as logged; and although Swamp forest (Fsw) is not considered a commercial production forest type, typical communities do include desirable timber species. In addition, sago, in the Swamp woodland (Wsw) component of the complex, has no commercial value as a timber species; and any extensive stands are likely to remain intact.

Plate 7.24 – Interior of Unlogged Open Alluvial Forest (Po)

Photo: Iain Woxvold.

Plate 7.25 – Interior of Sago Swamp Woodland (Wsw)

Photo: Iain Woxvold.

At the local scale, sago present near villages is often harvested by landowners; and coastal areas mapped as Land use (O) in the export pipeline corridor support linear, subparallel sago swamps occupying the poorly drained swales between relict parallel beach ridges behind the populated coastal front.

Where accessible, Alluvial forest (Pl) is among the first forest types to be harvested by commercial logging operations. The largest local occurrences in the lower Vailala River catchment (Southeast Hills ecological zone) east of the export pipeline corridor have mostly been logged (see Figure 7.20). In settled areas of the southern section of the export pipeline corridor (interior plains of the Southeast Coast ecological zone), much of the loss or degradation of the Alluvial forest (Pl) is associated with conversion for shifting agriculture, agroforestry or village developments, which is reflected in a high disturbance code of 5 applied to the vegetation type (i.e., Pl5) (Plate 7.26; see Figure 7.20). Conversions are most prevalent north of this area between Hepere and Paevera villages, with some of the remaining forest heavily logged in recent years. Some forest patches in this area have been retained by local landowners to provide a continuing supply of forest resources; however, remnant forest canopies are fragmented, uneven and varied in height.

Southeast of Paevera village, in the eastern half of the export pipeline corridor coastal approach, the Alluvial forest (Pl) is in better condition, despite the presence of garden developments and resource harvesting. The mapped occurrences of Littoral forest (B) are also in the southeast (Plate 7.27).

Plate 7.26 – Garden Development in Alluvial Forest (Pl) in Hinterland of Orokolo Bay

Photo: Iain Woxvold.

Plate 7.27 – Littoral Beach Vegetation on Accreting Sand Dunes (Foreground)

Photo: Iain Woxvold.

Largely undisturbed Mangrove (M) vegetation is present in the southwestern section of the export pipeline corridor (Plate 7.28 and Plate 7.29). Although areas of Land use (O) associated with permanent settlements are mapped along the coast, natural resources are harvested from adjacent forest areas, and gardens are planted in some areas of mangrove forest, the vast scale of the mangrove ecosystem in this deltaic zone means that these disturbances do not register as a FIMS disturbance code. The smaller areas of Mangroves (M) that line the creeks in the heavily settled Southeast Coast ecological zone are more disturbed (M7), as in these areas' settlements are more widespread and the mangrove vegetation more limited. To the far southeast of the corridor, the larger Mangrove (M) areas are in better condition and have been assigned a disturbance code of 9 (M9) (see Figure 7.20).

Plate 7.28 – Mangrove (M) Zonation Patterns: Parallel to Estuary Front at Right Foreground, Mosaic Interior in the Background

Photo: Iain Woxvold.

Plate 7.29 – Fringing Mangrove Backed by Nipa Palm

Photo: Iain Woxvold.

Riverways

Along the riverways, including the river transport corridor, downstream of PRL-15, alluvial and freshwater swamp vegetation types (including complexes) (Plate 7.30 and Plate 7.31) line much of the Purari River and its distributaries upstream of the Mangroves ecological zone (see Figure 7.20). These areas are sparsely populated; and apart from a few localized sites where logging of Open alluvial forest (Po) is mapped along the eastern banks of the Purari River distributary channel between Evara and Aivai villages, the vegetation types present remain effectively intact and no disturbance codes are applied.

Plate 7.30 – Swamp Woodland/Swamp Grassland (Wsw/Gsw) Complex

Photo: Iain Woxvold.

Plate 7.31 – Swamp Forest (Fsw), West of the Purari River Distributary Channel

Photo: Iain Woxvold.

7.7.6 Flora and Fauna

7.7.6.1 Overview

A total of 1,272 terrestrial plant and animal species was recorded (Table 7.12) during the 2016 biodiversity baseline surveys. This section provides an overview of surveyed faunal communities.

Table 7.12 – Number of Species Recorded in the Study Area

	Taxonomic Group						
	Flora	**Non-volant mammals**	**Bats**	**Birds**	**Reptiles**	**Frogs**	**Odonates**
Site 1	348	12	26	90	19	32	46
Site 2	282	7	23	81	22	26	27
Site 3	200	10	25	102	22	26	30
Site 4	318	16	23	106	21	25	31
Site 5	323	12	23	109	18	18	44
Site 6A	179	5	11	62	4	3	21
Site 6B	163	–	–	39	4	0	4
Site 6C	–	–	–	11	1	–	–
Site 6D	146	–	–	32	5	3	6
Site 7	301	13	24	113	18	24	44
Site 8	267	14	25	96	21	17	28
Site 8M	21	3	15	39	1	0	0
Site 9	294	14	21	92	15	13	30
Wi'i Ck Cave	–	23	2	–	–	–	–
Totals*	812	42	39	183 (214)	57(70)	42(49)	97

* Totals for all taxa show the number of species recorded during the 2016 Project surveys. In addition to species recorded at survey sites, information from informal records included: five species of non-volant mammals confirmed present from Middle Purari Hills based on local landowner information, plus one invasive rodent species observed only at Herd Base; three additional bird species seen only at Herd Base or the Purari airstrip. Totals shown in brackets for birds, reptiles and frogs include combined data from the Project and prior surveys. Prior surveys yielded no additional species for other taxonomic groups.

Non-volant Mammals

The study area supports populations of at least 42 non-volant mammal species representing three major taxonomic groups: monotremes (1 species), marsupials (19 species) and placental mammals (22 species). The marsupial fauna is dominated by herbivores from six families: bandicoots (Paramelidae), tree kangaroos and wallabies (Macropodidae), and possums, gliders and cuscuses (Acrobatidae, Petauridae, Pseudocheiridae and Phalangeridae). Four marsupial carnivores (Dasyuridae) were also confirmed present. Placental mammals include 20 species of rodent (Muridae), the dog (Canis familiaris) and pig (Sus scrofa). All terrestrial non-volant mammals are breeding residents (non-migratory), and six are invasive alien species (see Section 7.7.6.6) either not native to New Guinea (five species) or introduced from other parts of New Guinea (one species).

Forest environments support the highest non-volant mammal diversity, providing habitat for all native terrestrial species. Two habitat-specialist aquatic rodents rely on watercourses, often within forest environments: the water rat (Hydromys cf. chrysogaster) and the new-to-science small water rat (Hydromys sp. 1).

Bats

Thirty-nine bat species were recorded in the study area. The bat community is divisible into two major groups based on feeding strategy; fruit bats (family Pteropodidae, 11 species) and insectivorous bats (6 families, 28 species). The latter group use ultrasonic echolocation calls to detect their prey. The food resources of most bat species are distributed widely across the study area, both in intact forest environments and, for a variety of species, in open and disturbed habitats. Roosting behaviours vary; some species roost singly or in small groups while others form aggregations of hundreds or even thousands of individuals. Some species shelter beneath foliage or in tree hollows, while others rely on caves and other rocky habitats. Compared to arboreal roost sites, cave roosts are a relatively restricted resource in the study area landscape.

Birds

A total of 214 bird species has been recorded in the study area, including 183 species recorded during Project surveys.

The study area's forest environments support the highest diversity of bird species. Species richness is highest in hill and alluvial forest, and mangrove forest is notable for supporting a suite of habitat-specialist and near specialist avian taxa. Resident frugivores make up a high proportion of the study area's forest bird community. Compared to other tropical regions, New Guinea's avifauna includes a high proportion of frugivorous species (Pearson, 1977; Mack & Dumbacher, 2007), such as cassowaries (Casuariidae), pigeons and doves (Columbidae), a variety of parrots (Psittacidae), Blyth's hornbill (*Rhyticeros plicatus*) (Bucerotidae), flowerpeckers (Dicaeidae), starlings and mynas (Sturnidae) and most birds-of-paradise (Paradisaeidae) (Coates, 1985, 1990). Other important forest-dwelling guilds include nectarivores and insectivores. Most forest bird species reside permanently in New Guinea.

Birds of open and disturbed terrestrial environments comprise mostly resident species that also occupy intact forest, non-breeding migrants from Australia and the invasive alien Eurasian tree sparrow (*Passer montanus*). New Guinea includes relatively few resident land birds that are exclusively associated with open and disturbed habitats (Bowman et al., 1990).

Wetland bird species occurring in the study area include a variety of resident and migratory taxa. Focal habitat for these species includes tidal wetlands (e.g., tidal flats, lagoons and estuaries) in coastal and subcoastal zones and off-river waterbodies (including oxbow lakes) in freshwater environments.

Herpetofauna

Ninety-nine herpetofauna species were recorded during Project surveys, including 42 frogs and 57 reptiles.

Native frogs represent four taxonomic families, the most diverse being the Microhylidae with 22 recorded species. A fifth family, the Bufonidae, is represented by the invasive alien cane toad (*Rhinella marina*). New Guinean microhylids have a reproductive cycle that is independent of free-standing water; they lay eggs in trees or on or under the ground where their embryos develop directly into small frogs, bypassing the tadpole stage. All other frog groups occurring in southern mainland Papua New Guinea require free-standing water (e.g., watercourses or forest pools) to breed.

The reptile fauna includes 35 lizard species (4 families), 16 snakes (5 families), 2 crocodiles (Crocodylidae) and 4 turtles (3 families). Skinks (Scincidae, 21 species) were the most species-rich family, with geckos (Gekkonidae, 9 species) and colubrid snakes (Colubridae, 8 species) the next most diverse. Forest environments support most lizard and snake species, including two dangerously venomous snakes: the death adder (*Acanthophis laevis*) and the New Guinea small-eyed snake (*Micropechis ikaheka*). All crocodile and turtle species depend on marine or freshwater environments.

Seven additional frog species and 13 additional reptiles were recorded during prior surveys conducted in the study area.

Odonates

Ninety-seven species of odonates were recorded in the study area, including 46 species of damselfly (suborder Zygoptera) and 51 species of dragonfly (suborder Anisoptera). The families Coenagrionidae (18 species) and Platycnemididae (13 species) dominated the damselfly fauna, while the Libellulidae (38 species) was the most diverse dragonfly family.

With an aquatic larval stage and free-flying adult stage, all odonates rely on both freshwater and terrestrial environments. Compared to damselflies, most dragonflies are relatively strong fliers, exhibit a broader habitat tolerance and have broader geographic ranges. Limited range endemism is more prevalent among damselflies, many of which are closely associated with shaded forest environments.

7.7.6.2 Conservation-listed Species

Ninety-two IUCN listed and nationally Protected species have been recorded within the study area (61 species) or may occur based on known distribution and habitat preferences (31 species).[21]

For each major taxonomic group, Table 7.13 lists the number of species from each conservation category recorded or potentially occurring in the study area. A selection of these species is shown in Plates 7.32 to 7.37. Of greatest significance are those species listed under an IUCN Threatened category. They include:

- Three IUCN Critically Endangered species, three of which are confirmed present: the timber tree *Diospyros lolinopsis*, and Bulmer's fruit bat (*Aproteles bulmerae*) (Plate 7.37).
- Nine IUCN Endangered species, eight of which are confirmed present: the timber trees *Diospyros insularis, Pterocarpus indicus* and *Flindersia pimenteliana* (Plate 7.34), two tree kangaroo species (*Dendrolagus* spp.), the giant bandicoot (*Peroryctes broadbenti*) (Plate 7.35), the migratory far eastern curlew (*Numenius madagascariensis*) and the pig-nosed turtle (*Carettochelys insculpta*).
- Seventeen (17) IUCN Vulnerable species, 13 of which are confirmed present (Table 7.14): four tree species (e.g., *Archidendron forbesii* (Plate 7.32)), five non-volant mammals (e.g., grey dorcopsis *(Dorcopsis luctuosa)* (Plate 7.36)), three resident forest bird species and one freshwater turtle species.

21 The following changes have been made to the IUCN rankings of recorded or potentially occurring species since undertaking the terrestrial biodiversity baseline study (based on the 2018 IUCN Red List). Among previously Threatened species: Two have had their status downgraded to Least Concern: the tree *Gluta Papuana* and the southern cassowary (*Casuarius casuarius*); the butterfly *Ornithoptera meridionalis* has been downgraded to Near Threatened; and two previously Vulnerable taxa have had their status upgraded to Endangered: the timber tree *Pterocarpus indicus* and the pig-nosed turtle (*Carettochelys insculpta*). Two previously Data Deficient species and one Least Concern species are now categorised as Near Threatened: the Papuan sheath-tailed bat (*Saccolaimus mixtus*), the blue-black kingfisher (*Todirhamphus nigrocyaneus*) and the butterfly *Ornithoptera paradisea*. The New Guinea flightless rail (*Megacrex inepta*) has been downgraded from Near Threatened to Least Concern, and four previously Data Deficient species are now categorised as Least Concern (two bats and two birds). Three previously Least Concern or Not Evaluated species are now categorised as Data Deficient (one plant, one bat and one frog). There are no changes to nationally Protected status.

Figure 7.25 shows the number of IUCN listed and nationally Protected species potentially occurring in each ecological zone, and in each of 10 major natural environments identified in the study area. Most species occupy hill forest, alluvial forest and/or wooded swamp (swamp forest/woodland) environments. Diversity is highest in hill and alluvial forest, where most conservation-listed species are permanent residents. Wetlands, watercourses, and marine tidal flats and beaches each support multiple conservation-listed species, many of which are migratory or transient non-breeding visitors.

Plate 7.32 – *Archidendron forbesii* (VU)

Photo: Fanie Venter.

Plate 7.33 – Scheepmaker's Crowned Pigeons (*Goura scheepmakeri*) (VU)

Photo: Iain Woxvold.

Plate 7.34 – Seed Pods of the Timber Tree Maple Silkwood (*Flindersia pimenteliana*) (EN)

Photo: Fanie Venter.

Plate 7.35 – Giant Bandicoot *Peroryctes broadbenti* (EN) at Site 7

Photo: Iain Woxvold

Plate 7.36 – Grey Dorcopsis (*Dorcopsis luctuosa*) (VU) at Site 5

Photo: Iain Woxvold

Plate 7.37 – Teeth of Juvenile Bulmer's Fruit Bat (*Aproteles bulmerae*) (the Six Teeth at Right; Unerupted Teeth of Juvenile Dobsonia Shown at Left for Comparison) Collected from Owl Pellet Deposit at the Wi'i Creek Cave Site

Photo: Ken Aplin.

Table 7.13 – Number of Species From Each Conservation Category Recorded and Potentially Occurring in the Study Area

Taxonomic Group	IUCN*					PNG*
	CR	**EN**	**VU**	**NT**	**DD**	**P**
Flora	2/3	3/3	4/7	6/8	6/6	–
Non-volant mammals	–	3/3	5/5	1/1	1/2	4/4
Bats	1/1	–	–	–	1/3	1/1
Birds	–	1/2	3/4	3/15	1/3	14/18
Reptiles	–	1/1	1/1	–	–	–
Frogs	–	–	–	–	2/2	–
Odonates	–	–	–	–	4/4	–
Butterflies[#]	–	–	–	0/2	–	_/3
Total[†]	**3/4**	**8/9**	**13/17**	**10/26**	**15/20**	**19/26**

* Numbers indicate: recorded/potentially occurring; CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near Threatened, DD - Data Deficient, and P - Protected.
[#] Butterflies were not the subject of any field survey.
[†] This does not total 92 species as some are listed under both the IUCN and PNG categories.
Note: Least Concern species are not considered to be of conservation priority and are therefore not included in this table.

Table 7.14 – IUCN Vulnerable Species Confirmed Present in the Study Area

Species	Common Name
Trees	
Mammea grandifolia	-
Ceratopealum succirubrum	-
Archidendron forbesii	-
Intsia bijuga	Kwilia/merbau
Non-volant Mammals	
Zaglossus bartoni	Eastern long-beaked echidna
Dendrolagus spadix	Lowland tree kangaroo
Dorcopsis luctuosa	Grey dorcopsis

Table 7.14 – IUCN Vulnerable Species Confirmed Present in the Study Area (cont'd)

Species	Common Name
Non-volant Mammals (cont'd)	
Thylogale brunii	Dusky pademelon
Xeromys myoides	False water rat
Resident Forest Birds	
Harpyopsis novaeguineae	Papuan eagle
Goura scheepmakeri	Scheepmaker's crowned pigeon
Psittrichas fulgidus	Pesquet's parrot
Freshwater Turtles	
Pelochelys bibroni	Striped New Guinea soft-shelled turtle

7.7.6.3 New-to-science and Scientifically Undescribed Species

Sixty-three species recorded in the study area are scientifically undescribed, 48 of which are new-to-science, being discovered for the first time during Project surveys, and 15 of which were previously discovered but remain scientifically undescribed (Table 7.15).[22] Fifty-one species are so far known only from within the study area (see Table 7.15). A selection of new-to-science species is shown in Plates 7.38 to 7.43.

Table 7.15 – Number of New-to-science and Scientifically Undescribed Species from Each Surveyed Taxonomic Group

Taxonomic Group	New-to-science	Undescribed	Study Area Only
Flora	34	1	34
Non-volant mammals	2	0	2
Bats	0	1	0
Birds	0	0	0
Reptiles	2	1	2
Frogs	3	11	5
Odonates	7	1	8
Total	**48**	**15**	**51**

More than half (34 of 48) of all new-to-science species are plants, reflecting the higher species richness of this taxonomic group and the generally low prior survey effort conducted by taxonomic botanists in the interior lowlands of Gulf Province. Odonates yielded the next highest number of new discoveries (eight species, one now described), this being attributable to a relatively low historical survey effort into this insect group in New Guinea and a tendency toward limited-range endemism among damselflies. Limited-range endemism is also frequently observed in New Guinean frogs; five frog species are known only from the study area.

Among reptiles, one new gecko (*Gehyra* sp. 1; Plate 7.40) was discovered in logged hill forest, and a distinctive new snake species (*Stegonotus* sp. 1; Plate 7.43) is at present known only from alluvial forest in the study area. Among non-volant mammals, two new-to-science species of small rodent were identified among skeletal remains from an owl pellet deposit collected at the Wi'i Creek cave site.

22 Two species have been formally described and named since the terrestrial biodiversity baseline study: the frog *Choerophryne crucifer* (previously *Choerophryne* sp. 1) and the damselfly *Bironides ypsilon* (previously *Bironides* sp. 1).

IUCN LISTED AND NATIONALLY PROTECTED SPECIES POTENTIALLY OCCURRING IN ECOLOGICAL ZONES AND MAJOR NATURAL ENVIRONMENTS

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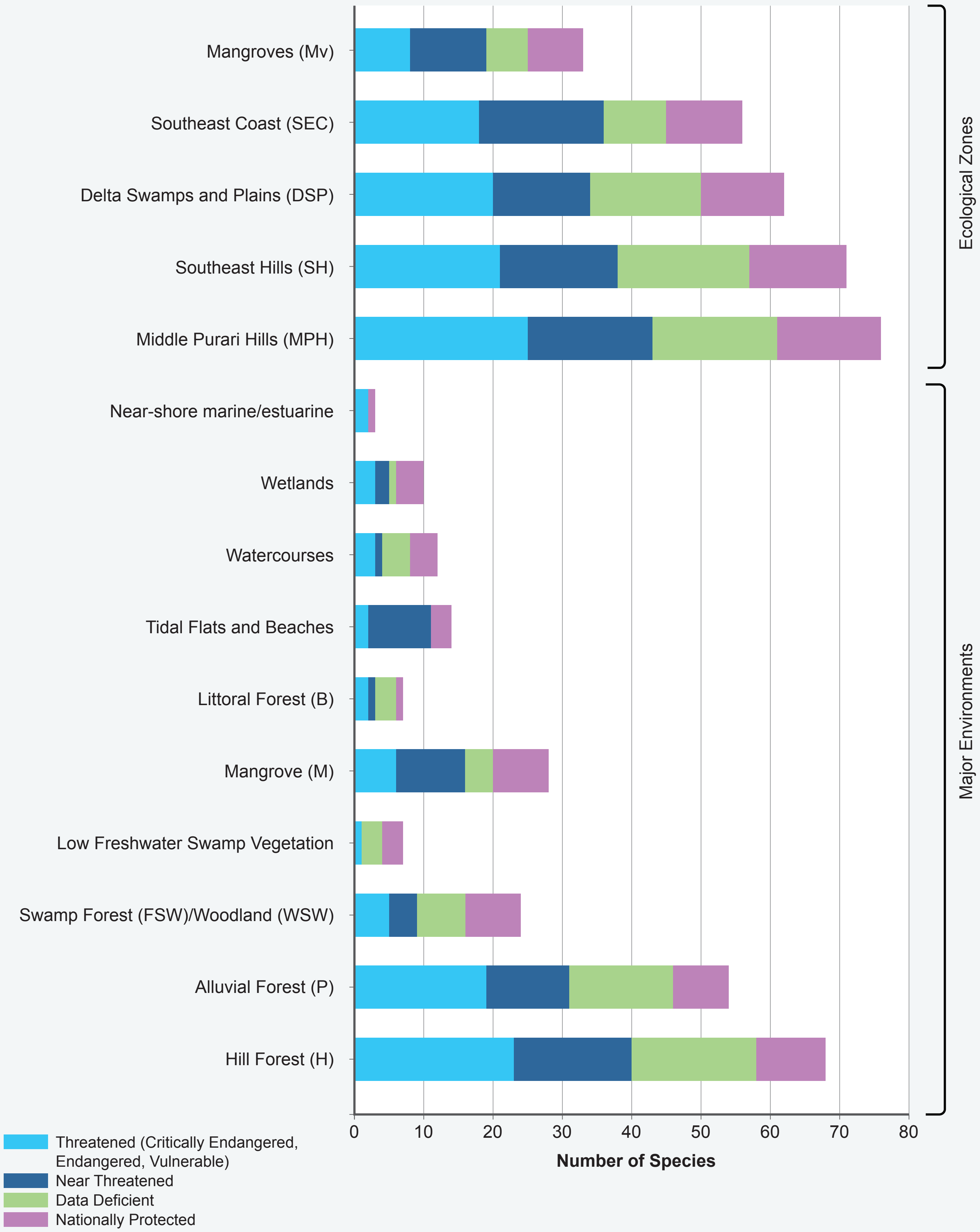
FIGURE 7.25



Discovery patterns throughout ecological zones and major environments are shown in Figure 7.26. Discovery rates were highest in hill forest in the Middle Purari Hills ecological zone, followed by alluvial forest on the Delta Swamps and Plains. Fewer discoveries in mangroves (two species), freshwater swamp vegetation types (five species) and littoral forest (zero species) reflect lower species richness, higher previous survey efforts and more widespread distributions of these lowland community components.

7.7.6.4 Regional Endemism and Restricted-range Species

New Guinea is among the most endemically rich regions on Earth (Mittermeier et al., 1997; Wikramanayake et al., 2002). While the biota of southern New Guinea share a strong affinity with Australian flora and fauna (Gressitt, 1982; Allison, 2007), the lowland rainforests of the study area support a high proportion of regionally endemic (i.e., those occurring only in New Guinea) and restricted-range species. The tendency toward regional endemism and limited-range distributions varies among major taxonomic groups.

Plate 7.38 – *Begonia* sp. 5

Photo: Fanie Venter.

Plate 7.39 – *Medinilla* sp. 1

Photo: Fanie Venter.

Plate 7.40 – *Gehyra* sp. 1

Photo: Steve Richards.

Plate 7.41 – *Oreophryne* sp. 1

Photo: Steve Richards.

Plate 7.42 – *Nyctophilus* sp. 1

Photo: Steve Richards.

Plate 7.43 – *Stegonotus* sp. 1

Photo: Steve Richards.

Among endemic taxa, the most sensitive species are those with the smallest geographic ranges. For this report and in accordance with International Finance Corporation (IFC) principles, these 'restricted-range' species include terrestrial fauna with a global distribution of less than 50,000 km^2. Among the species-rich plant dataset, screening for restricted-range flora focused on species known only from Gulf Province or from adjacent provinces in areas below 500 m asl in catchments that overlap the study area.

A total of 119 restricted-range species has been recorded or may occur in the study area (Table 7.16; Figure 7.27). A selection of restricted-range species is shown in Plates 7.44 to 7.49.

Table 7.16 – Restricted-range Species Recorded or Potentially Occurring in the Study Area

Taxonomic Group	IUCN*					PNG	New-to-science	Undescribed	Other Named RR	Total
	CR	EN	VU	NT	DD	P				
Flora	–	–	2	–	–	–	34	1	9	**46**
Non-volant mammals	–	1	1	–	1	1#	2	–	3	**8**
Bats	1	–	–	–	1	1#	–	1	1	**4**
Birds	–	–	1	1	1	1#	–	–	–	**3**
Reptiles	–	–	–	–	–	–	2	1	7	**10**
Frogs	–	–	–	–	2	–	3	11	9	**25**
Odonates	–	–	–	–	1	–	7	1	14	**23**
Total	**1**	**1**	**4**	**1**	**6**	**3#**	**48**	**15**	**43**	**119**

* CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near Threatened, DD - Data Deficient, and P - Protected.

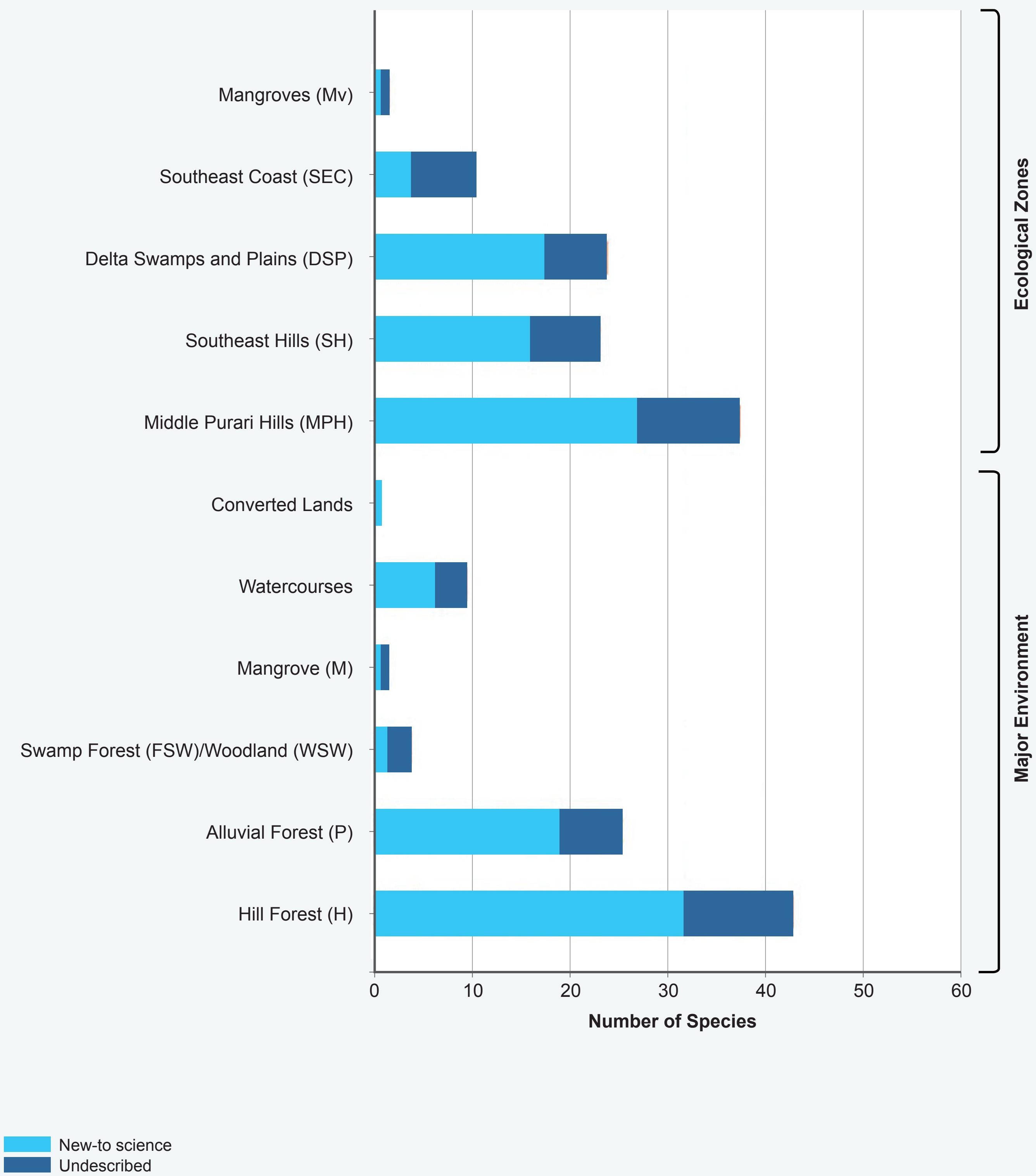
Some restricted-range (RR) species Protected under PNG law are also listed under an IUCN listed category; as such, Totals do not count these species twice.

Note: Least Concern species are not considered to be of conservation priority and are therefore not included in this table.

NEW-TO-SCIENCE AND UNDESCRIBED SPECIES RECORDED IN ECOLOGICAL ZONES AND MAJOR ENVIRONMENTS

Papua LNG Project | Environmental Impact Statement

FIGURE 7.26



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RESTRICTED-RANGE SPECIES RECORDED OR POTENTIALLY OCCURRING IN ECOLOGICAL ZONES AND MAJOR ENVIRONMENTS

Papua LNG Project | Environmental Impact Statement

FIGURE 7.27

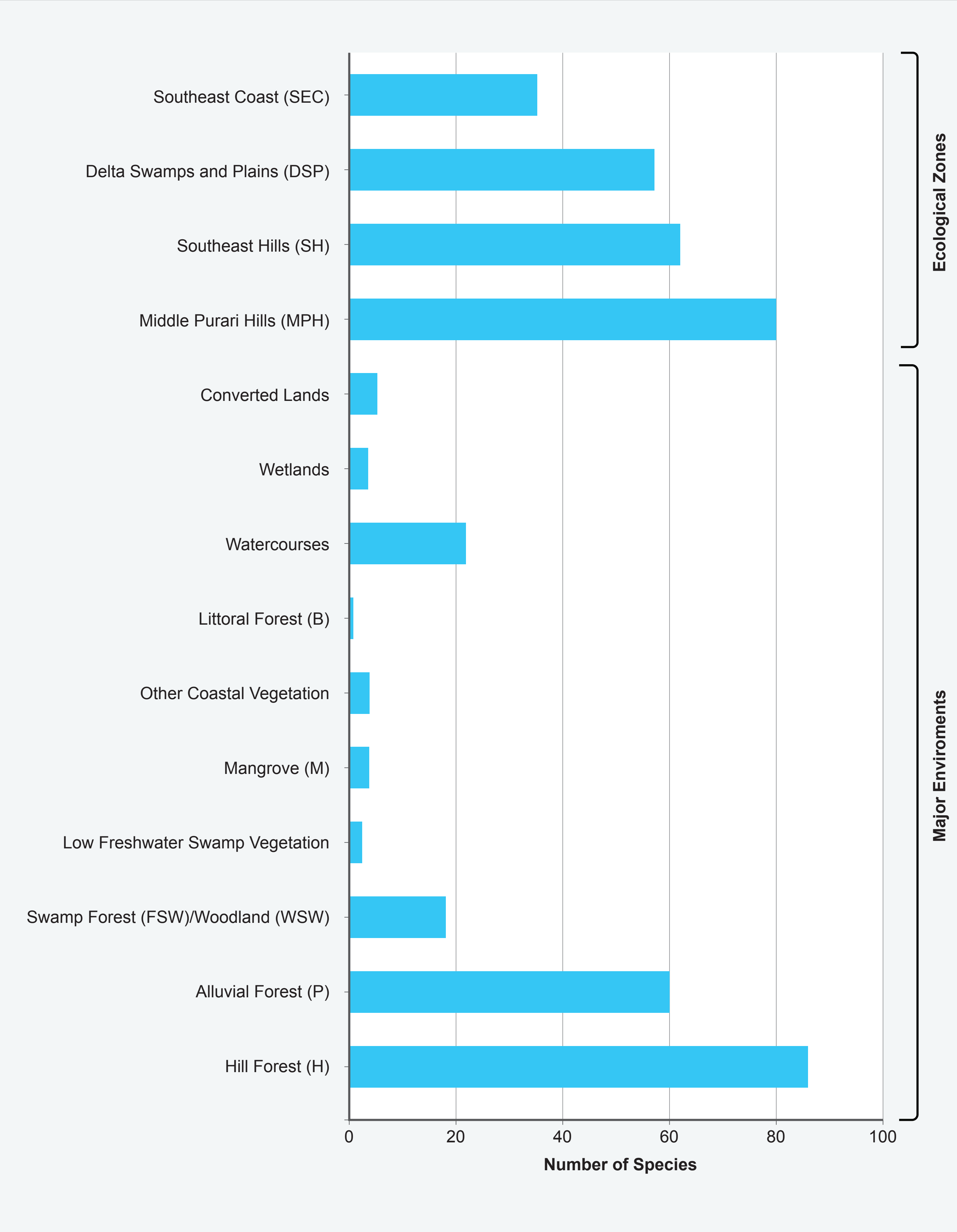

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Plate 7.44 – *Litoria exophthalmia*

Photo: Steve Richards.

Plate 7.45 – *Nososticta chrismulleri*

Photo: Steve Richards.

Plate 7.46 – *Psychotria purariensis*

Photo: Fanie Venter.

Plate 7.47 – *Pseuduvaria filipes*

Photo: Fanie Venter.

Plate 7.48 – Oriomo Bandicoot (*Echymipera oriomo*) at Site 5

Photo: Iain Woxvold.

Plate 7.49 – *Curtodactylus serratus*

Photo: Steve Richards.

The highest diversity of restricted-range taxa occurs among plants (46 species), frogs (25 species) and odonates (23 species) (see Table 7.16). Among plants, nearly half (48%) of the identified restricted-range species belong to three families—Rubiaceae (12 species), Begoniaceae (5 species) and Myrtaceae (5 species). Among odonates, more than 82% (19/23) of restricted-range species are damselflies (suborder Zygoptera). Flight-capable vertebrates are generally more wide ranging; the study area's bat and bird communities each include fewer than five restricted-range species.

Figure 7.27 shows the number of restricted-range species recorded or potentially occurring in each ecological zone and in various major environments. Hill and alluvial forest support the highest diversity of restricted-range species. Watercourses in forest environments provide important habitat for a suite of restricted-range odonates (18 species), frogs (4 species) and the new-to-science small water rat *Hydromys* sp. 1.

Species with the smallest recorded distributions include those known only from the study area. They include 48 new-to-science species discovered during Project surveys, two additional scientifically undescribed frogs previously known only from the Wabo area, and six restricted-range plant species. In most cases, the habitats known to support these species extend beyond the study area into the adjacent Kikori, Vailala and Lakekamu river catchments without apparent geographic barrier. Accordingly, most or all species presently known only from the study area are expected to occur more widely in Gulf Province, at least in other sectors of the local biogeographic regions of which the study area forms a part (see Section 7.7.4.2). Until it is possible to confidently predict that a species does occur in adjacent areas of suitable habitat, the possibility that one or more species is restricted to the study area cannot be ruled out.

7.7.6.5 Migratory and Congregatory Species

Overview

No terrestrial mammals or herpetofauna occurring in the study area engage in long-distance migration, and no terrestrial non-volant mammals or herpetofauna are known to congregate in large groups. More significant congregatory behaviors and localized landscape-level movements are observed among bats, birds and two large freshwater turtle species.

Bats

The seasonal and daily movements of New Guinean bats are poorly documented; however, many species are probably capable of long-distance flights, and some may travel many kilometers between regular roosting and feeding sites. It is not possible to identify regular bat movement corridors in the study area. They may be numerous and widespread and are expected to vary between taxa and potentially across seasons within taxa. The most permanent and well-defined flight corridors with the greatest number of individuals travelling through the narrowest aerial channel are expected to occur on approaches to caves that support large colonies of one or more bat species.

Many New Guinean bat species roost together in large groups, either habitually or seasonally for breeding. Flying-foxes of the genus *Pteropus* congregate seasonally in large 'maternity camps' in forest canopies, often located in mangroves, riparian forest or freshwater swamp vegetation. No flying-fox camps were observed during Project surveys, although their occurrence was reliably reported by local residents; reported locations include the PRL-15 oxbow wetlands.

A variety of bats roost in caves, including several large fruit bats (Pteropodidae) and small insectivorous bats belonging to the families Emballonuridae, Hipposideridae, Rhinolophidae, Miniopteridae and Vespertilionidae. Cave-roosting species recorded in the study area include the

IUCN-listed Bulmer's fruit bat (*Aproteles bulmerae*) (Critically Endangered), New Guinea sheath-tailed bat (*Emballonura furax*) (Data Deficient), Papuan sheath-tailed bat (*Saccolaimus mixtus*) (Data Deficient) and Semon's leaf-nosed bat (*Hipposideros semoni*) (Data Deficient). Aggregate numbers of animals depend on the species present and cave's chamber size; sizeable caves often include bats of multiple species. Cave habitats are discussed further in Section 7.7.7.

Birds

The study area includes habitats that support trans-oceanic migrant birds, both from the northern hemisphere and from Australia, and migratory and resident taxa that congregate together at various sites in the study area landscape.

At least 31 migratory shorebird species may occur in the study area. Of these, 23 species congregate on or near the coast, and more than one third of them (8 of 23) are listed by the IUCN as Threatened or Near Threatened with extinction. Additional migratory and resident bird taxa may join these coastal aggregations. In the study area, the largest aggregations of coastal bird species are expected to occur along the tidal flats, lagoons and estuaries of the Mangroves ecological zone and, to a lesser degree, of the Southeast Coast ecological zone.

Based on numbers of migratory shorebirds recorded previously in the nearby Kikori River delta (Jaensch & Watkins, undated; Bamford et al., 2008), the tidal wetlands of the Purari River delta may qualify as an internationally important wetland site under Criterion 6 of the Ramsar Convention for the greater sand plover (*Charadrius leschenaultia*) and Terek sandpiper (*Xenus cinereus*) and as an internationally important staging site for the IUCN Endangered far eastern curlew (*Numenius madagascariensis*).

In addition to coastal species, at least 36 migratory and congregatory bird species may occur in freshwater environments in the study area. The largest aggregations are expected to occur in off-river freshwater wetlands, such as the oxbow lakes and swamps of the Purari and Vailala river catchments, respectively, and in the Delta Swamps and Plains and Southeast Hills ecological zones. The potential importance of these coastal and freshwater habitats is discussed further in Section 7.7.7.

At least two and possibly as many as five swiftlet species (*Aerodramus* spp., *Collocalia esculenta*) occur locally, all of which nest and roost colonially in caves. Colonies range from a few individuals to hundreds of birds, depending on the dimensions of the shelter site. The importance of caves is discussed in Section 7.7.7.

No habitat for terrestrial (non-waterbird) migratory species requiring specific conservation action is found in the study area. Additionally, suitable trees used for lekking and colonial nesting by species such as birds-of-paradise and starlings, respectively, are widespread within and beyond the study area's forest environments.

Large Freshwater Turtles

The IUCN Endangered pig-nosed turtle (*Carettochelys insculpta*) (Plate 7.50) and the IUCN Vulnerable striped New Guinea soft-shelled turtle (*Pelochelys bibroni*) are recorded in the study area. These species nest on sandy river banks, and the pig-nosed turtle additionally (at least in the Kikori River delta) at the mouths of major rivers, on islands in river deltas and on coastal beaches. Both of these species nest along the Purari River or its tributaries in the southern part of PRL-15 and probably more widely in the study area. The nesting sites are used year after year, and each is visited by multiple laying females. The location and significance of the PRL-15 nesting sites is discussed in Section 7.7.7.

Plate 7.50 – Pig-nosed Turtle (*Carettochelys insculpta*) (EN)

Photo: Steve Richards.

Movement patterns in the Gulf Province drainages are poorly known; but in the Kikori River delta, movements may involve 'migrations' between nesting and feeding areas (Eisemberg et al., 2014, 2015); e.g., in the Purari and Kikori river catchments, hatchlings move to the lower delta to feed on mangrove fruit and other vegetation.

7.7.6.6 Invasive Alien Species

Weeds

Weeds are classified into three groups based on their potential to cause ecological harm:

- Priority 1 species – those species that can persist in unmodified native ecosystems, have the potential to cause ecosystem degradation by displacing native species or negatively impact on regeneration or rehabilitation measures.
- Priority 2 species – those species that can persist in disturbed areas and are unlikely to persist without some anthropogenic influence.
- Priority 3 species – those species that require ongoing disturbance and are unable to out-compete native species without regular human interference. These species are not considered an ecological threat.

Ninety-seven alien plant species were identified in the study area, of which seven are Priority 1 weeds and 34 are Priority 2 weeds. Nearly 60% of alien plants are Priority 3 weed species. The Priority 1 weeds and their occurrences in the study area are described in Table 7.17, and a selection is shown in Plates 7.51 to 7.56.

Table 7.17 – Priority 1 Alien Weeds Recorded from the Study Area

Species	Description and Occurrence in Study Area
Angelonia/monkey face (*Angelonia angustifolia*)	Erect herb to 1 m high. Forms dense stands on poorly drained sites. Widespread: in PRL-15 infesting wellpads and associated landslips, Antelope-3 Operations Camp, the Herd Base—Gas Field Road, the Purari Airstrip and nearby logging roads; in the export pipeline corridor present at Paevera village and coastal villages.
Water hyacinth (*Eichhornia crassipes*)	An erect perennial aquatic herb, free-floating or occasionally rooted in shallow water. Noted in Nea Creek, the PRL-15 oxbow wetlands in the southwest part of PRL-15 and at the Purari Airstrip.

Table 7.17 – Priority 1 Alien Weeds Recorded from the Study Area (cont'd)

Species	Description and Occurrence in Study Area
Anglestem willow (*Ludwigia leptocarpa*)	Annual herb. Infests wet sites where topsoil is exposed. Infestations reported: In PRL-15 at the Elk-2 wellpad and the Purari Airstrip and in the export pipeline corridor in waterlogged sites adjacent to logging roads.
Mile-a-minute vine (*Mikania micrantha*)	Fast-growing vine that tolerates partially shaded environments, commonly invading minimally to moderately disturbed, poorly drained sites. Highly invasive and can smother the canopy of large trees. Widespread in disturbed and open sites: In PRL-15 it is present at Herd Base, along the Herd Base—Gas Field Road, at the Purari Airstrip and nearby logging roads; in the export pipeline corridor it is present along logging roads, in undisturbed swamp grassland and in coastal villages.
Bamboo daka (*Piper aduncum*)	Shrub/small tree to 6 m. Tolerates a range of climatic conditions and will grow in shade and full sun. Highly invasive; establishes in natural gaps and on stream banks in primary forest. Widespread, particularly along roads: In PRL-15 it is present at Herd Base, along the Herd Base—Gas Field Road, at the Purari Airstrip and nearby logging roads, and along watercourses; in the export pipeline corridor it is present along logging roads; also in Pawaian villages and along the banks of the Purari River.
African tulip tree (*Spathodea campanulate*)	The only Priority 1 large tree (to 20 m tall) identified in the study area. Along with *Piper aduncum,* this is the most successful woody invader of disturbed forest environments in New Guinea. It invades post-logging secondary forest and out-competes regenerating native species. Recorded at Muro Mission, southern export pipeline corridor.
Coconut palm (*Cocus nucifera*)	A tall palm to 20 m. Forms localized infestations on areas of raised ground in Mangrove (M). Causes structural change in mangrove forest and has the potential to out-compete native species. A naturally occurring species, but with a commercial cultivar planted extensively in the Southeast Coast ecological zone since the early 1900s. Recorded in mangrove forest in the southwest export pipeline corridor (see Figure 7.21).

Plate 7.51 – Monkey Face (*Angelonia angustifolia*)

Photo: Howard Rogers.

Plate 7.52 – Water Hyacinth (*Eichhornia crassipes*)

Photo: Howard Rogers.

Plate 7.53 – Anglestem Willow (*Ludwigia leptocarpa*)

Photo: Howard Rogers.

Plate 7.54 – Bamboo Daka (*Piper aduncum*)

Photo: Howard Rogers.

Plate 7.55 – African Tulip Tree (*Spathodea campanulate*)

Photo: Howard Rogers.

Plate 7.56 – Coconut Palm (*Cocus nucifera*)

Photo: Iain Woxvold.

Invasive alien plant species were recorded at widespread infestation sites at heavily disturbed locations or converted lands, including in village and garden areas, particularly in the populated Southeast Coast ecological zone, at the Purari Airstrip, in logging camps, along the extensive network of logging roads and in an associated dieback area, and at Project facility and infrastructure sites, including Herd Base, Antelope-3 Operations Camp, wellpads, and along the Herd Base—Gas Field Road.

In contrast, few weeds were observed in intact natural environments; as such, expansive areas of natural forest habitat are essentially weed free. The lack of weeds in these environments reflects the relatively undisturbed quality of the forests that cover much of the PAOI and broader study area (see Section 7.7.5.3).

Animals

Invasive alien feral or domestic mammals present in the study area include rodents (Plate 7.57), cats, dogs and pigs (Plate 7.58). No invasive alien bats were recorded or are likely to occur in the study area. One bird species (Eurasian tree sparrow (*Passer montanus*)) and one amphibian (cane toad (*Rhinella marina*)) (Plate 7.59) were also recorded. The species' occurrences in the study area are described in Table 7.18.

Among invertebrates, an infestation of the giant East African snail (*Lissachatina fulica*) was recorded at Site 8 in the Southeast Coast ecological zone.

Plate 7.57 – Black Rat (*Ratus rattus*)

Photo: Ken Aplin.

Plate 7.58 – Feral Pig (*Sus scrofa*) Sow and Piglets

Photo: Iain Woxvold.

Plate 7.59 – Cane Toad (*Rhinella marina*)

Photo: Steve Richards.

Table 7.18 – Invasive Alien Animals Recorded from the Study Area

Species	Occurrence in Study Area
Mammals	
Rodents (Muridae) – Pacific rat (*Rattus exulans*), black rat (*R. rattus*), small spiny rat (*R. steini*) and house mouse (*Mus musculus*)	Currently restricted to anthropogenic habitats, including active Project facility sites, active logging roads and villages. The black and Pacific rats are the most widespread alien rodents; the small spiny rat and house mouse were recorded at single sites. A long-term resident black rat population (pre-1970s) is reported for the populated Southeast Coast ecological zone. By contrast, recent infestations are reported by local landowners residing near transport infrastructure sites: black and Pacific rats in Evara village appeared shortly after the construction of a nearby logging camp in 2000, and black rats at Wabo village in the last 1 to 2 years. Native rodent populations are presumed thus far to have kept alien species from invading natural habitats; and trapping results suggest that disturbance-tolerant native species are out-competing alien rodents, in at least some post-disturbance regrowth habitats. Alien rodent populations are, therefore, likely to be currently patchily distributed in heavily disturbed sites in the study area.
Pig (*Sus scrofa*)	Introduced into New Guinea approximately 2,500 years ago. Feral populations are now widespread and occupy a variety of habitats. Widespread in the study area; recorded at all flora and fauna survey sites except in mangroves. Highest densities were recorded in undisturbed alluvial forest; camera trapping rates suggest they are less abundant in hill forest and wherever they are subject to hunting by local communities.
Dog (*Canis familaris*)	Present in New Guinea since prehistoric times. Occur both as domestic and feral populations, with a regular interchange of individuals in some areas. Where present, feral dogs are the apex predator in New Guinea's terrestrial ecosystems. Domestic dogs are kept by local residents throughout the study area. The status of local feral populations is uncertain. At least one feral population is likely to be present north of the Purari River in PRL-15; unaccompanied dog prints seen at Site 6A were attributed to feral dogs by local residents who stated they were common in the area.
Cat (*Felis catus*)	Populations are rarely reported in New Guinea's rainforest environments and may be largely restricted to human settlements and nearby disturbed areas (Flannery, 1995). In the study area, cats are kept as pets in most villages and at some Project facility sites; no evidence of a feral population was obtained.
Birds	
Eurasian tree sparrow (*Passer montanus*)	Established colonies present at Herd Base, at the Antelope-3 Operations Camp and in coastal villages of Orokolo Bay. Strongly commensal in New Guinea. Restricted to open and disturbed habitats around human settlements.
Herpetofauna	
Cane toad (*Rhinella marina*)	Highly toxic introduced species. Patchy distribution in Papua New Guinea, restricted predominantly to open savanna habitats, urban areas, and disturbed forest environments; rare in closed canopy rainforest. Widespread but patchily distributed in anthropogenic habitats across the study area. Present in: ♦ PRL-15, at the Antelope-3 Operations Camp and at Herd Base. ♦ The export pipeline corridor, common in settled areas of the Southeast Coast ecological zone and were present along the logging road at Site 3, but not found in adjacent logged forest habitats. Easily introduced to novel, isolated disturbed sites via human transport vectors (road or air).

Table 7.18 – Invasive Alien Animals Recorded from the Study Area (cont'd)

Species	Occurrence in Study Area
Invertebrates	
Giant East African snail (*Lissachatina fulica*)	A severe infestation observed at Site 8. A serious agricultural pest, present in gardens, disturbed sites and adjacent alluvial forest south of the Muro River. Local residents indicated that this species had arrived in the last few years and that the Muro River was acting as a dispersal barrier with snails yet to be found north of there.

7.7.7 Protected Areas, Priority Ecosystems and Focal Sites

7.7.7.1 Protected Areas

Approximately 445 km^2 of the Crater Mountain Wildlife Management Area (WMA) overlaps the northern margin of the study area north of the Purari River (see Figures 7.17 and 7.18). The northern extremity of PRL-15 lies within this WMA. No current or proposed Project facilities are present in this area.

7.7.7.2 Priority Ecosystems

The study area includes a diverse array of major environments, including five BVGs (see Section 7.7.5), anthropogenic converted lands, tidal wetlands and freshwater aquatic environments.

The major environments are divided into 20 ecosystems to which a baseline sensitivity value has been assigned (see Section 7.7.8). The baseline sensitivity ranking of the various ecosystems is shown in Table 7.19, with features underpinning the assignments for those ecosystems considered to be Moderately Sensitive or higher. Examples of these ecosystems are shown in Plates 7.60 to 7.65. Further information on each ecosystem can be found in Part 6 of Volume 2.

Table 7.19 – Baseline Sensitivity of Ecosystems in the Study Area

Feature	Sensitivity*	Characteristics[#]
Terrestrial Ecosystems		
Hill forest (H) - primary	MS	♦ Expansive areas of primary hill forest remain in the northern study area, spanning most of the sparsely populated Middle Purari Hills ecological zone and most of PRL-15. ♦ Hill forest is the most common vegetation type across Papua New Guinea. It is widespread locally and regionally, and is well connected to comparable environments outside the Project area. ♦ The species composition and primary ecological functions are intact and succession processes occur following most natural disturbances. ♦ Supports a high diversity of IUCN Threatened and other Very Sensitive species. ♦ Middle Purari Hills landscape lies within multiple areas of biological importance recognized under the PNG Conservation Needs Assessment (Beehler 1993), including an area of biological importance to herpetofauna (Allison 1993) and major wilderness areas[†] (Allison, 1993; Beehler, 1993).
Hill forest (H) - logged	LS	Not applicable.

Table 7.19 – Baseline Sensitivity of Ecosystems in the Study Area (cont'd)

Feature	Sensitivity*	Characteristics[#]
Terrestrial Ecosystems (cont'd)		
Hill forest (H) on limestone (MPH)	VS	♦ Discrete occurrences in the Middle Purari Hills: in the west along the Kereru Range, in the extreme northwest where it contacts the Purari River at Hathor Gorge and around Mua Creek, and at the Wi'i Creek site in the northeast Middle Purari Hills. ♦ Supports a high diversity of Very Sensitive (including IUCN Threatened) and habitat-specialist species. ♦ Largely unmodified by human activity and is located in an area that is remote with recognized wilderness values.
Alluvial forest (P) - primary	VS	♦ Predominantly in discrete areas at the northern, southern and eastern margins of the Delta Swamps and Plains ecological zone, with more minor occurrences often too small to be mapped along major watercourses in the Middle Purari Hills and the Southeast Hills ecological zones, and at the base of the foothills in the Southeast Coast ecological zone. ♦ Supports the IUCN Critically Endangered tree *Diospyros lolinopsis* and relatively high densities compared to hill forest of a variety of IUCN Threatened fauna species. ♦ May be critical to the survival of a suite of new-to-science species not recorded in other forest environments. ♦ Elsewhere, regional equivalents have been extensively harvested and are under continuing pressure from logging operations.
Alluvial forest (P) – logged	MS	♦ Discrete areas at the southern and eastern margins of the Delta Swamps and Plains ecological zone, along major watercourses in the Southeast Hills ecological zone and at the base of the foothills in the Southeast Coast ecological zone. ♦ Connectivity remains with relatively undisturbed exemplars. ♦ Has potential to regenerate and support a variety of conservation significant species.
Riverine seral forest (Fri)	MS	♦ Minor occurrences on aggrading scroll arches along major watercourses in the Delta Swamps and Plains ecological zone. ♦ Part of the alluvial forest BVG; however, as a pioneer successional vegetation type it is prone to regular flooding disturbance, it has a high regenerative capacity and its occurrences are too small to support regionally important concentrations of conservation significant species.
Swamp forest (Fsw)	MS	♦ Covers extensive areas of the Delta Swamps and Plains ecological zone, with lesser occurrences in the Mangroves and the Southeast Hills ecological zones. ♦ Intact natural system that supports some conservation significant species.
Swamp woodland (Wsw)	MS	♦ Covers extensive areas of the Delta Swamps and Plains ecological zone, with lesser occurrences in all other ecological zones. ♦ Intact natural system that supports some conservation significant species.
Low freshwater swamp vegetation (Hsw, Gsw, Gri)	MS	♦ Discrete occurrences in flood prone areas, predominantly in the Delta Swamps and Plains ecological zone. ♦ Intact natural system that supports some conservation significant species.

Table 7.19 – Baseline Sensitivity of Ecosystems in the Study Area (cont'd)

Feature	Sensitivity*	Characteristics#
Terrestrial Ecosystems (cont'd)		
Mangrove (M)	VS	♦ Swamp forest under tidal influence, predominantly in the Mangroves ecological zone, additional discrete occurrences in the Southeast Coast ecological zone. ♦ Supports the IUCN Critically Endangered tree *Bruguiera hainesii.* ♦ May be critical to the survival of several plant species known only from single sites. ♦ Provides important physical and chemical regulating services necessary for supporting nearshore environments that act as nurseries for a range of fish and aquatic invertebrate species. ♦ Sensitive to disturbance.
Littoral forest (B)	LS	Not applicable
Converted land	NS	Not applicable
Freshwater Aquatic Ecosystems		
Forest streams	MS	♦ In hill forest and well drained alluvial forest. ♦ Important habitat for a variety of new-to-science and other restricted-range habitat-specialist species, predominantly frogs and odonates, but also including the new-to-science small water rat *Hydromys* sp. 1.
Open-canopy watercourses	MS	♦ Essentially unmodified systems that provide important habitat for two IUCN Vulnerable freshwater turtle species and for two crocodile species.
Oxbow lakes	VS	♦ Essentially unmodified systems that support a wide variety of habitat-specialist taxa, provide important breeding habitat for a variety of birds and herpetofauna. ♦ Sensitive to establishment and spread of aquatic plant invasive alien species.
PRL-15 oxbow wetlands	VS	♦ Approximately 25 km^2 of wetlands in the southwest of PRL-15 on the Delta Swamps and Plains. ♦ Comprises six open-water oxbow lakes, including the largest off-river waterbodies in the study area, and a surrounding area of integrated wetlands including permanently inundated swamp vegetation and two minor watercourses. ♦ Essentially an unmodified system that supports a wide variety of habitat-specialist taxa, provides important breeding habitat for a variety of birds and herpetofauna, and is sensitive to a variety of impacts, notably including the establishment and spread of aquatic plant invasive alien species.
Coastal freshwater lakes	MS	♦ 12 small freshwater lakes behind primary dune systems on recently aggraded shorefront in the Southeast Coast ecological zone. ♦ Support a variety of resident and migratory habitat-specialist species. ♦ Restricted local availability. ♦ May not recover easily from disturbance.
Near-shore marine/estuarine waters	LS	Not applicable.

Table 7.19 – Baseline Sensitivity of Ecosystems in the Study Area (cont'd)

Feature	Sensitivity*	Characteristics#
Coastal and Estuarine Aquatic Ecosystems		
Tidal wetlands - Purari River delta	VS	♦ Known to support congregations of migratory shorebirds, although the number of birds supported is unknown. Based on shorebird counts conducted immediately west of the study area, the Kikori River delta is recognized as an internationally important wetland site for three migratory shorebird species under Ramsar Convention threshold criteria (Bamford et al., 2008). The Purari River delta includes a similar area of tidal habitats.
Tidal wetlands - export pipeline corridor	LS	♦ Similar to the tidal wetlands of the Purari River delta, but are located in a settled shorefront, are more limited in extent and are more frequently visited by local landowners.

* Sensitivity: VS - Very Sensitive; MS - Moderately Sensitive; LS - Low Sensitivity; NS - Not Sensitive (see Section 7.7.8.1).
[#] Only provided for ecosystems considered to be Moderately Sensitive or higher.
[†] Areas with low human population density and a natural environment with little disturbance.

Plate 7.60 – Forest Stream in PRL-15

Photo: Steve Richards.

Plate 7.61 – Mid-reach of an Open-canopy Watercourse, PRL-15

Photo: TEP PNG.

Plate 7.62 – A Smaller Oxbow Lake in the PRL-15 Oxbow Wetlands

Photo: Iain Woxvold.

Plate 7.63 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor

Photo: Iain Woxvold.

Plate 7.64 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor

Photo: Iain Woxvold.

Plate 7.65 – Tidal Habitats, Western Export Pipeline Corridor

Photo: Iain Woxvold.

Terrestrial Ecosystems

Twenty terrestrial ecosystems are identified based on vegetation type, with hill and alluvial forest further divided according to condition (logged or primary) and substrate (limestone).

Among terrestrial ecosystems, hill and alluvial forests support the highest species richness, including the highest diversity and abundance of conservation significant species. Of these forest types, primary alluvial forest is of the highest conservation value due to: 1) its more restricted local and regional availability; 2) relatively limited connectivity with similar habitat outside of the study area; and 3) its high commercial value to the logging industry. The study area supports the largest primary formations of Alluvial forest (Pl) and Open alluvial forest (Po) remaining anywhere within the Kikori-Purari biogeographic region.

At the southern end of the export pipeline corridor, areas of Alluvial forest (Pl) that have not been commercially logged have been heavily disturbed by local residents, essentially comprising a patchwork of remnant natural forest and converted habitats in varying stages of regeneration (see Section 7.7.5.3).

Among other forest types, Hill forest (H) on limestone and Mangrove (M) are both considered to be of high conservation value due to their intact condition and their support for a variety of habitat-specialist species and conservation-listed species.

Freshwater Aquatic Ecosystems

Five freshwater aquatic ecosystems are identified, including forest streams, open canopy watercourses and three types of off-river waterbody ecosystem. Off-river waterbody ecosystems include oxbow lakes, coastal freshwater wetlands and the PRL-15 oxbow wetlands: a series of six oxbow lakes and surrounding swamp vegetation located in the southwest part of PRL-15 and including the largest off-river waterbodies in the study area.

Oxbow lakes and the PRL-15 oxbow wetlands are of the highest conservation value owing to their unmodified condition and their support for a variety of habitat-specialist flora and fauna. The importance of oxbow wetlands for aquatic fauna is further discussed in Section 7.6.

Coastal and Estuarine Aquatic Ecosystems

Three coastal and estuarine aquatic ecosystems are recognized in the study area: nearshore marine/estuarine waters, tidal wetlands of the Purari River delta and tidal wetlands in the export pipeline corridor. In terms of terrestrial flora and fauna, tidal wetlands of the Purari River delta are of the highest conservation significance, as they provide extensive areas of suitable foraging and roosting habitat for a variety of migratory shorebird species.

7.7.7.3 Focal Sites

Within the various ecosystems, focal sites occur as localized terrain and habitat features upon which multiple species or multiple individuals of one or more species are ecologically dependent. There is a heightened risk that the loss or degradation of such features, singly or otherwise, may disproportionately affect the activities or survivability of multiple individuals in a local population and, in some cases, may jeopardize the viability of local populations.

Nine types of focal site are recognized, including caves and rock shelters (three types), large trees (two types), nesting sites for IUCN Vulnerable freshwater turtles, crocodile nesting sites, hill forest pools and the site in which the IUCN Critically Endangered mangrove tree *Bruguiera hainesii* was recorded. Focal sites of highest conservation significance include:

- The Wi'i Creek cave and *Bruguiera hainesii* sites, both of which support IUCN Critically Endangered species.
- Other caves and nesting sites for crocodiles and two IUCN Vulnerable freshwater turtle species: the pig-nosed turtle (*Carettochelys insculpta*) and the striped New Guinea soft-shelled turtle (*Pelochelys bibroni*).

The baseline sensitivity ranking of important focal sites is shown in Table 7.20, with features underpinning the assignments for the sites considered to be Moderately Sensitive or higher. A map of off-river waterbodies is shown in Figure 7.28, while turtle and crocodile nesting site locations, documented in the southern PRL-15 area, are provided in Figure 7.29. The Wi'i Creek cave site area is shown in Figure 7.21.

Further information on each of these focal sites can be found in Part 6 of Volume 2.

Table 7.20 – Baseline Sensitivity of Focal Sites in the Study Area

Feature	Sensitivity*	Characteristics
Caves - general	VS	♦ Play a regionally significant and, in some cases, potentially globally significant (e.g., troglobitic fauna) role in supporting populations of multiple habitat-specialist species. ♦ Have a somewhat limited regional availability. ♦ Are sensitive to disturbance.
Caves - Wi'i Creek area	ES	♦ Potentially harbors a maternity roost of the IUCN Critically Endangered Bulmer's fruit bat (*Aproteles bulmerae*) (see Plate 7.37). ♦ Any other caves found to support this species would be considered to be similarly sensitive.
Other rock shelters (shallow rocky overhangs and fissures)	MS	♦ Often mentioned as secondary roost sites for cave-roosting bat species (Flannery, 1995; Bonaccorso, 1998). ♦ Likely to be localized but may occur anywhere in hilly terrain in the study area (Plate 7.66).

Table 7.20 – Baseline Sensitivity of Focal Sites in the Study Area (cont'd)

Feature	Sensitivity*	Characteristics
Large trees (general)	MS	♦ Defined as: – Greater than 1 m diameter at breast height (dbh) in areas of unlogged hill forest (all types), Alluvial forest (Pl) and Open alluvial forest (Po). – Greater than 75 cm dbh in areas of logged hill and alluvial forest and in vegetation types other than those above. ♦ Provide a concentrated source of natural resources that are important for maintaining the diversity of local wildlife populations (e.g., tree hollows, breeding and lekking sites).
		♦ Support heavier epiphyte loads, which provide additional habitat for fauna. ♦ Relatively rare in logged forest, where all accessible commercial species and greater than 50 cm dbh are typically removed.
Large trees (figs)	MS	♦ Defined as those with greater than 50 cm dbh. ♦ Among the most important food source for tropical frugivores in the world (O'Brien et al., 1998; Shanahan et al., 2001), including conservation significant species, some fig specialists and keystone species that play an important ecological role in dispersing seeds of rainforest trees.
Bruguiera hainesii site	ES	♦ A stand of the IUCN Critically Endangered mangrove tree, plus a 500-m radius (Plate 7.67).
Freshwater turtle nesting sites	VS	♦ Nesting sites for two large IUCN Vulnerable freshwater turtle species (Plate 7.68), the pig-nosed turtle (see Plate 7.50) and the striped New Guinea soft-shelled turtle.
Crocodile nesting sites	VS	♦ Nesting sites for the estuarine crocodile (*Crocodylus porosus*) and the New Guinea freshwater crocodile (*Crocodylus novaeguineae*).
Hill forest pools	MS	♦ Small pools in hill forest provide important breeding habitat for a variety of frogs and odonates, including two undescribed species of tree frog and a new-to-science damselfly. ♦ Widespread but sparsely distributed in steep terrain of the Middle Purari Hills and Southeast Hills ecological zones.

* Sensitivity: MS – Moderately Sensitive; VS – Very Sensitive; ES – Extremely Sensitive (see Section 7.7.8.1).

LOCATION OF OFF-RIVER WATERBODIES AND THE PRL-15 OXBOW WETLANDS WITHIN THE STUDY AREA

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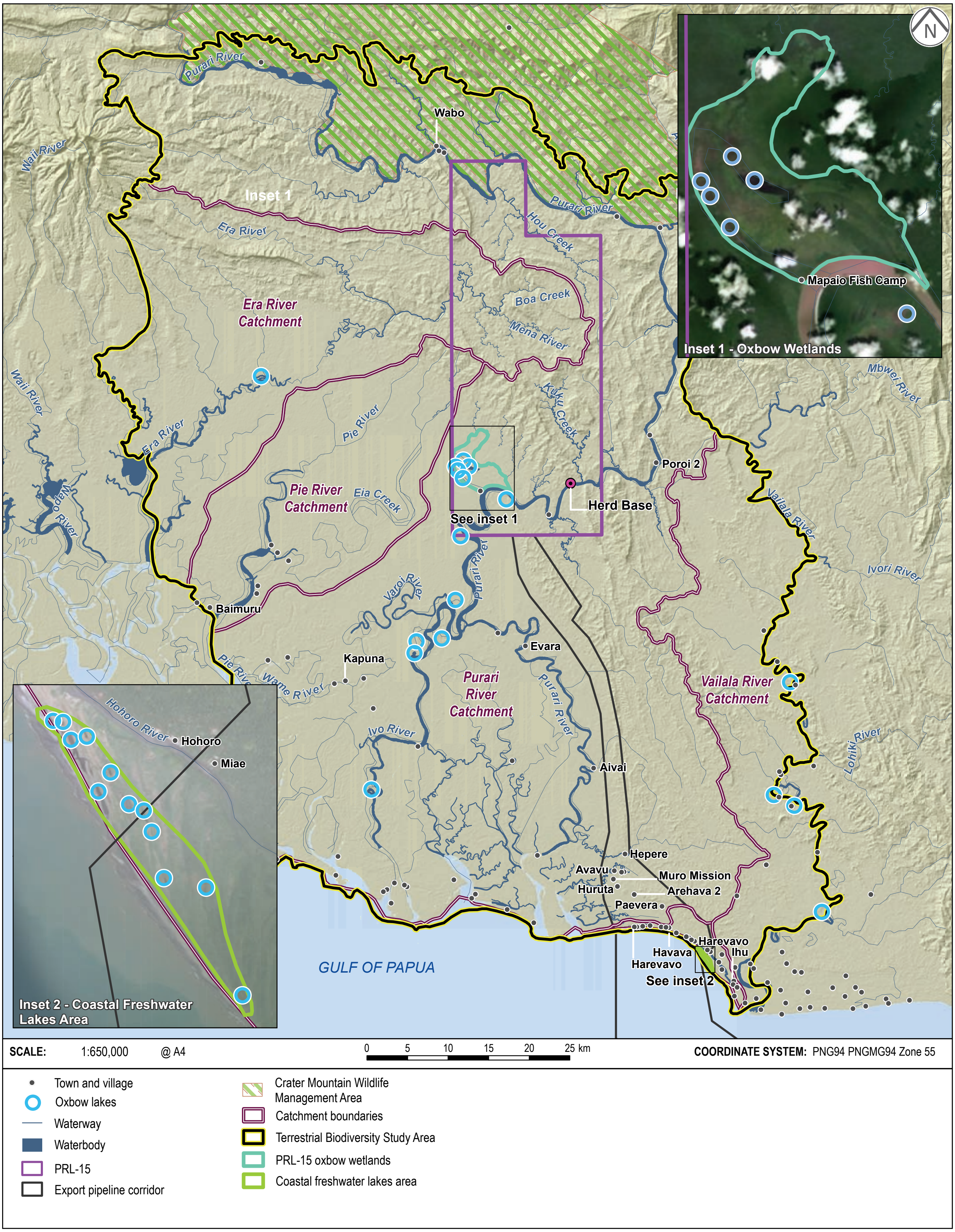
FIGURE 7.28



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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LOCATION OF TURTLE AND CROCODILE NESTING SITES DOCUMENTED IN SOUTHERN PRL-15

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FIGURE 7.29

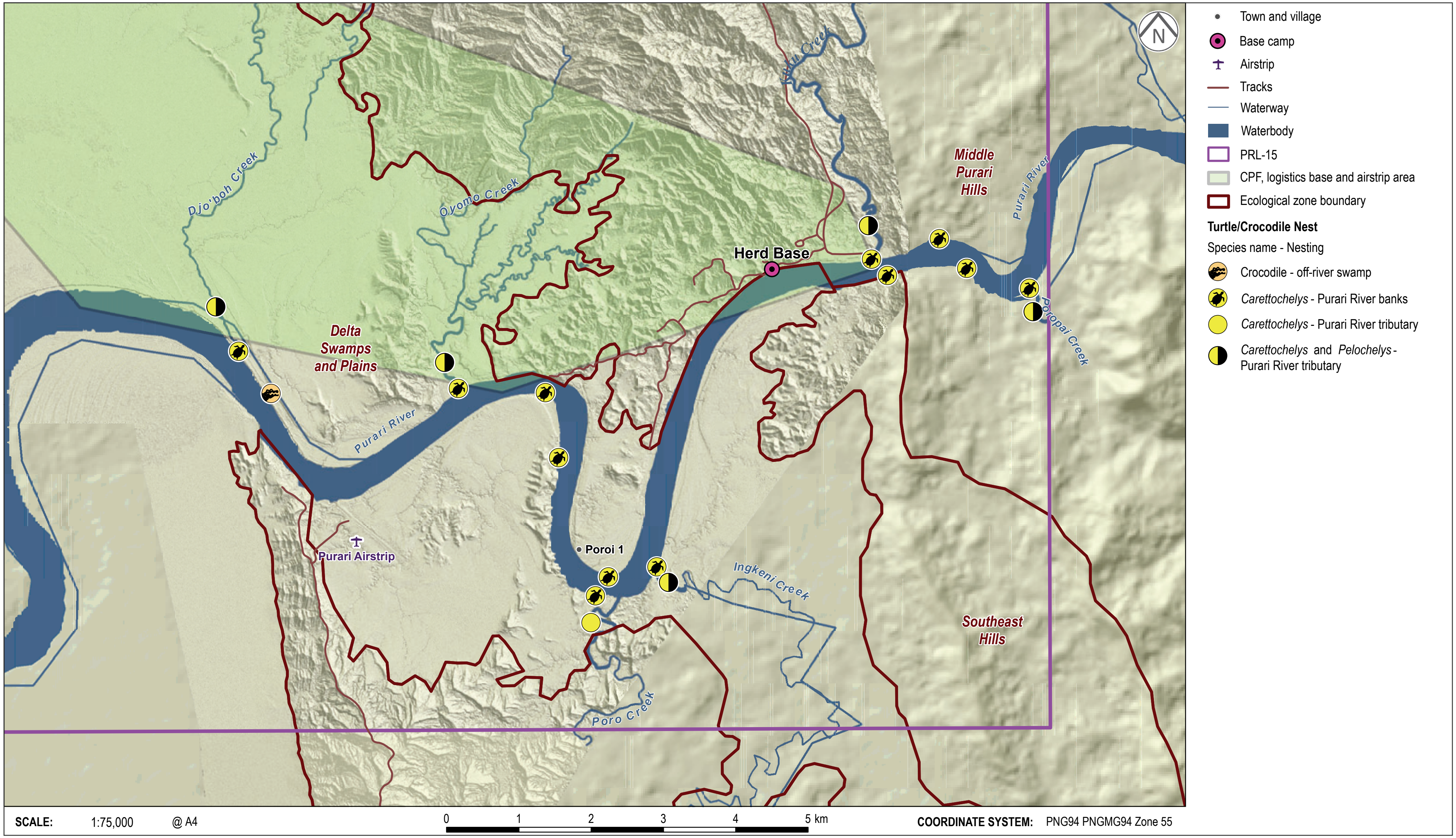

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Plate 7.66 – Sheer Cliffs of the Mena Basin Aure Beds Formation near the Antelope-3 Operations Camp

Photo: Iain Woxvold.

Plate 7.67 – Transitional Mangrove Forest Showing *Bruguiera hainesii* Trees on Left

Photo: Fanie Venter.

Plate 7.68 – Pig-nosed Turtle Nesting Bank, Purari River Downstream from Herd Base

Photo: Iain Woxvold.

7.7.8 Baseline Sensitivity

7.7.8.1 Assigning Sensitivity

The baseline sensitivity of biodiversity values is determined to facilitate the assessment of potential Project-related impacts and the development of appropriate management measures, including avoidance and mitigation, which are described in Part III of the EIS. The sensitivity of biodiversity values is evaluated at the species, ecosystem and focal site scales. Based on its inherent value and sensitivity to change, each biodiversity value is assigned one of the following five sensitivity rankings[23]:

- Not Sensitive.
- Low Sensitivity.
- Moderately Sensitive.
- Very Sensitive.
- Extremely Sensitive.

For this study, conservation significant species are defined as those species assigned a sensitivity ranking of Moderately Sensitive or higher.

23 These equate to sensitivity rankings of minimal, low, medium, high and very high, respectively, in Chapter 11.

More detailed information on the concepts underpinning sensitivity assignment is provided in Part 6 of Volume 2.

7.7.8.2 Flora and Fauna

A total of 164 conservation significant species was recorded or may occur in the study area, including 97 Moderately Sensitive, 62 Very Sensitive and 5 Extremely Sensitive species (Table 7.21).

Table 7.21 – Conservation Significant Species Recorded or Potentially Occurring in the Study Area

Taxonomic Group	Sensitivity*			Total Number of Species
	MS	VS	ES	
Flora	9/20/18/(30)	10/24/15/(31)	3/1/1/(4)	**65**
Non-volant mammals	2/3/–/(4)	8/4/2/(10)	–/–/–/(0)	**14**
Bats	2/1/–/(2)	–/–/–/(0)	1/1/–/(1)	**3**
Birds	29/1/-/1#	7/2/–/(7)	–/–/–/(0)	**37**
Reptiles	–/–/–/2/(2)#	2/2/2/(4)	–/–/–/(0)	**6**
Frogs	1/11/8/(11)	–/2/2/(2)	–/–/–/(0)	**13**
Odonates	2/14/4/(15)	–/8/4/(8)	–/–/–/(0)	**23**
Butterflies	3/–/–/(3)	-/–/–/(0)	–/–/–/(0)	**3**
Total	**97**	**62**	**5**	**164**

* Sensitivity: MS - Moderately Sensitive; VS - Very Sensitive; ES - Extremely Sensitive (see Section 7.7.8.1). Numbers indicate: conservation-listed/restricted-range/new-to-science and undescribed/(total). Within each cell, the total is not a sum of all figures, since many species occur in more than one category (e.g., conservation-listed and restricted-range).
# The fourth category refers to the southern cassowary (*Casuarius casuarius*) and two locally occurring crocodile species, species of importance to local communities but that are not conservation-listed, restricted-range or scientifically undescribed.

Of greatest significance are those species assigned Extremely Sensitive or Very Sensitive status:

- Extremely Sensitive: five species comprising four plants and one bat, including:
  - Four IUCN Critically Endangered species, three of which are confirmed present (see Section 7.7.6.2). The plant *Guioa hospita* may also occur.
  - One new-to-science species, the plant *Begonia* sp. 5 (see Plate 7.38), currently known only from a few individuals in or near the proposed CPF area.
- Very Sensitive: 62 species comprising 31 plants, 10 non-volant mammals, 7 birds, 6 herpetofauna species, and 8 odonate species, including:
  - Nine IUCN Endangered species, eight of which are confirmed present (see Section 7.7.6.2).
  - Seventeen IUCN Vulnerable species, 13 of which are confirmed present (see Section 7.7.6.2).
  - One IUCN Data Deficient species: starry owlet-nightjar (*Aegotheles tatei*).
  - Twenty-six restricted-range new-to-science and undescribed species.
  - Six restricted-range plants known only from the type material collected previously from the southeast sector of the study area; none are known from PRL-15, and all but *Cyrtandra externata* are expected to have been found outside of the export pipeline corridor. None were rediscovered during Project surveys.

– Four restricted-range damselflies, all habitat specialists of clear-flowing primary forest streams, previously known only from the type localities either north or west of the study area. Each of these species was recorded during Project surveys.

Further information on these significant species can be found in Part 6 of Volume 2.

7.7.8.3 Protected Areas, Priority Ecosystems and Focal Sites

The number of priority ecosystems and focal sites assigned sensitivity status of Moderately or higher is shown in Table 7.22. Sensitivity assignments for each ecosystem and focal site are shown in Tables 7.19 and 7.20. A sensitivity map of protected areas, terrestrial ecosystems and selected focal sites is provided in Figure 7.30.

Table 7.22 – The Number of Priority Ecosystems and Focal Sites Assigned Sensitivity Status of Moderately Sensitive or Higher

Feature	Sensitivity*		
	MS	VS	ES
Priority ecosystems	9	6	0
Focal sites	4	3	2

* Sensitivity: MS – Moderately Sensitive; VS – Very Sensitive; ES – Extremely Sensitive (see Section 7.7.8.1).

Protected Areas

The Crater Mountain WMA is considered to be Very Sensitive due to its ongoing recognition as part of the New Guinean protected areas network.

Priority Ecosystems

Sixteen priority ecosystems (see Section 7.7.7.2) are assigned Moderately Sensitive or Very Sensitive status. No Extremely Sensitive features are identified at the ecosystem scale.

Very Sensitive priority ecosystems include:

- Three terrestrial ecosystems: Hill forest (H) on limestone, unlogged Alluvial forest (P) and Mangrove (M).
- Two freshwater aquatic ecosystems: oxbow lakes and the PRL-15 oxbow wetlands.
- One coastal and estuarine aquatic ecosystem: tidal wetlands of the Purari River delta.

The features underpinning the assignments for those ecosystems considered to be Moderately Sensitive or higher are outlined in Table 7.19.

Sensitivity values assigned to freshwater aquatic and estuarine aquatic ecosystems are based on a terrestrial biodiversity perspective; additional information on these aquatic ecosystems is provided in Section 7.6.

Focal Sites

Nine focal sites (see Section 7.7.7.3) are assigned a sensitivity status of Moderately Sensitive or higher.

Two focal sites are considered to be Extremely Sensitive:

- The Wi'i Creek cave, in which remains of the IUCN Critically Endangered Bulmer's Fruit Bat were found (see Plate 7.37).
- The site supporting a population of the IUCN Critically Endangered mangrove tree *Bruguiera hainesii*.

SENSITIVITY MAP OF ECOSYSTEMS AND SELECT FOCAL SITES

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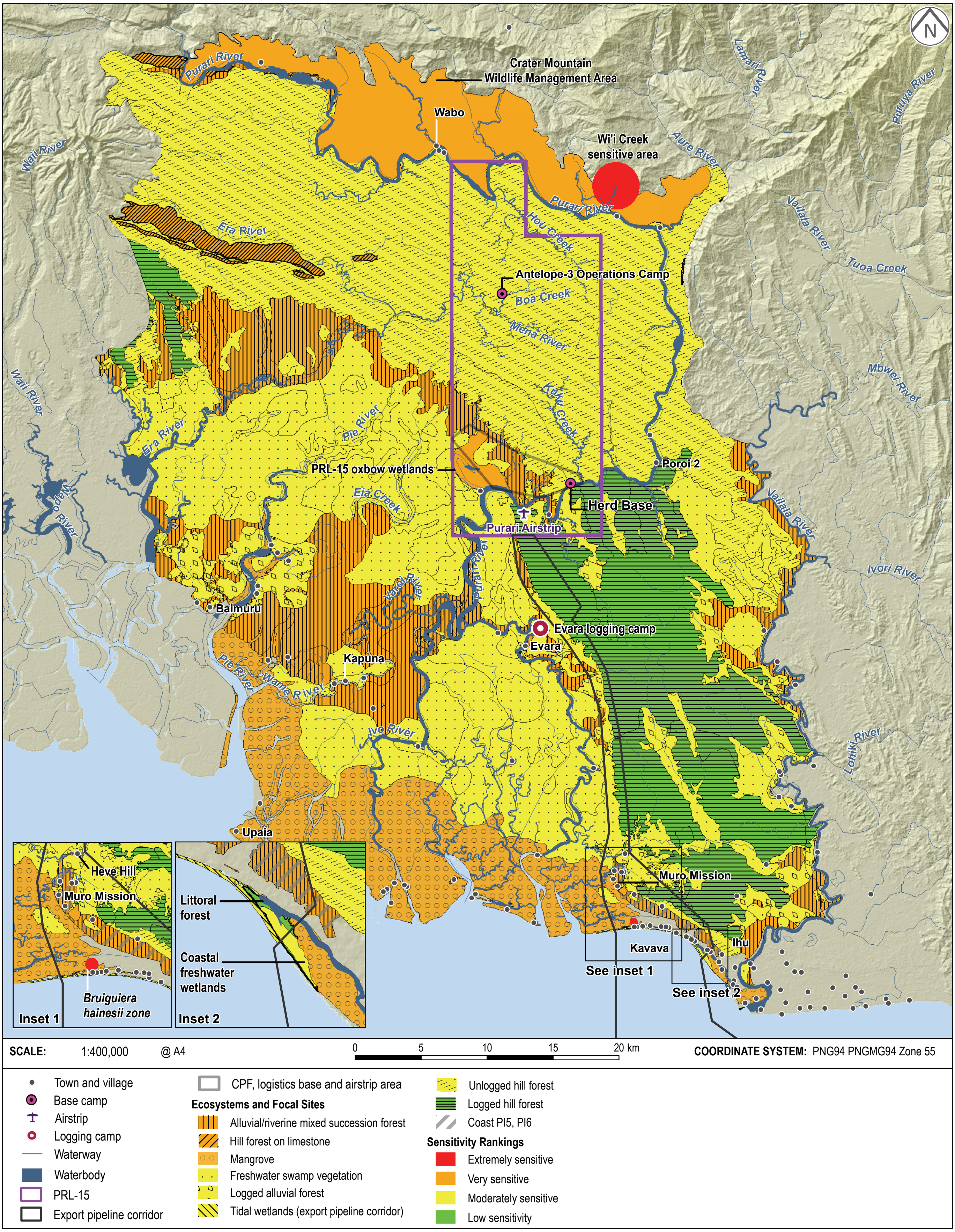
FIGURE 7.30



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Three focal sites are considered to be Very Sensitive:

- Caves: in general (i.e., other than the Wi'i Creek cave), for their potential to play a regionally significant role in supporting populations of multiple habitat-specialist species, for their somewhat limited regional availability and for their sensitivity to disturbance.
- Nesting sites for two crocodile species occurring in the study area.
- Nesting sites for two IUCN Vulnerable freshwater turtle species.

The features underpinning the assignments for those focal sites considered to be Moderately Sensitive or higher are outlined in Table 7.20.

7.8 Vegetation Regeneration

The information in this section has been summarized from the Upstream Vegetation Regeneration Baseline Report (Part 8 of Volume 2). Further, more detailed information is contained in that report.

7.8.1 Study Overview

The Upstream Vegetation Regeneration Baseline Report characterizes natural regeneration of different vegetation types on various landforms and substrates to identify the factors that will influence the assessment of rehabilitation requirements for areas that may be disturbed by Project construction activities. The regeneration requirements were investigated through assessment of:

- Passive rehabilitation by natural regeneration of a range of disturbed and constructed surfaces.
- Active rehabilitation requirements in potentially sensitive vegetation communities and poorly represented vegetation types (if present).
- Regeneration response/impacts in potential spoil sidecasting areas.
- Sensitive vegetation type resilience to potential impacts from (e.g., construction-related) earthworks.
- Potential effects of plant pathogens, in terms of rehabilitation success.

This baseline study was completed through a literature and spatial data review and by field surveys in June/July and September 2016 involving aerial survey, ground observation and vegetation sampling (regeneration assessment), and soil collection in a representative range of disturbed sites. Sites assessed included natural forest gaps, slumps and landslips, road alignments and associated cut and fill slopes, disturbed sites where vegetation has been cleared but topsoil remained intact, disturbed sites where topsoil has been cleared or eroded, and sensitive vegetation types where present and accessible.

Rehabilitation was assessed contextually in the terrestrial biodiversity study area, as outlined in Section 7.7.2 (see Figure 7.17), while the field-based assessment was undertaken in the area in which the proposed Project-related disturbance will occur, including PRL-15 and the export pipeline corridor.

7.8.2 Tropical Forest Rehabilitation

Influencing Factors

Broad approaches to and factors influencing tropical rainforest rehabilitation that are likely to be important for rehabilitation in the study area include soil type, water infiltration rates, soil modification, natural regeneration and active rehabilitation.

The five major soil-forming factors are climate, parent material, vegetation, relief and time. Differences in the combination of these factors result in soil types varying over relatively short distances, such as between ridge, slope, toe slope and valley features. The different soil types are characterized by differences in chemical and physical properties (Bleeker, 1983), which may affect their response to disturbance and their ability to act as a successful rehabilitation substrate once they are disturbed. Study area soils have been described in Section 7.2.

Rainfall infiltration into tropical soils is essential for ecosystem function and natural recovery processes and is dominated by two systems: 1) rapid drainage with short residence time through macropores created by soil fauna, and 2) slow drainage with longer residence in micropores where the moisture is retained by capillarity (Nortcliff & Thornes, 1989). If infiltration is inadequate, then accelerated runoff is likely to lead to an increased erosion risk.

Soil quality typically declines on modified (e.g., disturbed or constructed) surfaces due to degradation of the soil nutrient status and physical properties. Changes to soil physical properties include changes to soil texture (the proportion of sand, silt and clay), an increase in the proportion of rock fragments and an increase in the bulk density with an associated decrease in infiltration due to compaction (Ahirwal & Kumar, 2016). In addition, soil fertility is typically lower due to a loss of topsoil exposing less fertile subsoil or the leaching of nutrients from loss of the protective vegetation cover. In some circumstances, soils are completely lost leaving bare rock, which may have a 1 to 2 cm bryophyte crust on flat surfaces that eventually facilitates soil development and the establishment of pioneer plants in the thinnest of new soils.

Depending on the degree of disturbance, many plant species from tropical forests have the potential to rapidly regenerate or re-establish without intervention. Natural regeneration is highly successful for re-establishing native species to restore forest along flat terrain or even gently sloping terrain, provided that topsoil remains, erosion is not excessive and fire is excluded (Rogers, 2005). Relying entirely on natural regeneration; however, can be slow and ineffective, depending on the landscape and ecological conditions. Key aspects in natural regeneration that have been identified by both Parrotta (2002) and Holl and Cairns (2002) include:

- Seed availability.
- Seed germination.
- Competition with existing vegetation.
- Microclimate.
- Microhabitats.
- Fire.
- Soil nutrients.
- Soil microbial communities.
- Herbivores and predation.
- Social factors.
- Time.

Limitations or constraints may occur in each of the identified aspects of the rehabilitation process, which may limit the overall development rate of a forest ecosystem. Consequently, prior identification of constraining rehabilitation factors is important in assessing the likely success of natural forest re-establishment.

Active tropical forest rehabilitation, as distinct from relying entirely on natural regeneration processes, is an important approach to restore forest ecosystems, particularly on previously cleared lands (ITTO, 2002) where natural regeneration is unlikely to have the desired success. Typical strategies are built on understanding the establishment ecology of tropical forest species and may include:

- Defining any potential soil constraints to plant establishment and growth.
- Introducing topsoil where appropriate and when available.
- Planting seedlings of appropriate early colonizing tree species.
- Controlling grasses and groundcovers to prevent smothering and competition for resources.
- Enrichment planting as an appropriate microclimate develops, including using shade-tolerant tree species; incorporating the longer-lived largest forest trees that will eventually form the forest canopy; or indirectly encouraging the establishment of these species by attracting seed-dispersing fauna, such as through fruit-bearing pioneer tree species (Jasper & Tongway, 2005), which typically grow fast, reach sexual maturity quickly and produce prolific quantities of fruit. The seed-dispersing fauna subsequently introduce other species through seed in their droppings.

Where topsoil remains intact, rehabilitation by natural regeneration is considered to be the best approach to rehabilitate the range of vegetation types that occur in the study area. Where topsoil has been lost, active rehabilitation is likely to be required, involving dispersing cleared vegetation across disturbed and reformed surfaces, and planting fast-growing pioneer species. At very sensitive sites, further action (e.g., hydromulching) may warrant consideration.

Constraints to Successful Rehabilitation

In addition to the broad approaches to and factors influencing rehabilitation as described above, erosion, weeds and dieback have the potential to constrain successful rehabilitation in the study area.

Erosion

Erosion causes soil to be moved or worn away from an area, primarily leading to the loss of nutrient-rich topsoil and its associated viable seed bank. The soil seed bank is essential for providing rapid regeneration across disturbed surfaces; and most of the seeds (99%) are pioneer species with fast growth rates, and short life cycles that quickly reproduce to replenish the soil seed bank. The seeds of pioneer species remain viable in the soil for several years, from which forest regeneration occurs.

Disturbance from construction activities (e.g., roads or a pipeline right of way) will expose the landscape to modified levels of erosional forces from rain, flowing water and gravity (mass movement), the effects of which will vary according to the soil type (including stability or erodibility of the exposed surface soils or subsoils), terrain and position in the landscape (e.g., ridge, slope or valley), and the construction drainage techniques.

Consequently, construction activities result in different erosion risks throughout the Project footprint, especially activities in areas with unstable dispersive soils on steep slopes. High rates of erosion on Project construction surfaces without prompt mitigation will create challenges for rehabilitation.

Weeds

Weed infestations, especially if severe, can reduce the rehabilitation success by out-competing native species. While some weed species already exist in the Project area (see Section 7.7.6.6), construction activities can provide a migration pathway for these weeds (e.g., through transport of equipment and machinery) into areas that were previously weed free or can bring additional invasive species into an area where they were previously not present. Further information on weeds that typically invade construction surfaces can be found in the Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2) and its annexes.

Dieback

Forest dieback has the potential to prevent successful rehabilitation and can be spread through Project-related activities. The two main natural causes of forest dieback in Papua New Guinea are:

- Root rot associated with the fungal pathogen *Phytophthora* sp.
- Prolonged inundation from severe flood events, particularly across the lowlands of Papua New Guinea.

Phytophthora-related dieback in Papua New Guinea is confined to montane *Nothofagus* forests (southern beech) (Arentz, 1984, 1988), and therefore is irrelevant to the Project, as no *Nothofagus* forest is present in the study area.

Dieback related to plant pathogens (probably fungal) also occurs in Papua New Guinea's lowland zone (i.e., below 1,000 m asl), it but appears to be restricted to volcanic soils and is associated with roads and extensive pig activity.

Prolonged inundation occurs naturally, but changed hydrological conditions associated with construction earthworks can also cause flooding and therefore needs to be considered during the development of construction management plans at a later stage to reduce the risk of Project-induced dieback.

Localised patchy dieback, believed to be associated with land inundation due to changed surface hydrology from logging road construction, was recorded during the terrestrial biodiversity surveys along the export pipeline corridor, in an area of open alluvial forest (see Plate 7.69).

Plate 7.69 –Aerial View of Dieback with Dead Trees Adjacent to the River

Photo: Howard Rogers

7.8.3 Regeneration Response to Disturbance Across Different Surfaces

The regeneration characteristics of disturbed sites visited during the study are summarized in Table 7.23.

Table 7.23 – Regeneration Response to Different Disturbance Types

Disturbance Type	Substrate and Regeneration Response
Temporary clearance/cutting of woody vegetation	Vegetation is expected to rapidly regenerate where woody vegetation has been temporarily cleared, but soils and cut stumps remain relatively intact. Examples of good recovery from analogous natural disturbance events occur throughout the areas of hill forest where slumping has occurred. Based on forest recovery rates in logging gaps (Rogers, 2010), the rate of recovery from this type of disturbance is likely to be relatively fast with a closed canopy approximately 9 m tall being reached around five years after disturbance. Small clearings will regenerate, although typically regeneration is less abundant than in a large clearing. Raised microsites in these areas (e.g., a root mound) appear to be important for plant establishment. A raised microsite typically has better drainage and may receive more direct sun exposure to promote seedling/sapling growth. **Summary**: Excellent regeneration, particularly from cut stumps and previously suppressed saplings.
Complete removal of vegetation exposing topsoil	Where vegetation including stumps had been completely cleared, but topsoil remained, excellent regeneration was observed on gentle slopes around existing infrastructure sites. This capacity reflects moisture and temperature conditions that favor germination, a relative lack of competition from weed species, the application or dumping of salvaged topsoil with a viable soil seed bank, and/or relatively abundant seed rain from the adjacent forest. On sloping sites where the vegetation has been cleared, topsoil is particularly exposed to erosive rainfall events. Field observations suggest the topsoil and subsoil are rapidly lost in these high-rainfall events exposing unconsolidated sandstone or mudstone in areas of hill forest (Plate 7.70). These surfaces provide poor rehabilitation substrates and are mostly colonized by weeds or, on steeper slopes, vegetation may be absent.
Complete removal of vegetation exposing topsoil (cont'd)	Where surfaces are on gentle slopes with exposed unconsolidated sandstone substrate, several tree species will regenerate, particularly *Trichospermum*, *Alphitonia incana*, *Duabanga moluccana* and *Pipturus*. *Duabanga moluccana* was common along the ANT-3 access road and had a wide spreading crown that may assist with weed suppression. **Summary**: Poor regeneration on steep slopes due to high levels of topsoil erosion exposing subsoil; however, on gentle slopes in hill forest areas, regeneration on exposed topsoil was successful. On exposed sandstone substrate on gentle slopes, some tree species regenerate in the absence of topsoil.
Removal of vegetation and soil	Where complete removal of vegetation and topsoil occurs exposing subsoil and bedrock (e.g., during typical infrastructure construction), reinstatement may be required. In the study area, this is particularly applicable across hill forest where erosion will be at its highest, as this forest is underlain predominantly by siltstone and mudstone bedrock that forms part of the Southern Fold Mountains geomorphology region (see Section 7.2). Field observations suggest these substrates may be difficult to rehabilitate, as observed regeneration was poor and vegetation cover (apart from the occasional weed) was low across the representative sites (Plate 7.71). Poor regeneration is possibly reflecting the absence of topsoil and the associated soil seed bank, and a combination of poor rooting medium due to poor water-holding capacity, the blocky mudstone structure with little potential to form soil aggregates, and possibly low fertility. In particular, on slopes exposed to the sun, the mudstone is friable and dry and becomes hot with increasing sun exposure. **Summary**: Poor regeneration in areas of hill forest particularly across mudstone substrates, which become dry and friable. Sites often dominated by weeds.

Table 7.23 – Regeneration Response to Different Disturbance Types (cont'd)

Disturbance Type	Substrate and Regeneration Response
Sidecasting surfaces	In general, sidecast slopes are poor rehabilitation mediums because of a lack of topsoil and the small aggregate size of the upper slopes; better regeneration tends to occur at the base of sidecast slopes, as that is where large aggregates (e.g., large blocks of sidecast material) typically accumulate. Large aggregates are important for trapping organic matter (e.g., leaf litter and other plant debris) and plant propagules, and the organic matter decomposes providing a growing medium for seed germination. In PRL-15, sidecasting of excess spoil in hilly terrain was previously undertaken for exploration works associated with the construction of the existing Antelope and Elk wellpads. This sidecasting resulted in exposed surfaces; however, good regeneration was present on all the sidecast surfaces, except on a steep slope at ANT-3 where subsequent surface landslips had occurred (Plate 7.72). Where sidecast slopes are stable, the majority of them support good regeneration. The presence of regenerating forest reflects the sidecasting of topsoil, within which the first 10 cm supports the majority of the soil seed bank. **Summary**: Good regeneration where topsoil has been dispersed across the slope, but potential for landslips across steep slopes.
Wellpad surfaces	Wellpad surfaces are characterized by flat hardpack, normally made of crushed bedrock with variable drainage, possibly attributable to differing degrees of compaction. They often have steep side slopes. In the study area, where surfaces are waterlogged, little or no forest regeneration was present; however, weeds were abundant, including the Priority 1 weed *Angelonia angustifolia* at Elk-1 (see Section 7.7.6.6 and Plate 7.51). In contrast, well-drained hardpack surfaces lead to poor surfaces being present for any type of vegetation establishment other than occasional grasses and cryptograms, for example at ANT-1 (Plate 7.73). Bryophyte crusts were also present in the study area, particularly on the flat wellpad surface at ANT-1. **Summary**: Poor regeneration due to waterlogging across a surface, or poor regeneration caused by compacted well-drained hardpack. Poorly drained surfaces infested by weeds.

Plate 7.70 – Erosion of a Sandstone Substrate Leaving a Subsoil Pedestal

Photo: Howard Rogers.

Plate 7.71 – Regeneration Failure on a Convex Mudstone Substrate Surface

Photo: Howard Rogers.

Plate 7.72 – Landslip on a Sidecast Slope Showing Failed Regeneration

Photo: Howard Rogers.

Plate 7.73 – Bare Hardpack on a Wellpad Surface

Photo: Howard Rogers.

7.8.4 Rehabilitation of Vegetation Types and Landforms

Major differences in forest types in the study area are associated with varying landforms, also reflecting major differences in drainage and potentially in soil type. Construction works may impact vegetation and soil types associated with these different landforms in different ways, reflecting variation in natural regeneration capacity and associated soil properties such as stability (resistance to erosion) and fertility.

The proposed Project infrastructure will traverse a range of lowland vegetation types and associated landforms. Of these, some are poorly represented across the study area, while others are sensitive vegetation types that are likely to be difficult to rehabilitate, may be subject to regeneration failure if disturbed or are a particularly important resource of restricted distribution for local communities for ecosystem services. Disturbances that result in topsoil loss, drainage changes, soil compaction or substantial sedimentation may impact all the vegetation types. Consequently, where impacts are more severe, any vegetation type may be more difficult to rehabilitate (i.e., potentially sensitive) than at other locations.

Vegetation types and landforms often impacted by general construction activities, such as earthworks, are summarized in Table 7.24 with their rehabilitation requirements. Of these, three vegetation types are identified as potentially sensitive and may require additional rehabilitation measures if disturbance cannot be avoided.

Table 7.24 – Rehabilitation Constraints of Vegetation Types and Landforms

Vegetation Type (Hammermaster & Saunders, 1995a)	Landform (Field Observations and Löffler (1974))	Main Rock Type	Rehabilitation Constraints
Low Altitude Forest on Uplands – Below 1,000 m			
Hill forest (Hm)	Hilly terrain with weak or no structural control Homoclinal ridges and cuestas	Mixed or undifferentiated sedimentary Fine grained sedimentary	The hilly terrain and erosive soils of the hill forest BVG may present constraints to rehabilitation due to rapid topsoil loss in a high-rainfall environment where the vegetation cover has been removed. Rehabilitation of hill forest will be most challenging across steep slopes where erosion is likely to be high and particularly where mudstone is exposed, which quickly dries to a blocky friable structure in which plants appear not to regenerate (see Plate 7.71).
Small crowned hill forest (Hs)	Hilly terrain with weak or no structural control	Mixed or undifferentiated sedimentary	
Low Altitude Forest on Plains and Fans – Below 1,000 m			
Alluvial forest (Pl)	Composite levee plain	Alluvial deposits	Rehabilitation of alluvial forest across the upstream study area may present constraints due to the potential for damage of poorly drained soils if disturbed (e.g., compaction or damage to soil structure and the associated soil seed bank). Forest dieback was identified at one location in the export pipeline corridor in an area of Open alluvial forest (Po) where canopy dieback and tree mortality was evident across low-lying areas in approximately 60 ha of forest (see Plate 7.69). While this area is likely to have been naturally swampy and subjected to prolonged inundation, the partial logging of the area and construction of a major logging truck haul road within 100 m of the area may have further impeded drainage.
Open alluvial forest (Po)	Composite levee plain	Alluvial deposits	
Freshwater Swamp Habitats			
Swamp forest (Fsw)	Composite levee plain	Alluvial deposits	Swamp forest (Fsw) is a very poorly drained forest type and is likely to be subjected to more prolonged inundation than other alluvial forest types. Consequently, a higher degree of water ponding and localized regeneration failure may occur. The soil structure of more poorly drained soils will also be more sensitive to damage from compaction by heavy machinery movements.
Swamp woodland (Wsw)	Composite levee plain	Alluvial deposits	Swamp woodland (Wsw) is a poorly represented vegetation type in the study area; and the waterlogged nature of the soil profile is potentially very susceptible to disturbance from construction damage, particularly from heavy machinery. Swamp woodland (Wsw) is usually dominated by sago palms (*Metroxylon sagu*), which have the capability to regenerate from seed and suckers. Consequently, Swamp woodland (Wsw) has good regeneration characteristics when only palms are cut back, as it can recover quickly from suckers. Additionally, sago seed is water transported and will float back into disturbed

Table 7.24 – Rehabilitation Constraints of Vegetation Types and Landforms (cont'd)

Vegetation Type (Hammermaster & Saunders, 1995a)	Landform (Field Observations and Löffler (1974))	Main Rock Type	Rehabilitation Constraints
Freshwater Swamp Habitats (cont'd)			
Swamp woodland (Wsw) (cont'd)			sites once construction has been completed. The main rehabilitation limitation is sedimentation, which can cause vegetation dieback. Sedimentation can cover the aerial roots and can impede drainage, resulting in fine root death caused by a lack of oxygen. *Pandanus* sp. also occasionally dominates Swamp woodland (Wsw). In the study area, this is a poorly represented vegetation type. *Pandanus* species regenerate from seed, but many *Pandanus* species also regenerate from branch cuttings. This vegetation type is restricted in occurrence and associated with heavily waterlogged soils; disturbance of this vegetation type can damage soils and interfere with water flows. ***Pandanus*-dominated Swamp woodland (Wsw) has been identified as potentially sensitive and may require additional rehabilitation measures if disturbance cannot be avoided.**
Herbaceous swamp (Hsw)	Composite levee plain	Alluvial deposits	Herbaceous swamp (Hsw) is often a thick mat of vegetation floating on relatively shallow water; it will not support heavy machinery. Herbaceous swamp (Hsw) is not a common vegetation type in the study area. **Herbaceous swamp (Hsw) has been identified as potentially sensitive and may require additional rehabilitation measures if disturbance cannot be avoided.**
Swamp grassland (Gsw)	Composite levee plain	Alluvial deposits	Swamp grassland (Gsw) often occurs along the river banks. Construction in this vegetation type can therefore cause river bank erosion. This vegetation type will not support heavy machinery. **Swamp grassland (Gsw) has been identified as potentially sensitive and may require additional rehabilitation measures if disturbance cannot be avoided.**
Estuarine Community			
Mangrove (M)	Mangrove swamps	Estuarine deposits	Mangroves are important for erosion protection, are an important resource for local communities for fishing and harvesting mud crabs, and present high-value ecosystem attributes (e.g., fish nurseries); therefore, mangrove rehabilitation is a priority. In the study area, mangroves dominated by the palm *Nypa fruticans* are lower lying than those dominated by forest. They are important for preventing coastal erosion (Ellison, 1997). Regeneration of palm-dominated mangroves is primarily from seed but also occurs from its rhizomatous stem when the plant is damaged (e.g., after severe disturbances such as

Table 7.24 – Rehabilitation Constraints of Vegetation Types and Landforms (cont'd)

Vegetation Type (Hammermaster & Saunders, 1995a)	Landform (Field Observations and Löffler (1974))	Main Rock Type	Rehabilitation Constraints
Estuarine Community (cont'd)			
Mangrove (M) (cont'd)			tsunamis). Rhizomatous-vegetative regeneration may allow palm-dominated mangroves to regenerate effectively without intervention (Dahdouh-Guebas et al., 2005), while regeneration from seed may not always be effective since most of the seed is likely to be washed away at high tide (Rozainah & Aslezaeim, 2010). Mangrove forest rehabilitation has been achieved through planting and through natural regeneration, with different degrees of success. Mangroves are mostly shade intolerant and can also suffer heavy seed predation by crabs, preventing seedling establishment (Barnuevo et al., 2017). When planted in high density, shade can prevent natural regeneration; and a planted mangrove forest can lack the stand structure and diversity of the original forest. Natural mangrove regeneration has been found to be more successful than planting; however, tidal flows strongly influence the initial species composition, which results in a wide dispersal (i.e., reduced retention) of lighter propagules and large clusters of species with heavier propagules, particularly in cleared areas. Overall, the level of tidal inundation a disturbed site is influenced by determines the suite of regenerating species due to the species-specific thresholds to flooding (Friess, 2016). **Mangrove (M) has been identified as potentially sensitive and would likely require additional rehabilitation measures if disturbance cannot be avoided.**
Littoral Forest			
Littoral forest (B)	Beach ridge complexes	Marine sands	Littoral vegetation is considered a sensitive vegetation type because of potential rehabilitation constraints. It consists of herbaceous beach vegetation (Plate 7.74), beach scrub, beach woodland and Littoral forest (B) communities. Littoral forest (B) is also a poorly represented vegetation type, reflecting its naturally restricted distribution on older marine sands in the Southeast Coast ecological zone (see Section 7.7.3). Most of the communities present have a relatively thin topsoil layer that would be difficult to salvage for rehabilitation and would be readily dispersed or easily eroded by heavy rainfall if the vegetation were cleared. **Littoral vegetation has been identified as potentially sensitive and may require additional rehabilitation measures if disturbance cannot be avoided.**

Plate 7.74 – Littoral Forest Herbaceous Beach Vegetation

Photo: Howard Rogers.

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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 8: Existing Environment - Marine

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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8. Existing Environment – Marine

This chapter has drawn on information from a series of interdependent marine studies that have involved detailed bibliographic reviews, numerical modeling and marine field surveys. Part 23 of Volume 2 has further information on the scope and methods of these field surveys. The field surveys were undertaken in the upstream Project study area between 20 June and 9 July 2016, during the southeast trade wind season, and between 12 and 31 January 2017, during the northwest monsoon season. Based on this information, descriptions are provided of the following components of the marine environment:

- Seabed and coastal geomorphology (Section 8.2) derived from the Seabed and Coastal Geomorphology Baseline Report (Part 9 of Volume 2).
- Physical oceanography (Section 8.3) derived from the Physical Oceanography Baseline Report (Part 10 of Volume 2).
- Marine water and sediment quality (Section 8.4) derived from the Marine Water and Sediment Quality Baseline Report (Part 11 of Volume 2).
- Marine biodiversity (Section 8.5) derived from the Marine Biodiversity Baseline Report (Part 12 of Volume 2).
- Marine fisheries and resources (Section 8.6) derived from the Marine Fisheries and Resources Baseline Report (Part 13 of Volume 2).

A desktop assessment of the existing underwater acoustic environment was also undertaken (Attachment 8.1) and is described in Section 8.7.

The baseline characterization of the marine setting primarily focused on three sectors of the export pipeline corridor:

- Orokolo Bay.
- Offshore export pipeline corridor through the Gulf of Papua.
- Caution Bay.

8.1 General Setting

The proposed export pipeline corridor crosses the coastline at Orokolo Bay in the Gulf of Papua east of the Purari River delta. It then traverses the continental shelf along the eastern side of the gulf, adjacent to the existing PNG LNG Gas Pipeline, to Caution Bay (Figure 8.1).

The Gulf of Papua covers an area of approximately 50,000 km^2. It is open to the south adjacent to the Coral Sea and bordered by Torres Strait to the west and mainland Papua New Guinea to the northwest, north and east. Parts of the northern and western shorelines are low-lying swamps comprising the delta complexes of large rivers (including the Fly, Bamu, Turama, Kikori and Purari), which drain the mountainous highlands of central Papua New Guinea.

Large amounts of terrigenous sediments enter the northern and western parts of the gulf throughout the year, carried by flows from these large rivers. These riverine inflows have a large influence on conditions in the gulf, with freshwater sediment plumes sometimes extending to the boundary of the gulf (50 to 100 km from the coast) (Wolanski et al., 1995).

REGIONAL SETTING

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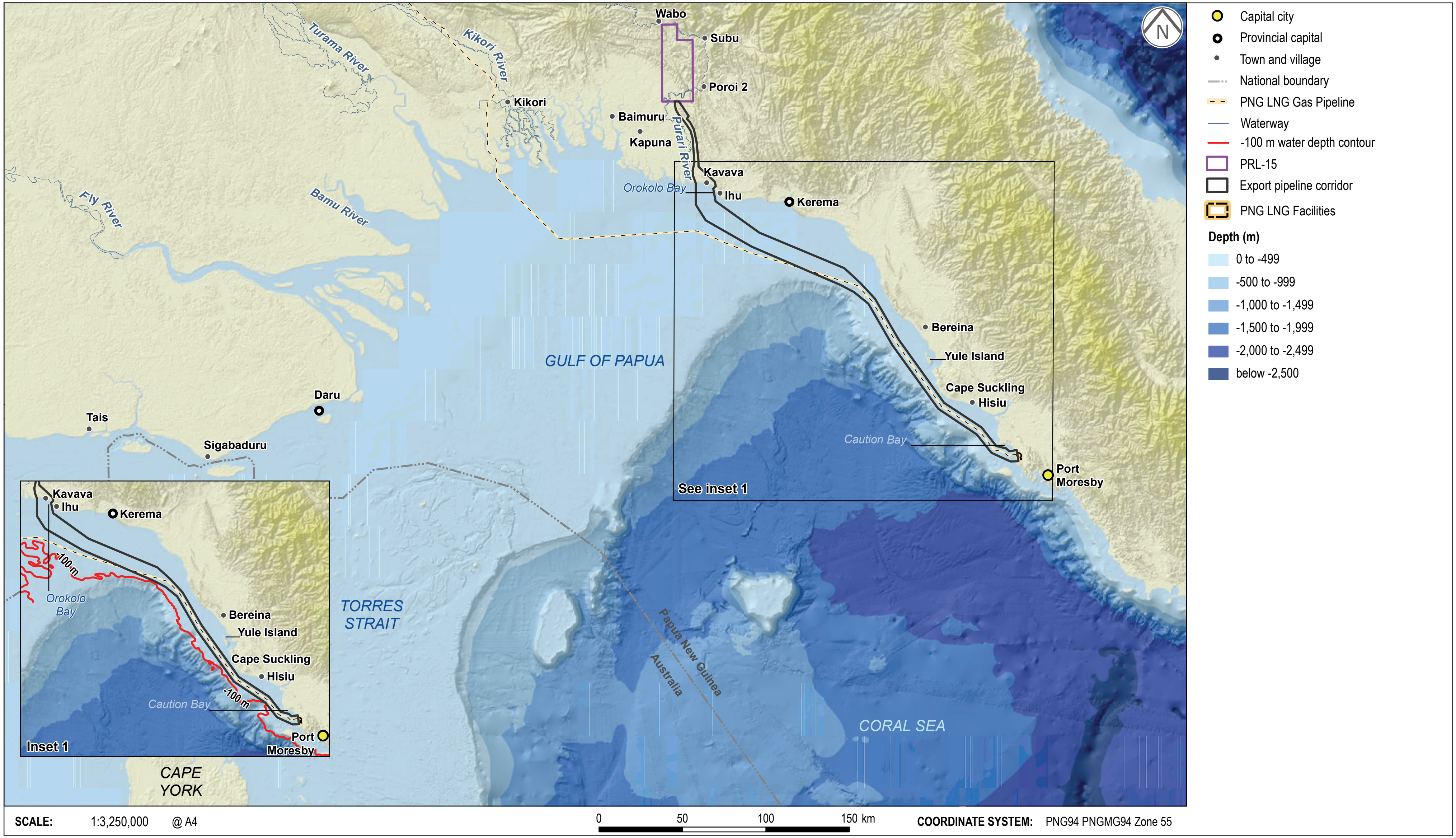
FIGURE 8.1



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The Gulf of Papua experiences two seasons, the southeast trade wind season (May to October) and the northwest monsoon season (December to March) with April and November considered transitional months with more variable conditions.

8.2 Seabed and Coastal Geomorphology

8.2.1 Regional Context

Much of the seafloor in the Gulf of Papua is located on the continental shelf at water depths less than 100 m. In particular, a large section of the western gulf, up to 200 km from land, has a depth no greater than 100 m. Beyond this section, the depth increases to 200 m over 30 to 50 km from land before reaching the edge of the continental shelf where the seafloor descends to a depth of 2,000 m over about 100 km (see Figure 8.1). By contrast, on the eastern side of the gulf, the edge of the continental shelf is within 30 to 50 km of the mainland, and the seafloor rapidly falls to 2,000 m deep within 50 km of the continental shelf.

Significant quantities of terrigenous sediment are contributed to the northern and western parts of the gulf throughout the year, carried by flows from several large rivers (including the Fly, Bamu, Turama, Kikori and Purari). A conceptual understanding of sediment transport processes for the Gulf of Papua is presented in Figure 8.2 and is based on existing literature and numerical modeling described in the Physical Oceanography Baseline Report (Part 10 of Volume 2) (Section 8.3).

Terrigenous sediment discharged by the rivers is initially deposited in shallower areas (less than 15 m deep) but is remobilized and transported by wave activity and increased currents (Walsh et al., 2004). During the southeast trade wind season, larger waves and currents remobilize finer sediments, and the clockwise current circulation pattern in the gulf transports sediment to the southeast. At the same time, waves coming predominantly from the southeast transport sediment in a northwesterly direction along the shoreline. During the northwest monsoon season, there is an anticlockwise circulation pattern on the continental shelf in the gulf. Lower-energy wave conditions cause more of the sediment delivered by the rivers to be deposited locally, and there is a much lower rate of shoreline sediment transport.

Off-shelf removal of terrigenous sediment occurs due to the Coral Sea Coastal Current, which flows northwards (entering the gulf along the eastern edge of the Torres Strait) and transports sediment in a northeasterly direction toward a narrow section of the continental shelf where it is removed by gravity currents (Harris et al., 1996).

8.2.2 Baseline Characterization

8.2.2.1 Study Overview

Description of the seabed and coastal geomorphology in the study area is based on existing information from previous studies, the scientific literature and the marine field surveys, which involved:

- Acoustic data collection to identify and map benthic features, including different substrate types.
- Sediment sampling to assess particle size distribution, and visual observation of benthic sediment (discussed in Section 8.4.3).
- Visual observation of coastal and seabed geomorphological features.

CONCEPTUAL SEDIMENT TRANSPORT PATTERNS IN THE GULF OF PAPUA DURING THE SOUTHEAST TRADE WIND SEASON AND NORTHWEST MONSOON SEASON

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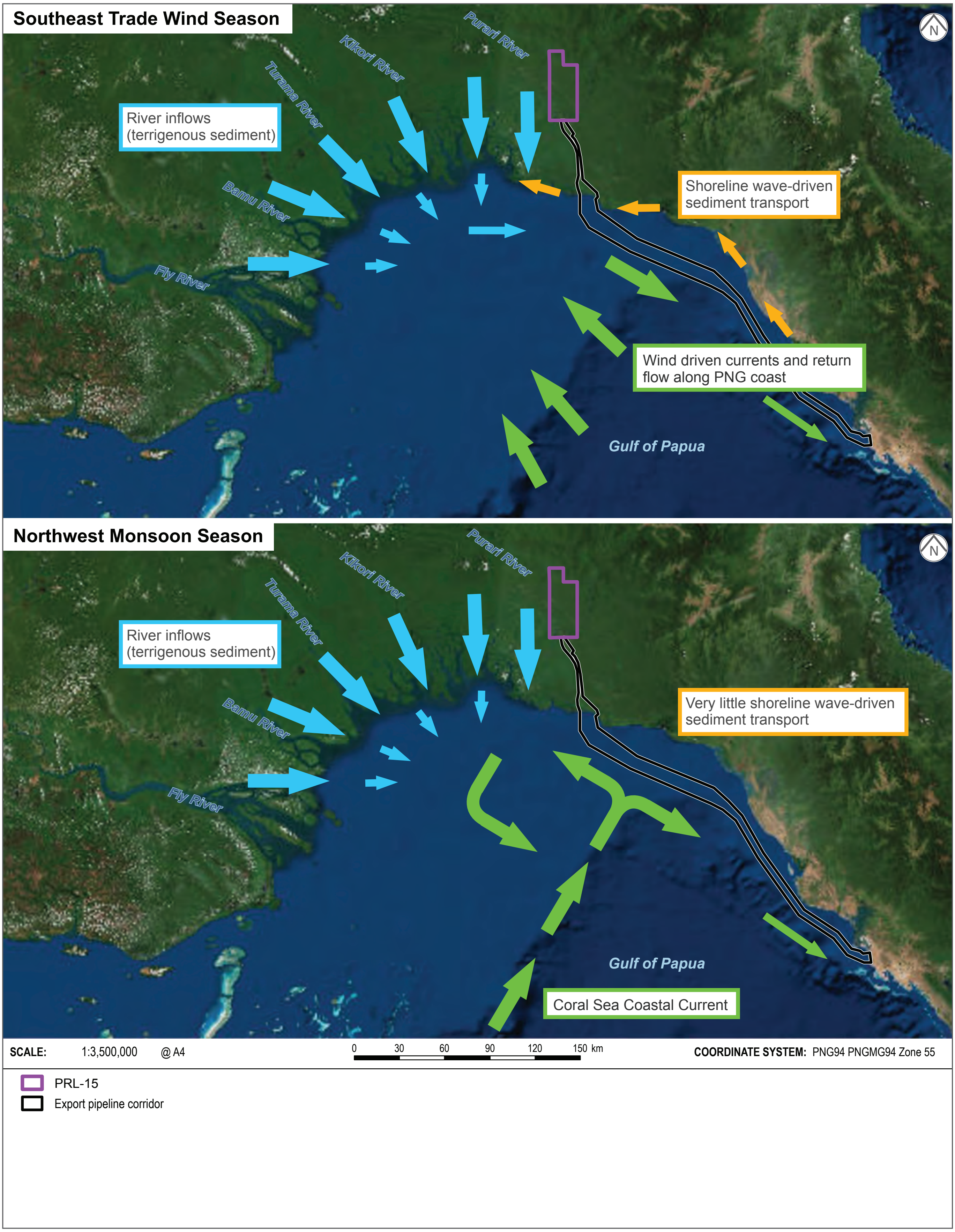
FIGURE 8.2



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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8.2.2.2 Purari River Delta

The Purari River delta is a large low-lying deltaic complex that drains the Purari River catchment into the Gulf of Papua. It comprises three main distributary channels, namely the Wame-Varoi River, Urika-Ivo River and the Purari River (via Aievi and Alele passages; Plate 8.1), and smaller distributaries (see Figure 7.4). The Purari catchment discharges approximately 88.6 Mm^3/yr of sediment across the delta primarily through the three main river channels (Pickup, 1983; Thom & Wright, 1983). This sediment is predominantly silt and clay, with a small proportion of sand (Thom & Wright, 1983; Ruxton et al., 1969). As noted in Section 8.2.1, prevailing sediment transport along the shoreline is in a northwesterly direction, which is caused by the southeast trade winds.

Plate 8.1 – Aerial View of the Purari River Mouth (Alele (left) and Aievi (right) Passages) Terminating in Orokolo Bay

Photo: BMT WBM.

The Purari and Urika-Ivo channels discharge directly into the gulf and are exposed to substantial wave action, resulting in the formation of longshore bars and shoals. These two wave-dominated river mouths are subject to large ongoing changes in morphology (Thom & Wright, 1983). In contrast, the Wame-Varoi channel discharges into the sheltered environment of the Pie River estuary, where wave effects are small and tidal flows are more important. The Pie River estuary is considered to be tidally dominated, having a much deeper entrance channel than the Purari and Urika-Ivo channels due to greater tidal scour and lower fluvial sediment loads (Thom & Wright, 1983). This channel delivers only a small fraction of the total sediment discharged from the Purari River catchment.

The primary landform of the Purari River delta is saltwater tidal flats. Mangrove wetlands dominate much of the coastline of the Purari River delta, with sandy beaches found intermittently between tidal inlets and river mouths. The formation of these sandy beaches is partly the result of strong erosion pressures on vegetated areas caused by the shifting of river mouths (Thom & Wright, 1983). The Purari River delta is also slowly prograding, which has led to the generation of sandy spits and bars across the delta.

8.2.2.3 Orokolo Bay

The Orokolo Bay coastline is located east of the Purari River delta and extends southeast from the Alele Passage of the Purari River mouth for approximately 25 km to the mouth of the Vailala River (see Figure 7.4). The primary landform along this stretch of coast is classified in geomorphological maps as being beach ridges and beach plains (Ruxton et al., 1969).

Sediment supply to Orokolo Bay is predominantly from the Purari and Vailala rivers. A bathymetry survey in November 2009 found sediment accumulated in a very shallow zone extending approximately 2 km offshore from the Alele Passage, with water depths less than 3 m during high tide. Wind-generated littoral currents at Orokolo Bay move sediment westward along the coast as a result of stronger winds during the southeast trade wind season. This has led to the westward growth of trains of sandy spits and a pattern of broad composite beach ridges separated by tidal creeks (Plate 8.2), i.e., chenier plains (Ruxton et al., 1969; Thom & Wright, 1983). This sediment deposition is causing the movement of beach ridge barriers seaward, causing the degradation of inland margins by tidal scour and leading to the development of swamps in the swales of older dune systems. These beach ridges are characterized by strongly gleyed undifferentiated sandy soils containing heavy mineral sands that give sediment a dark color (i.e., black sand beaches). Inland of the beach ridges are the degraded remnants of historical ridges and beach plains, backing on low-relief hills.

Plate 8.2 – Beach Ridges and Tidal Creeks Along Orokolo Bay Coastline

Photo: Iain Woxvold.

Analysis of historical satellite imagery shows that the Orokolo Bay shoreline remains largely unchanged; however, some notable changes have occurred in the southeastern part of the bay, northwest of the Vailala River. An island has been increasing in size in this area over the past few decades, is currently around 7 km long and 1 km wide, and is now considered an extension of the mainland (Figure 8.3). This is likely attributable to the net northwesterly longshore transport of sediment from the Vailala River during the southeast trade wind season.

A conceptual understanding of sediment transport processes in the vicinity of Orokolo Bay is presented in Figure 8.4 and is based on existing literature and modeling of this area of the Gulf of Papua described in Part 10 of Volume 2 (Section 8.3).

This conceptual diagram shows large sediment inflows to the Orokolo Bay area from the Purari and Vailala rivers across the year (as evident from Figure 8.3). Sediment movement in Orokolo Bay follows the seasonal pattern outlined in Section 8.2.1 for the Gulf of Papua. Due to the weaker effect of currents during the northwest monsoon season, sediment deposition occurs in Orokolo Bay at this time of year. During the southeast trade wind season there is a clockwise circulation pattern in the Gulf of Papua due to wind-driven currents. This generates a return flow toward the southeast along the southern coast of Papua New Guinea. Under these conditions wave-related resuspension, together with the southeasterly-directed current, causes net sediment transport in a southeast direction offshore from Orokolo Bay. Closer to the shore, wave-driven

LANDSAT SATELLITE IMAGERY OF OROKOLO BAY

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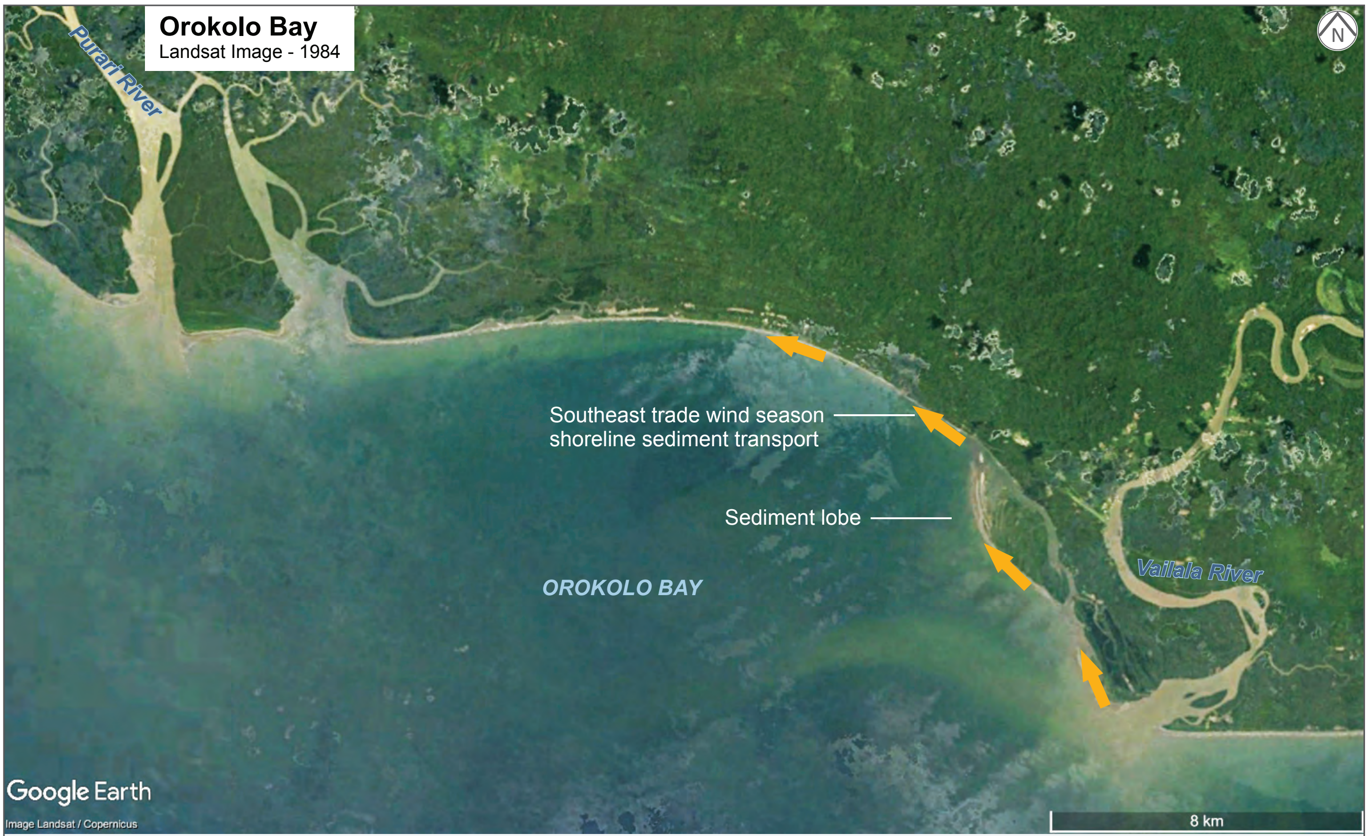
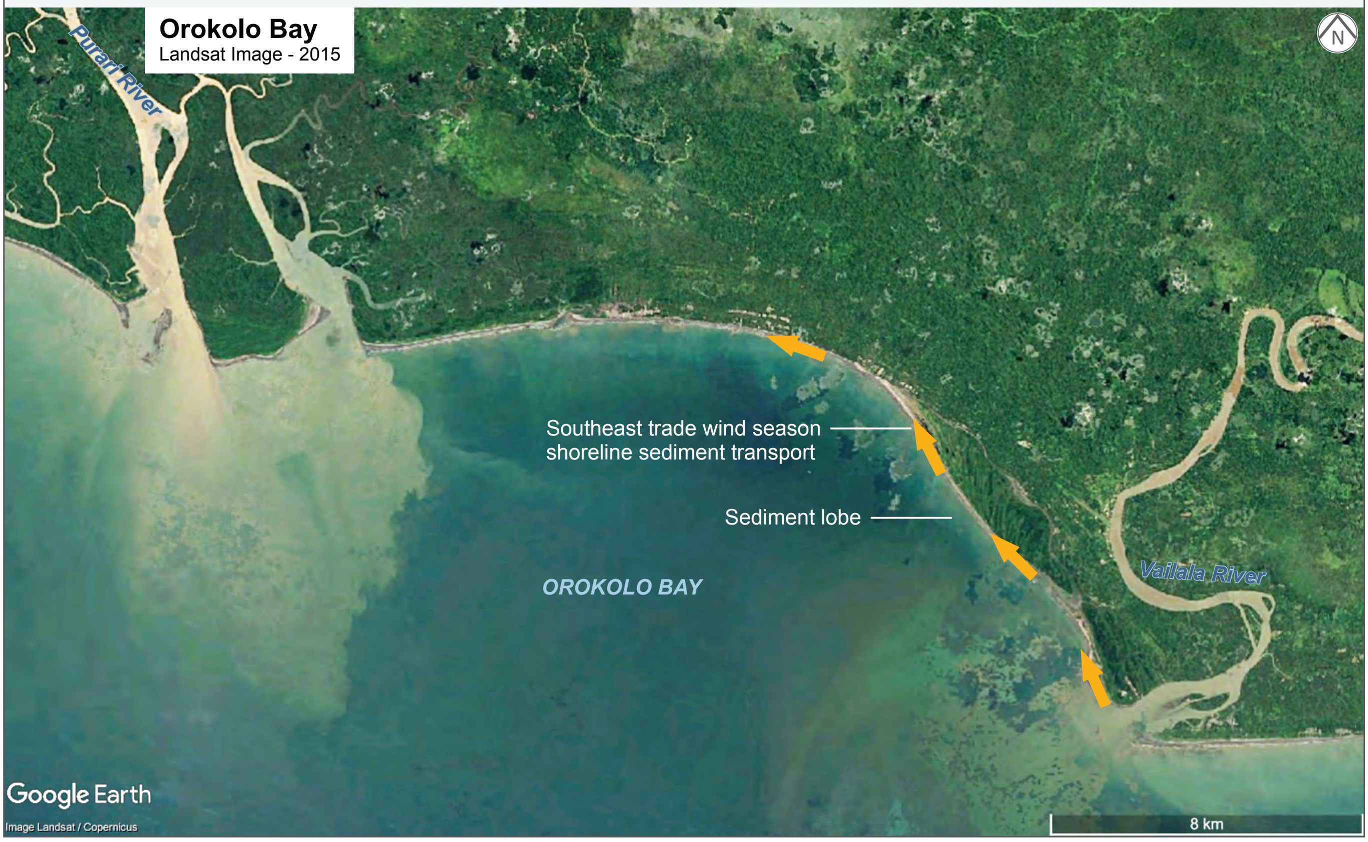
FIGURE 8.3





Source: Google Earth

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CONCEPTUAL SEDIMENT TRANSPORT PATTERNS IN OROKOLO BAY DURING THE SOUTHEAST TRADE WIND SEASON AND NORTHWEST MONSOON SEASON

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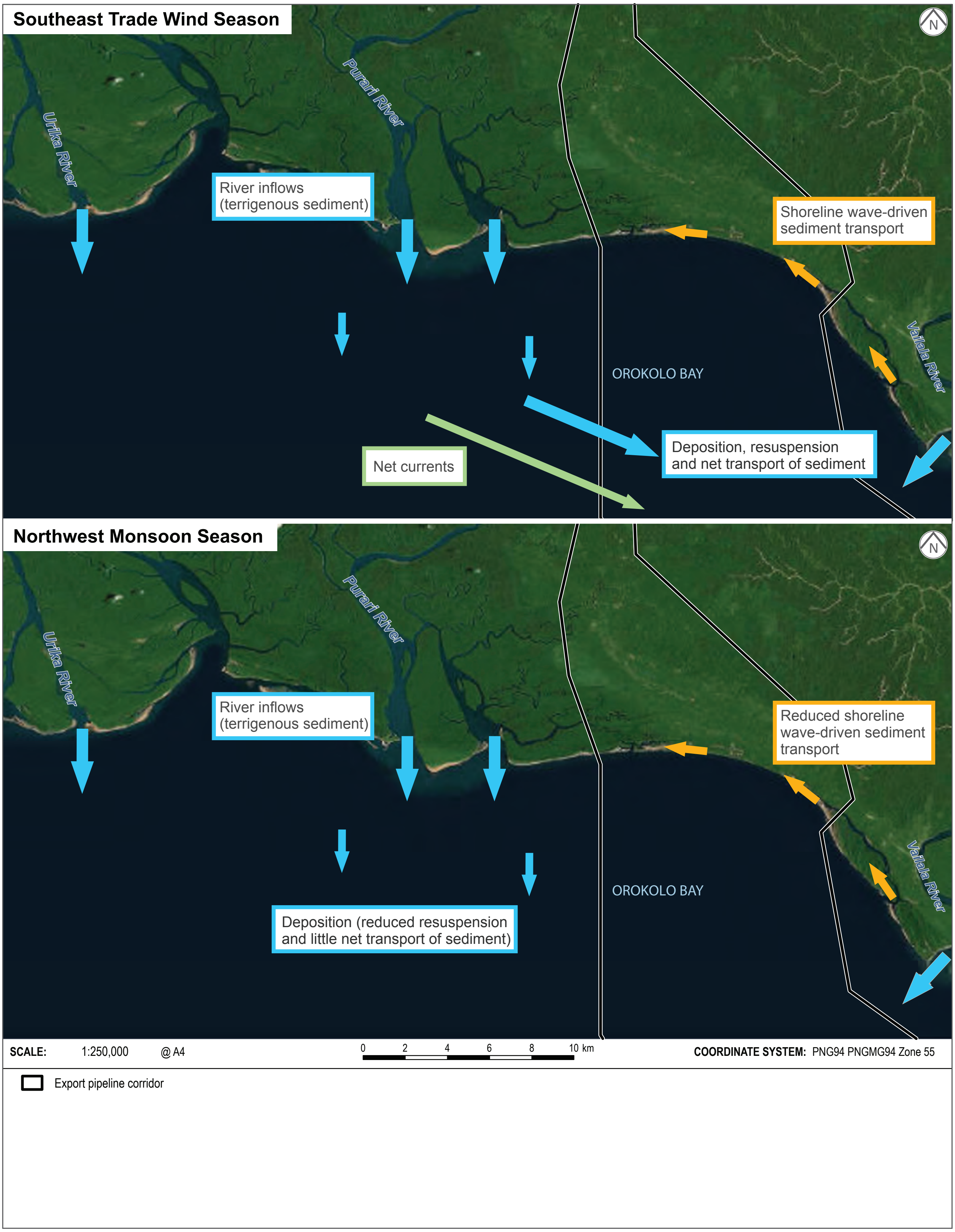
FIGURE 8.4



transport generated by the strong southeast trade winds moves sediment northwest along the coastline. Plate 8.3 shows a depositional lobe of sediment at Orokolo Bay.

Plate 8.3 – Example of Depositional Sediment Lobe at Orokolo Bay

Photo: Iain Woxvold.

8.2.2.4 Offshore Export Pipeline Corridor

Sediment characteristics on the continental shelf in the Gulf of Papua transition from deltaic terrigenous muds in shallow waters to reef and non-reef shelf carbonates in deeper areas (Harris et al., 1996).

The offshore export pipeline corridor extends along the continental shelf, where water depths are between 50 and 100 m for most of the corridor’s length. The seafloor is typically smooth, without notable trenches or canyons. Acoustic surveys indicate that the seafloor is featureless, with the exception of some reef platforms and shoals near Yule Island (see Figure 8.1) and the outer parts of Caution Bay.

As described in detail in Section 8.4.3, sediments along the offshore export pipeline corridor are predominantly silt and clay, except near Yule Island where there is a large volume of sand, which is attributed to the occurrence of shoals at Yule Island.

The sediment transport dynamics along the offshore export pipeline corridor are driven by the wave and current circulation patterns of the broader gulf, which are described in Section 8.2.1.

8.2.2.5 Caution Bay

The Caution Bay coastline has a wide strip of mangroves extending 7 km along the coast and up to 1 km wide in parts, in the vicinity of the PNG LNG Facilities (Figure 8.5 and Plate 8.4). A narrower mangrove strip also occurs between Boera and Porebada, with small patches between Papa and Lea Lea to the north. Mudflats back the major mangrove area around the PNG LNG Facilities. Small patches of sandy beach are found along the coast, notably to the south in areas where mangroves are absent (CNS, 2008a).

Fringing coral reefs are extensive in Caution Bay and parallel the eastern shoreline between 200 to 500 m offshore (CNS, 2008a). The large outer barrier reef in the southwest of Caution Bay includes the coral cay, Idihi Island, at its western extent (Figure 8.5). This reef system shelters the bay from ocean swells during the southeast trade wind season. Offshore reefs also exist around Vari Vari Island to the northwest, just outside of Caution Bay. Patch reefs, coral outcrops and low-relief rubble slopes are also present in the southern and central regions of Caution Bay. These reefs are further described in Section 8.5.

MARINE HABITATS OF CAUTION BAY

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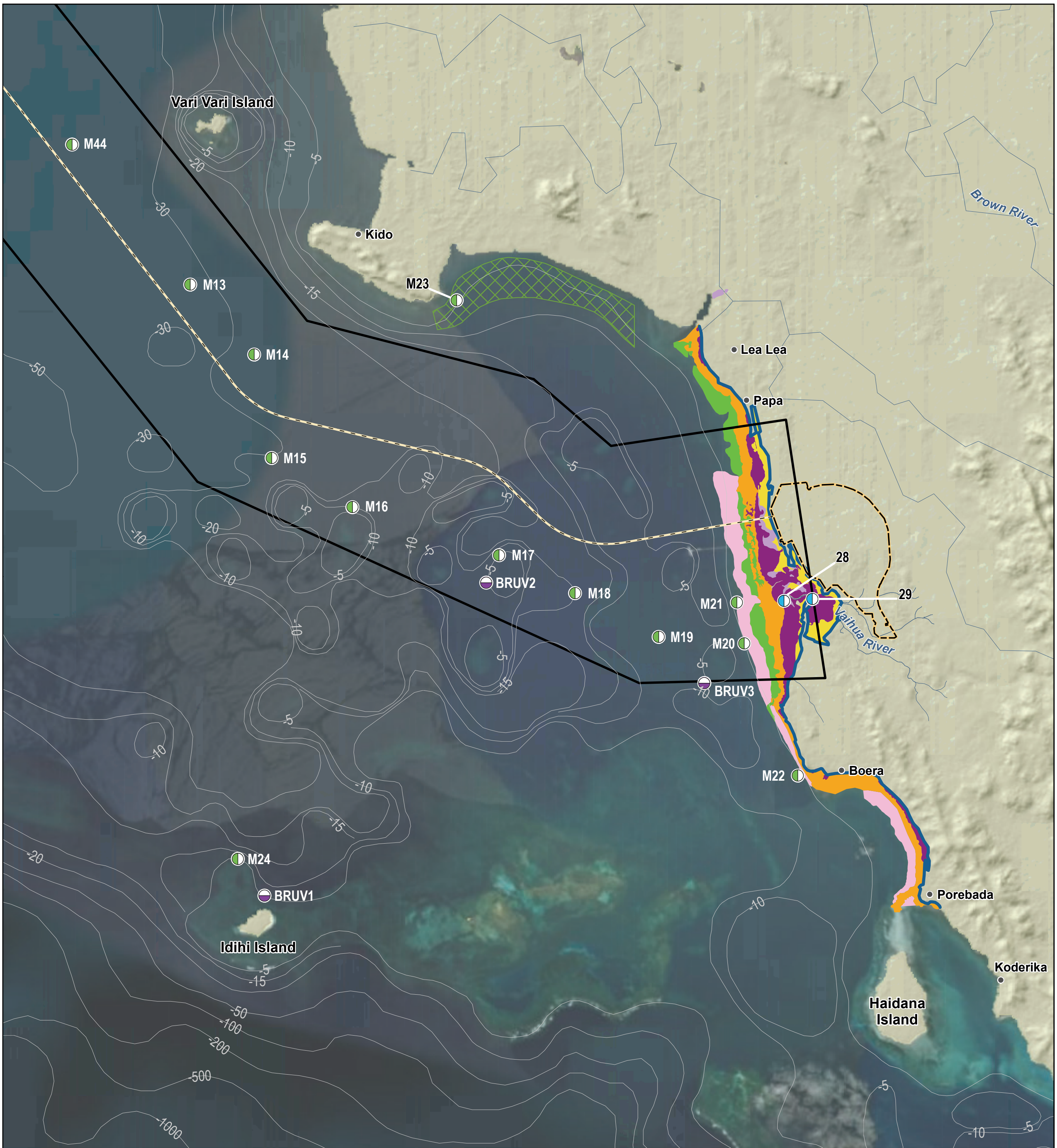
FIGURE 8.5



SCALE: 1:150,000 @ A4

0 1 2 3 4 5 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- PNG LNG Gas Pipeline
- Waterway
- Export pipeline corridor
- PNG LNG Facilities

Aquatic Sampling Locations

- Bailed remote underwater video (BRUV)
- Water quality and aquatic biodiversity
- Water quality and marine biodiversity
- Bathymetry depth contours
- Indicative estuarine freshwater boundary

Caution Bay Marine Habitats

- Fringing coral reef
- Seagrass
- Submerged sand patches
- Mangrove *(Avicennia sp.)*
- Mangrove *(Rhizophera sp.)*
- Saltflat
- Possible extent of *Halophila* meadows

Plate 8.4 – Mangrove-lined Coastline Near PNG LNG Facilities

Photo: BMT WBM.

Sediments in shallow waters less than 30 m deep are predominantly sandy, with coral, rubble and shell debris close to coral reefs (CNS, 2008a). As indicated by acoustic surveys undertaken in 2017 (which are further described in Section 8.5), the deeper areas of Caution Bay (i.e., 30 to 50 m deep) have silty and clay sediments. Mudflats occur in intertidal areas.

The southern barrier reef system provides protection from waves during the southeast trade wind season, but it provides less protection in the northwest monsoon season when waves are predominantly from the west (Section 8.3). Unlike Orokolo Bay, no large rivers flow into Caution Bay to deliver substantial sediment loads. The short and seasonally ephemeral Vaihua River catchment delivers intermittent sediment into the bay (CNS, 2009). Sediment transport rates are therefore expected to be small in magnitude, and any associated morphology changes would be gradual.

There is little evidence that the shoreline in Caution Bay is undergoing active change. Comparison of Landsat satellite imagery from the 1980s and from 2015 shows little change in the extent of mangroves and no change in shoreline position (Part 9 of Volume 2).

8.3 Physical Oceanography

8.3.1 Regional Context

The physical oceanography of the Gulf of Papua is strongly influenced by the climate, which is characterized by the distinct northwest monsoon and southeast trade wind seasons (see Section 7.3).

Winds during the northwest monsoon season are calmer than winds during the southeast trade wind season, with January and February considered the calmest months. Wind strength then gradually increases throughout the year to a peak, with the strongest southeast trade winds in July, and then progressively decreases with the return of the monsoon season (Evesson, 1983; Saint-cast & Condie, 2006). Monsoon surges with strong northwest winds have been observed in the region (CNS, 2008b). These short-lived squalls of about one-hour duration, with wind speeds of 55 to 65 km/hr (15 to 18 m/s), are known locally as *gubas*.

The southeast trade wind–driven waves have a long fetch from across the Coral Sea, generating waves in the Gulf of Papua with seasonally averaged significant wave height (i.e., average height of the highest third of the waves) of 1.5 m (Hemer et al., 2004). These waves attenuate as water becomes shallower. During the northwest monsoon season, wave heights are smaller due to the calmer winds and shorter fetch.

Tides in the gulf are semidiurnal (i.e., two high and two low tides per lunar day), with the largest tidal range of 5 m occurring in the western gulf near the mouth of the Fly River (Wolanski et al., 1995). Tidal range then attenuates heading eastward, with the maximum tidal range in the eastern gulf being approximately 3 m.

The Hiri Current forms a clockwise gyre in the Gulf of Papua (Saint-Cast & Condie, 2006). The strength of the Hiri Current is unlikely to be significantly altered by El Niño given a lack of response observed in the Coral Sea Current, which is thought to drive the Hiri Current (Saint-Cast & Condie, 2006).

Water inflows from the large rivers (including the Fly, Bamu, Turama, Kikori and Purari rivers) entering the Gulf of Papua also have a significant influence on hydrodynamics and sediment dynamics in the gulf (Wolanski et al., 1995).

The bathymetry of the Gulf of Papua is described in Section 8.2.1 (and shown in Figure 8.1).

8.3.2 Baseline Characterization

8.3.2.1 Study Overview

Description of the physical oceanographic processes in the study area is based on existing information from previous studies, scientific literature, marine field surveys (Part 23 of Volume 2) and numeric modeling specifically undertaken for the study area. The physical oceanographic modeling used several linked models, which included the following:

- Bathymetric digital elevation model (DEM).
- Three-dimensional (3D) hydrodynamic model and 3D advection-dispersion (i.e., water quality) TUFLOW-FV model.
- SWAN (Simulating Waves Nearshore) wave model.
- Sediment transport model, based on TUFLOW-FV and SWAN wave model outputs.

The numeric modeling was validated by comparing the model outputs to existing literature and data from previous studies. Detailed descriptions of the modeling and findings are presented in Part 10 of Volume 2.

Temperature and salinity in the study area are discussed in Section 8.4.

8.3.2.2 Orokolo Bay

Bathymetry

Orokolo Bay is relatively shallow and flat, with a uniform slope throughout the bay (Figure 8.6). As described in Section 8.2.2.2, a very shallow zone extends approximately 2 km offshore from the mouth of the Purari River eastern channel, with water depths less than 3 m during high tide. The 15 m depth contour is approximately 8 km from the shoreline. Although some shallow shoals (e.g., naturally submerged ridges, banks or bars) are shown in Figure 8.6, including two locations west of Auma Point at the mouth of the Vailala River charted as being 3.8 m to 1.3 m deep, such features were not found to occur at these locations during the marine field surveys. One subtidal rocky reef was identified east of Orokolo Bay offshore from the Vailala River in approximately 15 m of water (shown in Figure 8.6 and described in more detail in Section 8.5.2.2).

BATHYMETRY OF OROKOLO BAY

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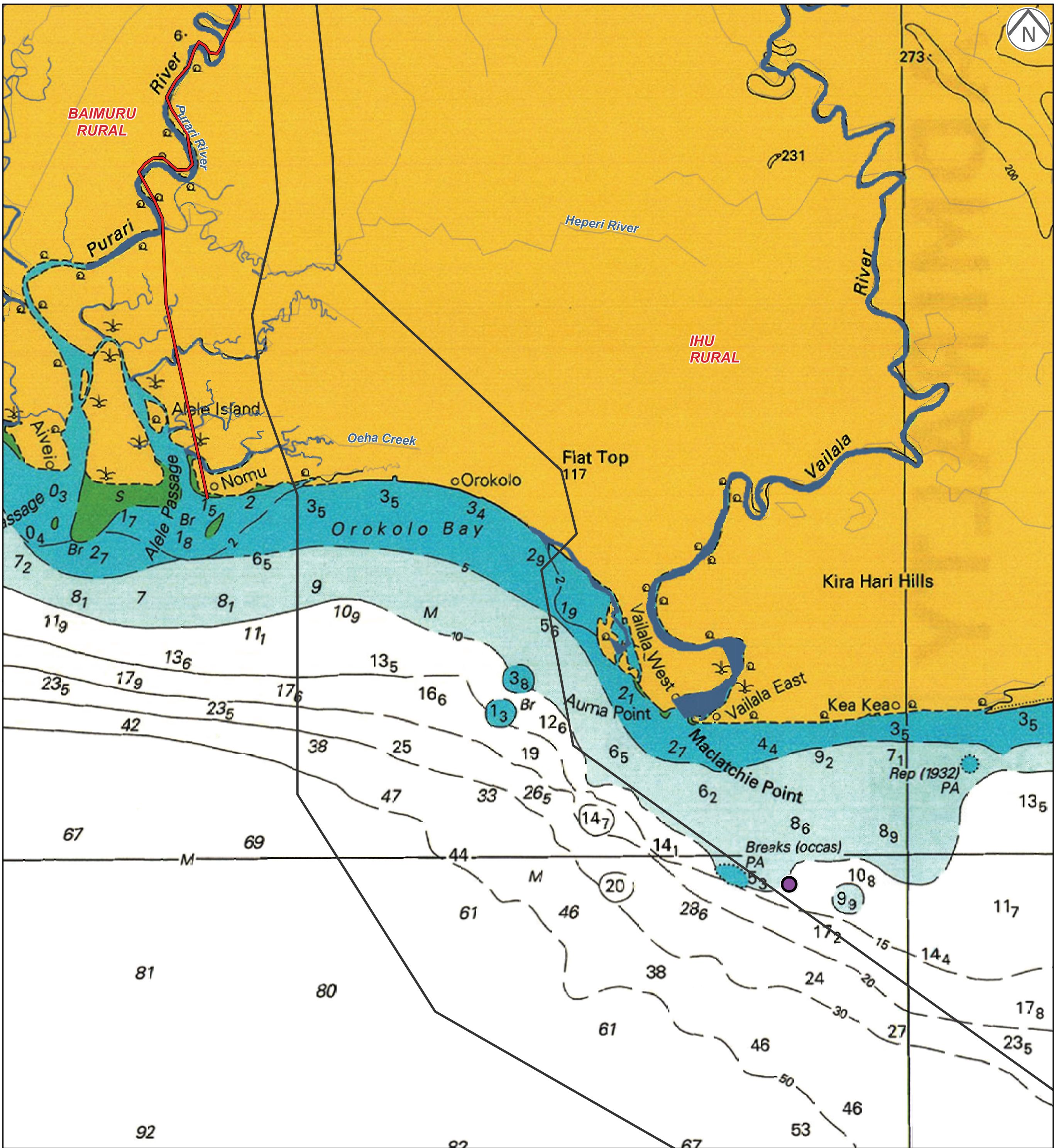
FIGURE 8.6



SCALE: 1:250,000 @ A4

0 2 4 6 8 10 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Local level government boundary
- Waterway
- Waterbody
- Export pipeline corridor

Depth Contours (m)

- Depth anomalies not expected but may exist
- Depth anomalies may be expected

- Subtidal rocky reef

Depth (m)

- Land
- Sandy seabed (exposed at times)
- 0 to -5
- > -5 to -10
- > -10

Source: Australian Hydrographic Service (2008) AUS 378

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Tides

Tides are semidiurnal, with a tidal range in Orokolo Bay of approximately 3 m measured during the 2016 and 2017 marine field surveys. The TUFLOW-FV modeling shows the tidal range to be approximately 1 m during neap tides and 3 m during spring tides.

Currents

No measured current data is available in the vicinity of Orokolo Bay; therefore, current speed and direction were extracted from the TUFLOW-FV numerical model. The net current velocities beyond the 15 m contour are larger during the southeast trade wind season than during the northwest monsoon season, with maximum velocities of up to 0.5 m/s in the upper 10 m of the water column, and are directed toward the southeast. This is related to the Hiri Current, a large-scale clockwise current circulation pattern in the Gulf of Papua (more detail on currents in the gulf are provided in Section 8.3.2.3). During the northwest monsoon season, the current magnitude is generally small (i.e., less than 0.25 m/s in the upper 10 m of water) and is directed toward the northwest in the offshore part of Orokolo Bay (i.e., which is more than 15 m deep), which is part of an anticlockwise circulation pattern in the Gulf of Papua (Section 8.3.2.3).

Waves

Waves during the southeast trade wind season come predominantly from the south to southeast with significant wave heights up to 1.6 m. Waves during the northwest monsoon season are predominantly less than 1 m and, although variable, are mostly from the south-southwest (Figure 8.7). Wave height decreases closer to shore during both seasons.

8.3.2.3 Offshore Export Pipeline Corridor

Bathymetry

The offshore export pipeline corridor traverses the edge of the continental shelf along the eastern side of the gulf, with depths reaching up to 90 m.

Tides

Measurements of water level and the TUFLOW-FV modeling show that tides are semidiurnal along the offshore export pipeline corridor, with a tidal range of approximately 3 m, the same as occurs at Orokolo Bay.

Currents

A maximum current speed of 0.6 m/s was previously recorded along the offshore export pipeline corridor, approximately 40 km south-southeast of Kerema, with a regular tidal variation of around 0.2 m/s (CNS, 2008b). The net current during the southeast trade wind season was usually directed toward the southeast with an average velocity of 0.2 m/s. The current direction in the opposite direction to the prevailing wind is due to the overall pattern of circulation in the gulf, with water further offshore driven by the wind into the gulf and returning via a coastal current along the southern PNG coastline. During the northwest monsoon season, currents were more variable but often moved in a westerly direction, with an average velocity of 0.1 m/s.

Figure 8.8 presents the net current patterns indicated by the TUFLOW-FV numerical model. The modeled current patterns are consistent with the measured currents described in CNS (2008b). The model results indicate that the currents along the offshore export pipeline corridor during the southeast trade wind season are generally directed toward the southeast. During the monsoon season, the currents are smaller in magnitude and are directed toward the northwest along the northern part of the pipeline corridor and to the southeast along the southern part of the pipeline

TYPICAL WAVE PATTERN IN OROKOLO BAY DURING THE SOUTHEAST TRADE WIND SEASON AND NORTHWEST MONSOON SEASON

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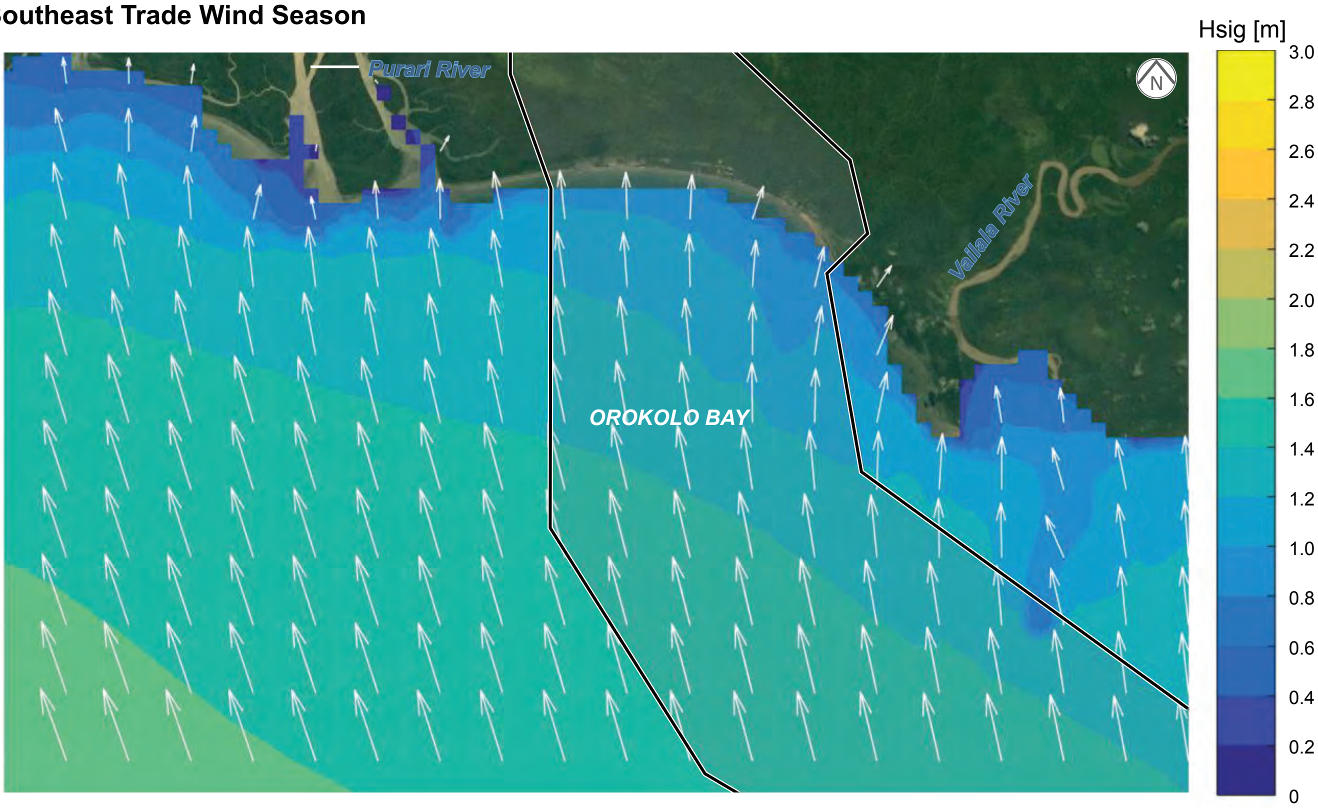
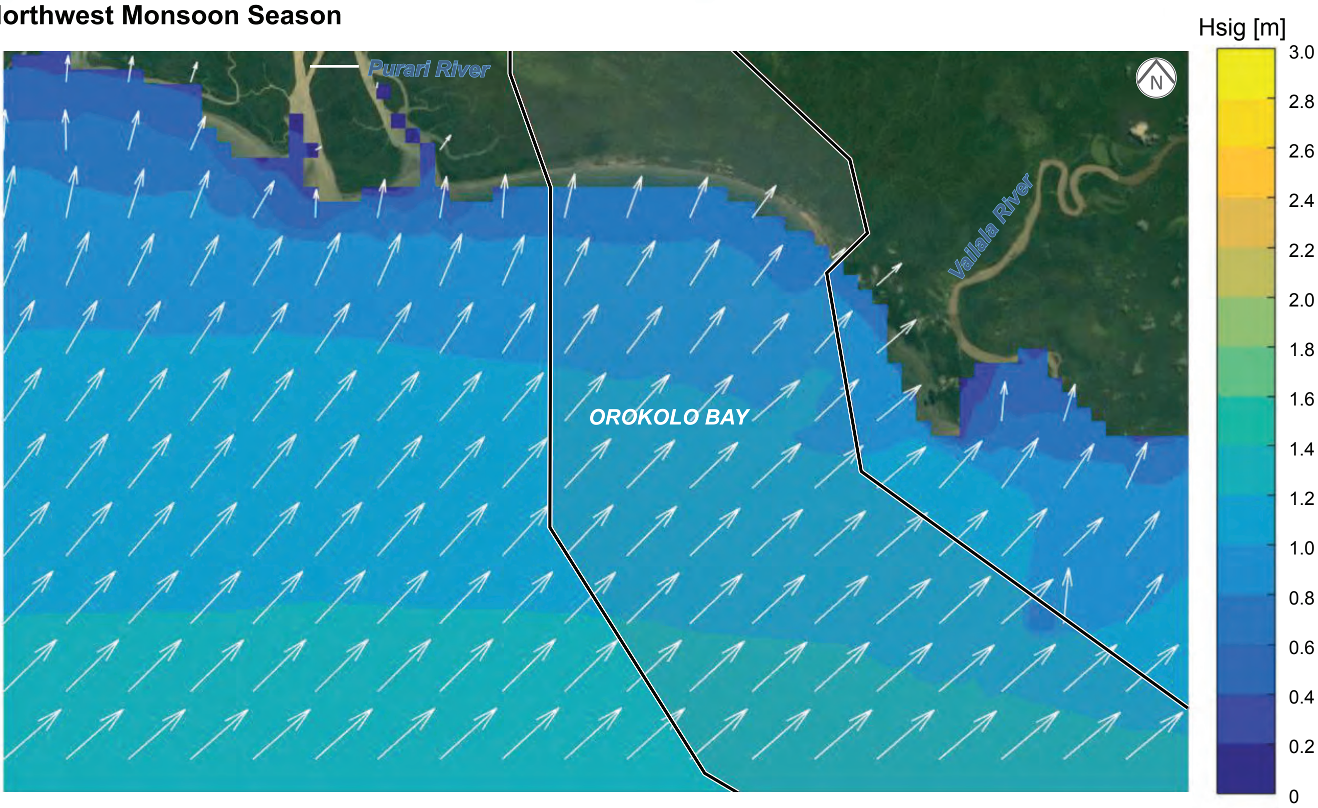
FIGURE 8.7

Southeast Trade Wind Season



Northwest Monsoon Season



Export pipeline corridor

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MODELED NET CURRENTS FOR THE SOUTHEAST TRADE WIND SEASON AND NORTHWEST MONSOON SEASON

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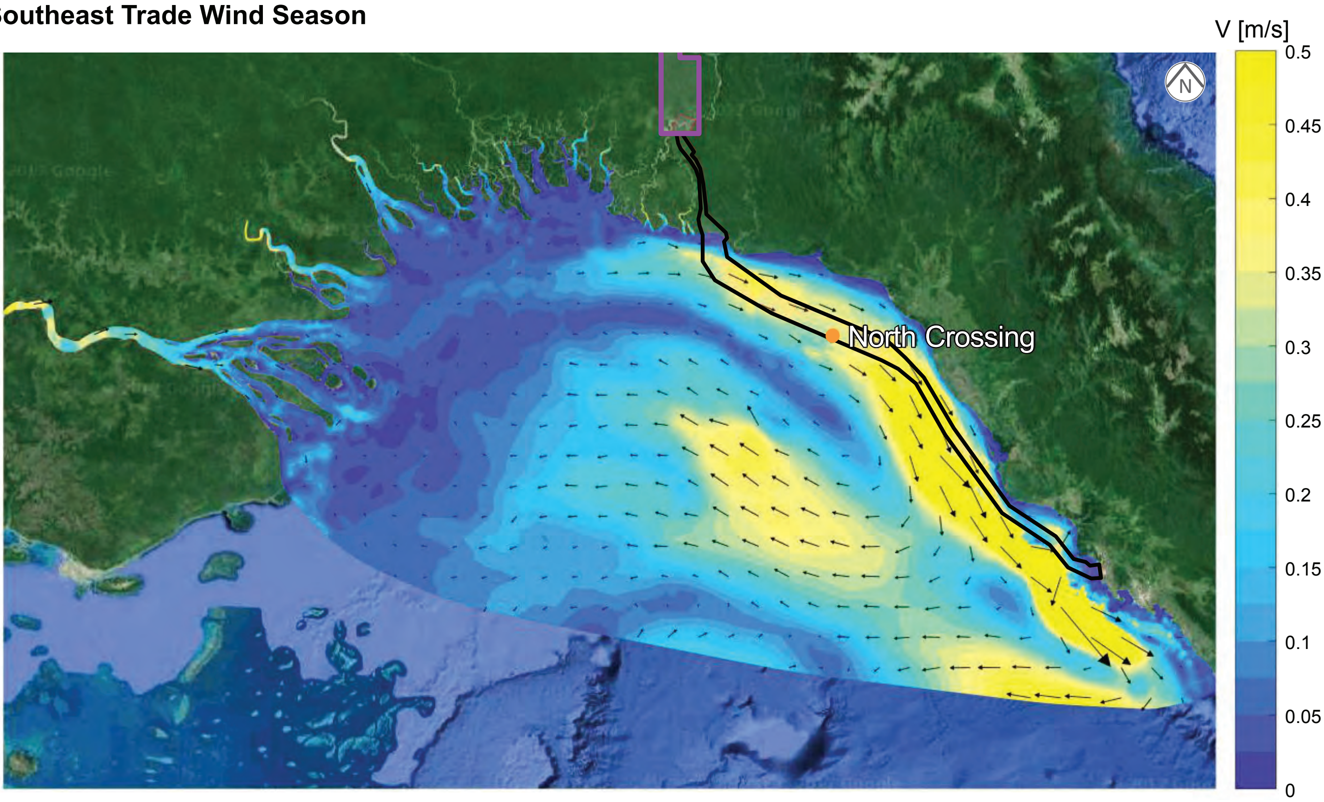
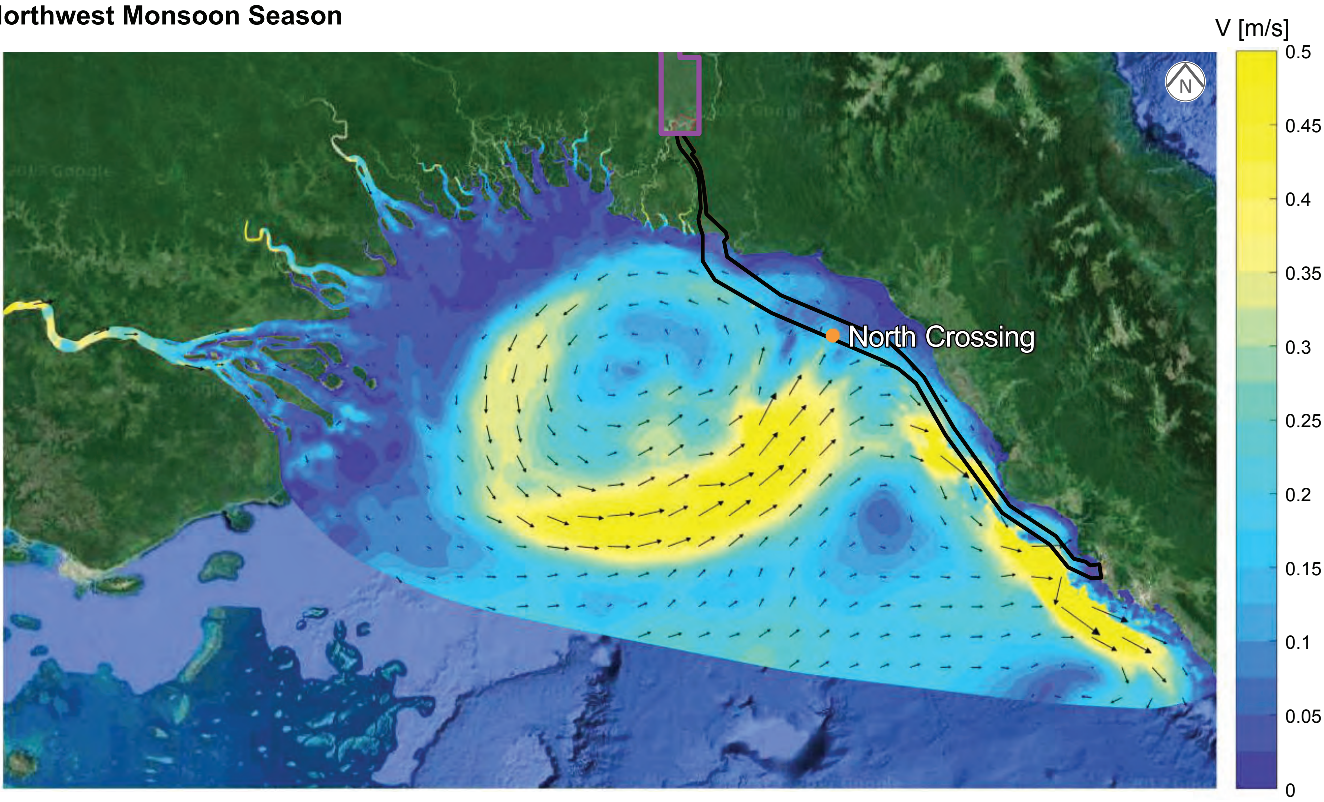
FIGURE 8.8

Southeast Trade Wind Season



Northwest Monsoon Season



PRL-15
Export pipeline corridor

corridor. The model results indicate that the Hiri Current clockwise gyre operates further offshore in the northwest monsoon season off the continental shelf in concert with a separate anticlockwise gyre in the gulf, which is also referred to by Wolanski et al. (1995). In the southeast trade wind season, the model indicates that the prevailing winds from the southeast set up a larger clockwise gyre that encompasses the entire gulf.

The current patterns indicated by the numerical model are consistent with the results of previous studies, including Slingerland et al. (2008).

Waves

The SWAN wave model shows that waves during the southeast trade wind season are predominantly from the south due to the prevailing southeast wind direction and the pattern of wave refraction in the gulf (Figure 8.9). The significant wave height has an average of around 1.5 m and a maximum of 2 m. During the monsoon season, the wave direction is more variable, coming from the west to the south. The magnitude is also much lower, with a maximum significant wave height of around 1 m. Wave roses based on modeled data are provided for both seasons in Part 10 of Volume 2.

8.3.2.4 Caution Bay

Bathymetry

The bathymetry of Caution Bay is complex, with extensive coral reef formations and shoals, and deeper channels (see Figure 8.5). The average water depth in the bay is around 25 m. The bay is protected to the south by an outer barrier reef, which includes the coral cay, Idihi Island (see Figure 8.5). Beyond this outer barrier reef, the seafloor drops sharply to depths reaching over 1,000 m.

Tides

Water level measurements undertaken by bottom-mounted acoustic doppler current profilers for extended periods in 2007 to 2009 show that the tides in Caution Bay are semidiurnal with a maximum tidal range of approximately 3 m (CNS, 2008b).

Currents

Previous studies undertaken in Caution Bay have found that current speeds are generally low (i.e., less than 0.5 m/s) (CNS, 2008b). The direction tends to vary according to the tide during the northwest monsoon season but has a net northwesterly direction during the southeast trade wind season. In contrast, currents in Orokolo Bay and along the offshore export pipeline corridor move in a southeasterly direction in the southeast trade wind season. The difference in net current patterns in Caution Bay in the southeast trade wind season is likely due to a local current generated by the prevailing southeasterly winds. The TUFLOW-FV model also shows net currents in Caution Bay to be minimal and less than 0.1 m/s.

Waves

Measurements obtained from acoustic doppler current profilers deployed in Caution Bay during 2007 to 2009 found waves were predominantly from the south to southwest during the southeast trade wind season, with significant wave height predominantly less than 1 m. During the northwest monsoon season, the wave direction is from the west to southwest, with a significant wave height up to 1.5 m. The higher wave heights recorded during the northwest monsoon season are likely due to a higher incidence of waves from the less protected westerly direction. The outer barrier reef protects the bay from waves approaching from the south.

TYPICAL WAVE PATTERN ALONG THE OFFSHORE EXPORT PIPELINE CORRIDOR DURING THE SOUTHEAST TRADE WIND SEASON

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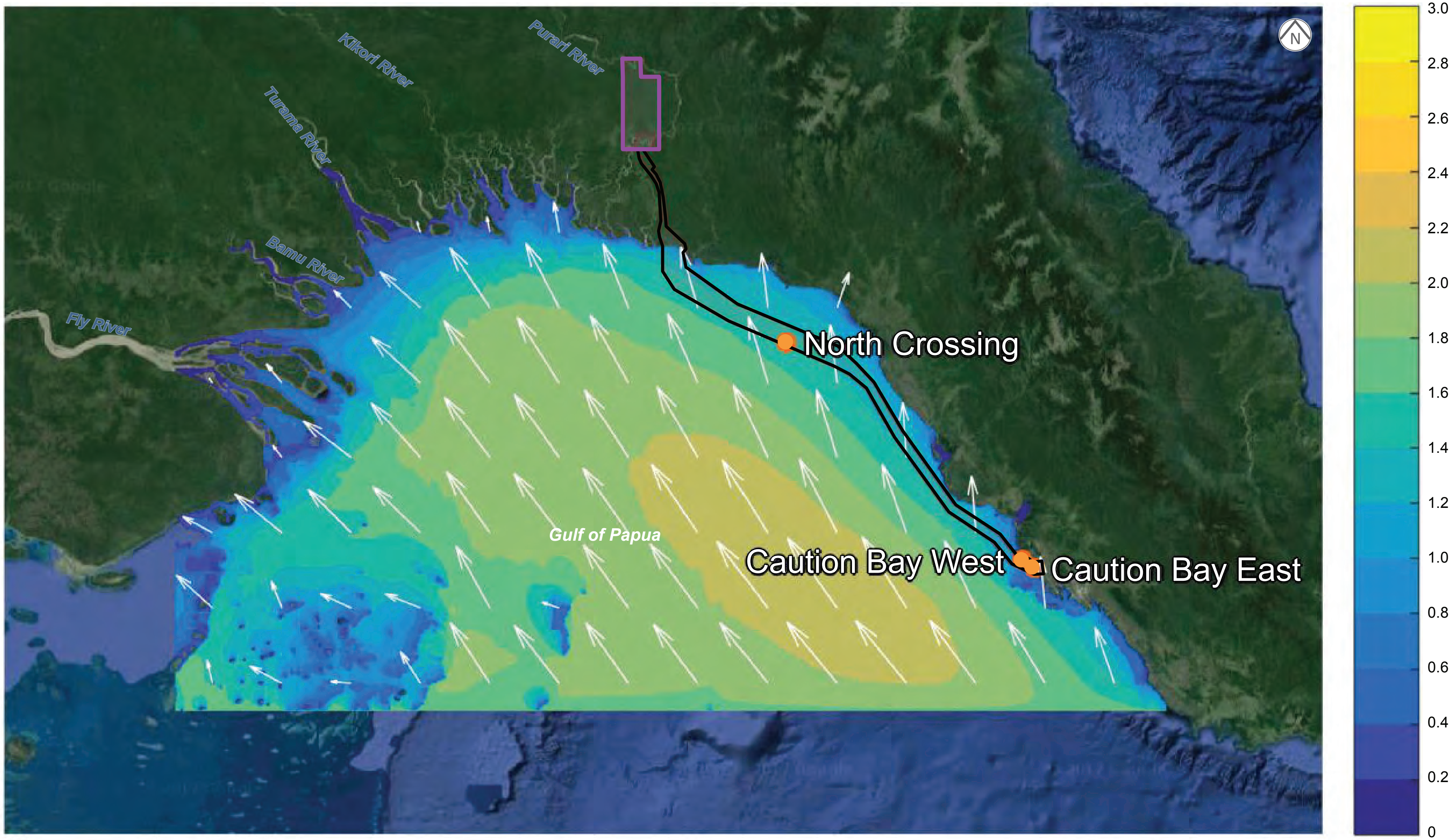
FIGURE 8.9

Southeast Trade Wind Season



PRL-15
Export pipeline corridor

The typical wave patterns (significant wave height and direction) in Caution Bay from TUFLOW-FV modeling of the southeasterly trade wind season and northwest monsoon season conditions are shown in Figure 8.10. Clearly, wave propagation into the bay can be much greater during the northwest monsoon season under westerly wind conditions.

8.4 Marine Water and Sediment Quality

8.4.1 Regional Context

The waters of the gulf are influenced by seasonal changes in wind and current patterns and by seasonal rainfall. Turbidity in the gulf is affected by inputs of terrigenous sediments delivered by some of the largest rivers in Papua New Guinea, which deliver over 365 million tonnes (Mt) of sediment per year into the river floodplains and deltas and the gulf (Milliman, 1995). Fluvial sediment loads are discharged into the gulf at a fairly consistent rate year-round but are highest during the northwest monsoon season (Slingerland et al., 2008). Turbid brackish plumes have been noted to extend up to 50 km from the mouth of some of the larger gulf rivers (CNS, 2008b). The 2015 Landsat imagery in Figure 8.3 shows a turbid plume extending approximately 10 km from the Purari River mouth. A turbid plume from the Purari River is also shown in Plate 8.5.

Plate 8.5 – Turbid Plume from the Purari River in Orokolo Bay

Photo: ERIAS Group.

Salinity and temperature profile measurements undertaken by Robertson et al. (1998) have shown that a surface lens of low-salinity water extends across the inner gulf within 50 km of the coast, with a thickness of up to 40 m in the upper water column. Martins and Wolanski (2015) reported that this freshwater discharge produces a brackish water plume that covers most of the gulf, extending to 20 m deep and progressively thinning out with increasing distance from the coast.

Wind-driven waves resuspend sediments in the gulf, which results in increased turbidity (Saint-cast & Condie, 2006). Turbidity generated from wind-driven waves is generally highest during the southeast trade wind season when wind speeds are generally strong, reaching their peak in July then progressively weakening.

TYPICAL WAVE PATTERN IN CAUTION BAY DURING THE SOUTHEAST TRADE WIND SEASON AND NORTHWEST MONSOON SEASON

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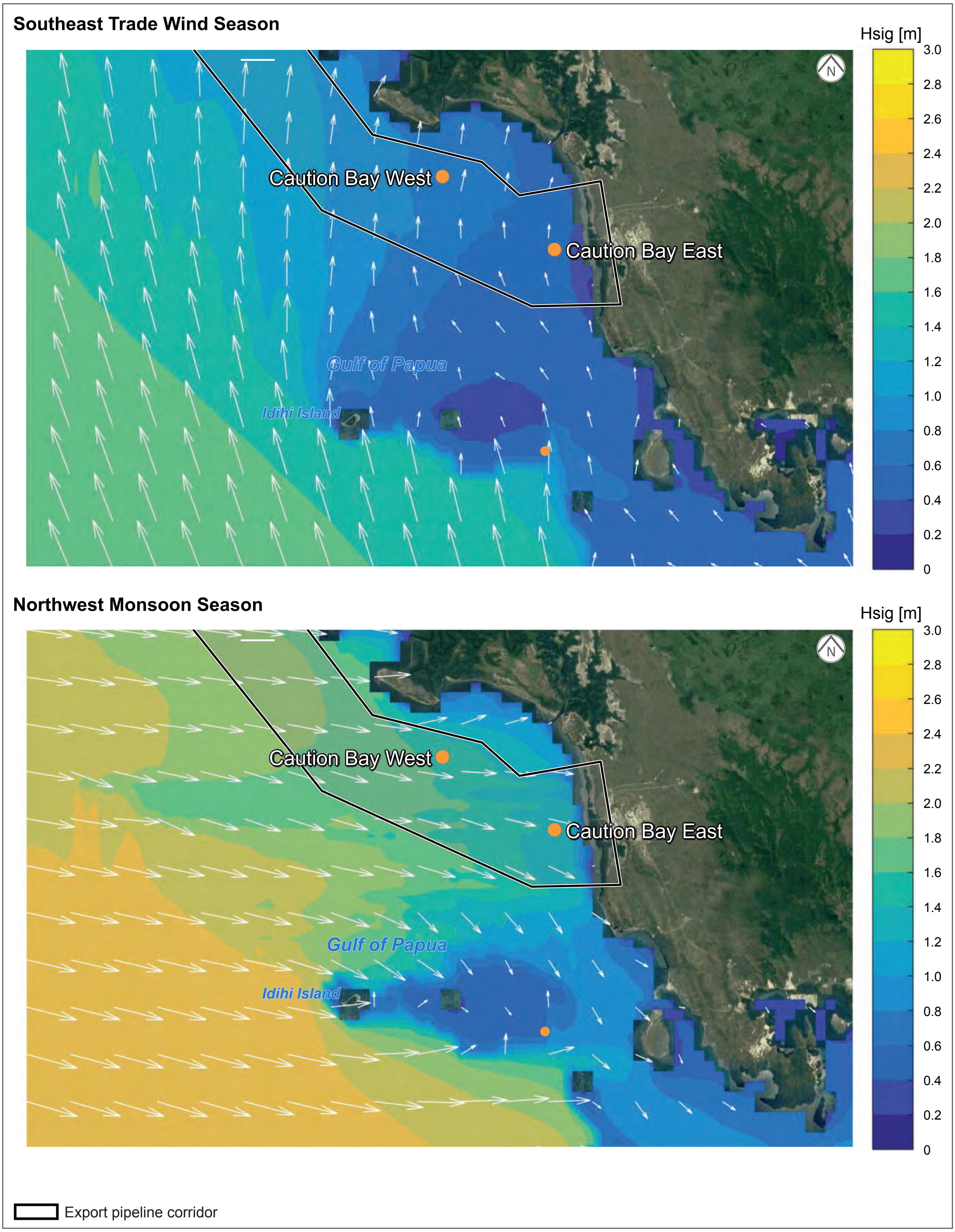
FIGURE 8.10



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8.4.2 Marine Water Quality Baseline Characterization

8.4.2.1 Study Overview

Two field surveys of marine waters were completed during the southeast trade wind season and the northwest monsoon season (Part 23 of Volume 2). The survey sites are shown in Figure 8.11.

The surveys involved in situ water column profiling of physicochemical parameters (i.e., turbidity, conductivity, salinity, temperature and dissolved oxygen) at 46 sites. Grab samples were obtained at 28 sites from various depths (i.e., surface, middle and bottom waters) for laboratory analysis of nutrients (i.e., ammonia, nitrate/nitrite, total nitrogen, filterable reactive phosphorus and total phosphorus), chlorophyll-a and contaminants (i.e., total and dissolved metals/metalloids, polyaromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), and benzene, toluene, ethylbenzene and xylenes (BTEX)). Water quality instruments were deployed at two sites in Orokolo Bay during both surveys. These instruments collected continuous bottom measurements of turbidity, conductivity, salinity, temperature and water depth.

This data was considered in conjunction with available information from previous studies to describe existing marine water quality in the study area, incorporating Orokolo Bay, the offshore export pipeline corridor and Caution Bay.

To provide a benchmark for the water quality results, data was compared to Schedule 1 of the *Environment (Water Quality Criteria) Regulation 2002* for marine waters, which provides legally enforceable water quality criteria in Papua New Guinea. The assessment also considered Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ, 2000), which provide good international industry practice guidance relevant to the region. Guidelines do not exist for all water quality parameters and analytes, including some nutrients and metals, such as aluminium and strontium; therefore, these are discussed in relative terms.

8.4.2.2 Orokolo Bay

Freshwater discharges from the Purari River and seasonal conditions strongly influence water quality in Orokolo Bay, e.g., sediment remobilization due to wind-driven waves during the southeast trade wind season.

Water quality profiling measurements of temperature, salinity, turbidity and dissolved oxygen were taken at each of the sampling sites during the southeast trade wind season and northwest monsoon season surveys (Figures 8.12 and 8.13). The temperature and salinity profiles show that the water column was significantly stratified at all measurement sites due to large freshwater inflows. This was particularly evident during the southeast trade wind season survey, when higher temperatures and lower salinities were observed in the upper 5 m of the water column compared to deeper waters.

Turbidity was low, being below 15 nephelometric turbidity units (NTU) throughout the water column at all sites in Orokolo Bay during the southeast trade wind season sampling event. Turbidity in the northwest monsoon season was generally lower and below 5 NTU at most sites. Two additional sites close to the Purari River mouth, sampled in the northwest monsoon season, recorded turbidity between 75 and 145 NTU nearest the river mouth (site M45), decreasing to less than 10 NTU about 5 km south of the river mouth at site M46 (Figure 8.11). Total suspended solid (TSS) levels were below 20 mg/L at all sites during the southeast trade wind season and generally less than 5 mg/L during the northwest monsoon season, correlating with turbidity. The highest TSS levels recorded were near the Purari River mouth, where concentrations were about 100 mg/L in surface and bottom waters during the northwest monsoon season.

MARINE SURVEY SITES

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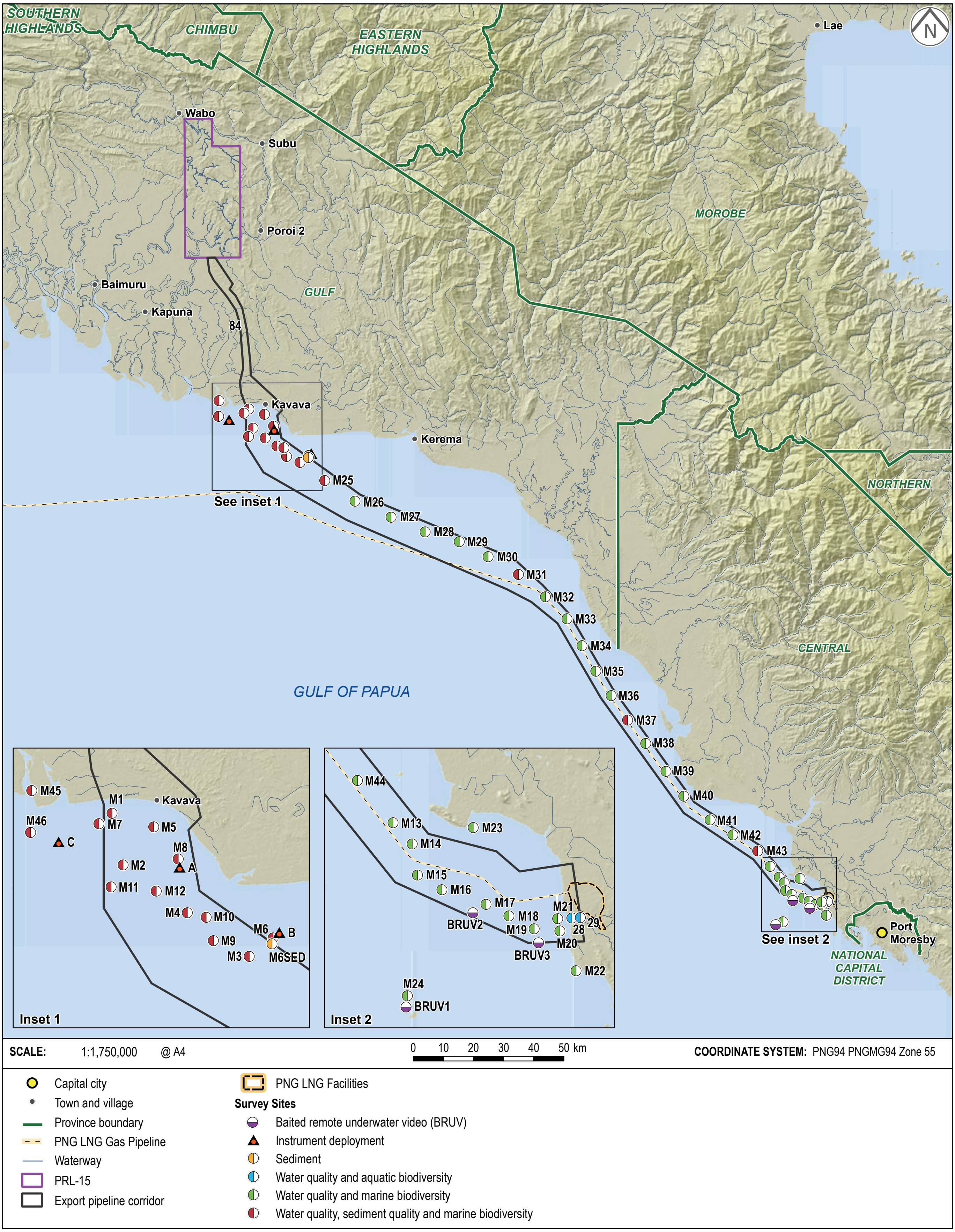
FIGURE 8.11



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TEMPERATURE AND SALINITY PROFILES IN OROKOLO BAY

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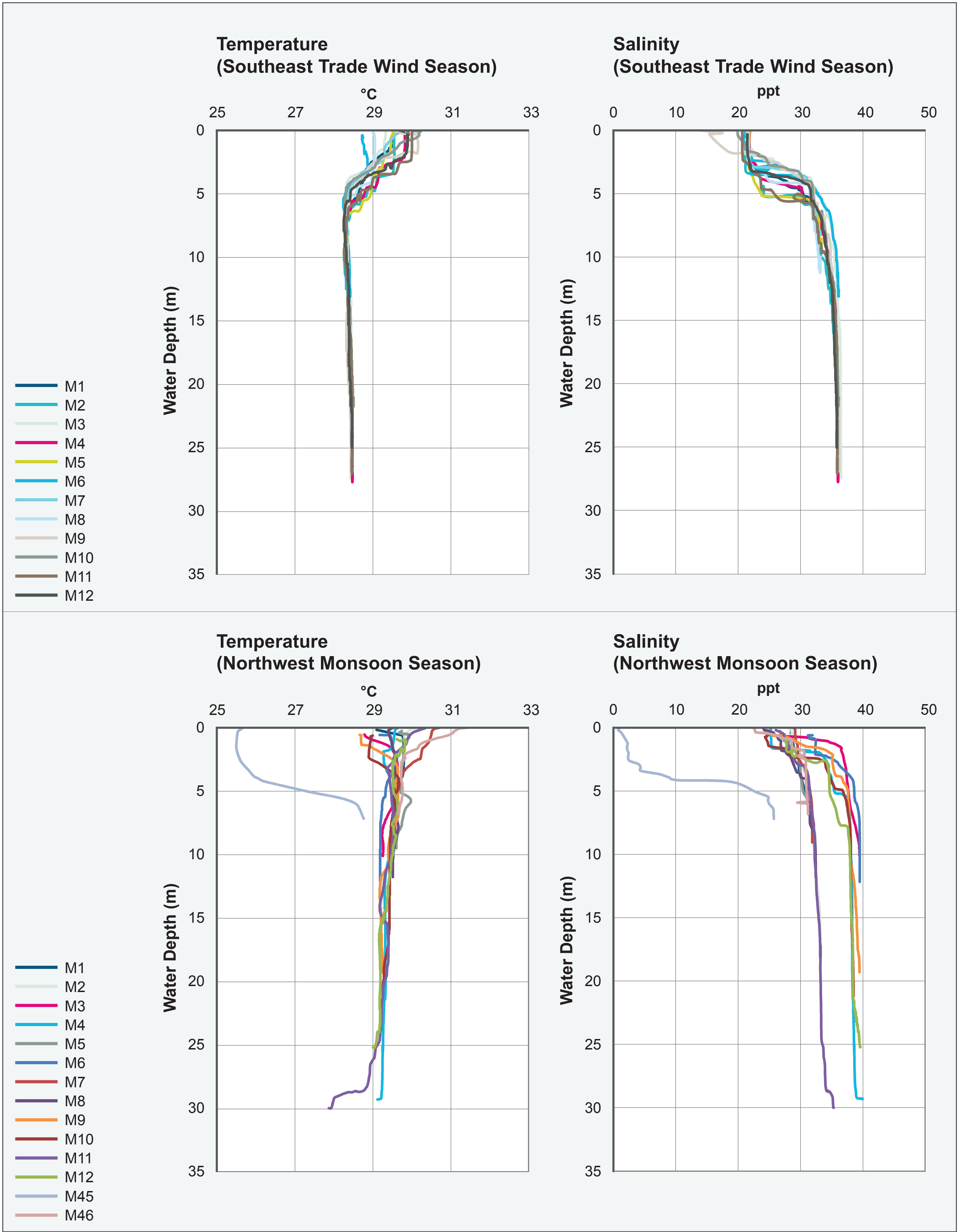
FIGURE 8.12



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TURBIDITY AND DISSOLVED OXYGEN PROFILES IN OROKOLO BAY

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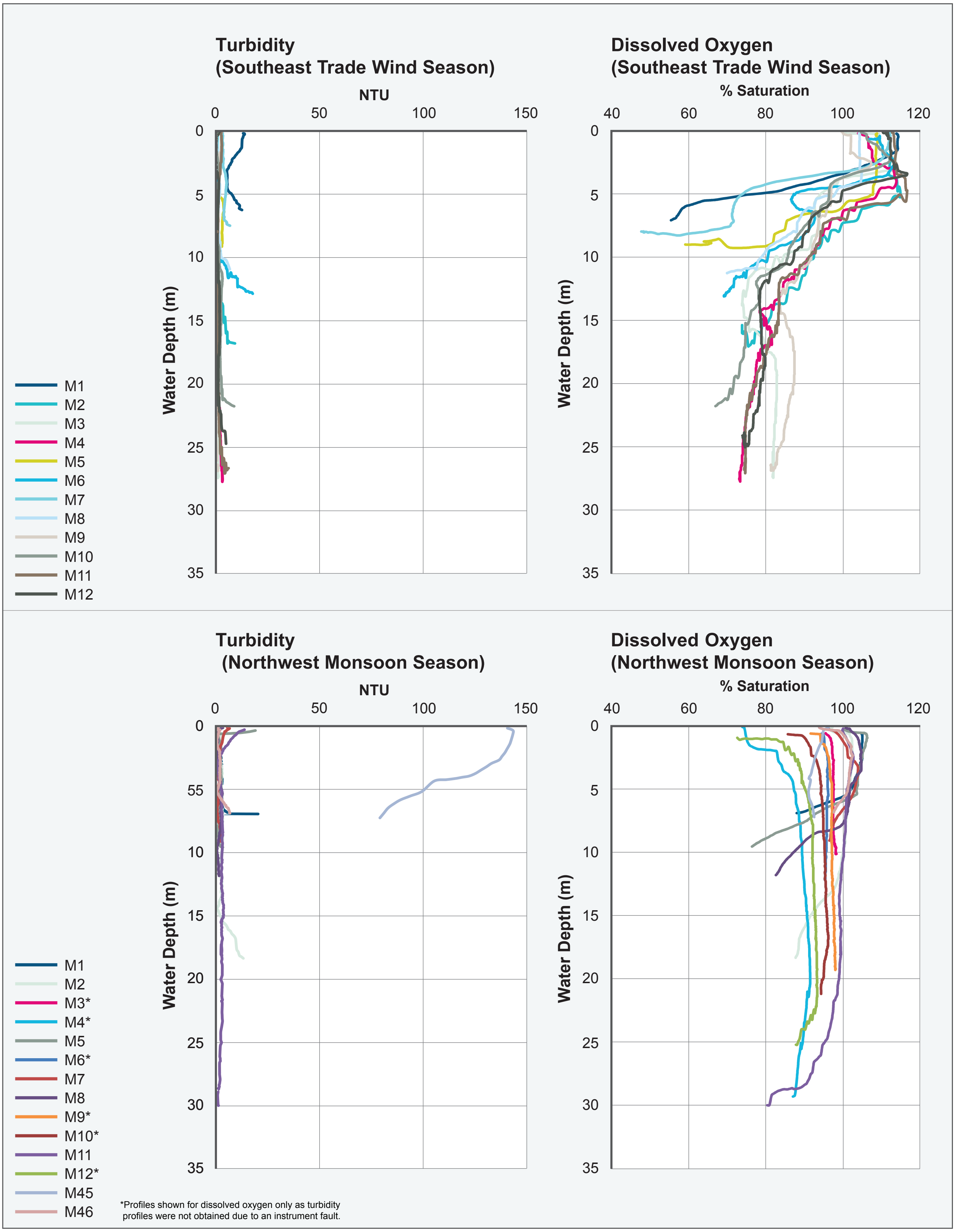
FIGURE 8.13



Continuous turbidity data collected from bottom-mounted instruments indicates that turbidity in Orokolo Bay is strongly linked to weather conditions. Higher winds and rougher seas resulted in increased turbidity levels to nearly 450 NTU in the southeast trade wind season during June to July 2016. During the northwest monsoon season, high flow events in the Purari River also increased turbidity levels close to the river mouth with values around 450 NTU recorded during one such event in January 2017 (Figure 8.14). The turbidity data collected from the bottom-mounted instruments is generally much higher than the water quality profiling data, which were below 15 NTU at most sites. This is due to the nature of profiling through the entire water column, and timing of profiling, i.e., undertaken during calmer periods when turbidity was lower. The bottom-mounted instruments are also exposed to resuspended bed sediments mobilized in water currents and wave action, and were located closer to river mouths than many of the profiling sites.

During the southeast trade wind season, dissolved oxygen levels in surface waters were greater than 100% saturation but decreased to 70 to 80% at around 5 to 10 m below the surface, which is below the ANZECC/ARMCANZ (2000) guideline value of 90% saturation. During the northwest monsoon season, dissolved oxygen levels varied less with depth and in some cases increased with depth, indicating greater mixing of waters during this sampling event.

Water pH at sampling sites in Orokolo Bay ranged from 7.8 to 8.3 and was generally similar between depths, sites and seasons. Freshwater inflows to Orokolo Bay have relatively little influence on pH, although the higher pH in the upper 5 m of the water column during the southeast trade wind season indicates that the riverine inflow is more alkaline than the receiving marine water.

All sites in Orokolo Bay had relatively low nutrient concentrations, with most results below laboratory limits of reporting during both surveys. Ammonia was an exception, with generally higher concentrations during the northwest monsoon season survey, when fluvial inputs would be expected to be higher. Ammonia concentrations in all samples were below the ANZECC/ ARMCANZ (2000) toxicity-based guideline value (0.91 mg/L) for the protection of aquatic ecosystems. Nitrate/nitrite concentrations were above laboratory reporting limits at some sites (i.e., ranging from 0.01 to 0.1 mg/L). The higher levels (i.e., up to 0.1 mg/L at site M3; see Figure 8.11) were measured in the southeast trade wind season in contrast to observations for ammonia. Total phosphorus concentrations during the southeast trade wind season survey were mostly below the limit of reporting (0.05 mg/L); however, higher concentrations (i.e., up to 0.26 mg/L) were measured at some sites during the northwest monsoon season survey.

Elevated nutrient levels can result in nuisance algal growth depending on a number of factors; however, chlorophyll-a levels, which are indicative of phytoplankton growth, were low, with all results being below or close to the laboratory limit of reporting (1 μg/L). Fluvial discharges can typically lead to increased chlorophyll-a levels due to nutrient inputs; however, there was no evidence of this, with chlorophyll-a levels at sites most likely influenced by fluvial discharges (i.e., those closest to the Purari River mouth and sites M45, M46 and M7) less than 2 μg/L.

Concentrations of dissolved (i.e., filtered less than 0.45 μm) metals/metalloids in Orokolo Bay were generally similar between different sites, water depths and seasons. With the notable exception of strontium, levels were low, mostly less than laboratory reporting limits and below Schedule 1 of the *Environment (Water Quality Criteria) Regulation 2002* and ANZECC/ARMCANZ (2000) guideline values. Copper and mercury marginally exceeded the ANZECC/ARMCANZ (2000) guideline values in separate single samples from Orokolo Bay; however, these results were only marginally above the limit of reporting.

CONTINUOUS BOTTOM TURBIDITY MEASUREMENTS AT OROKOLO BAY

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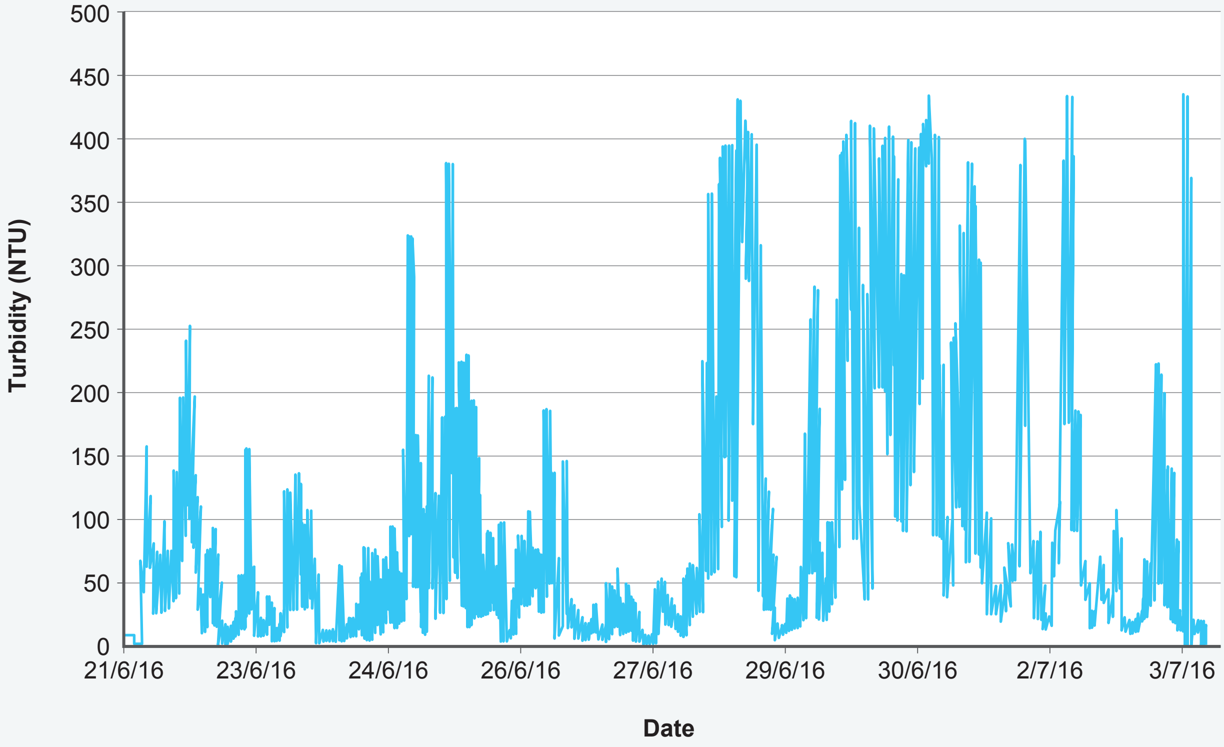
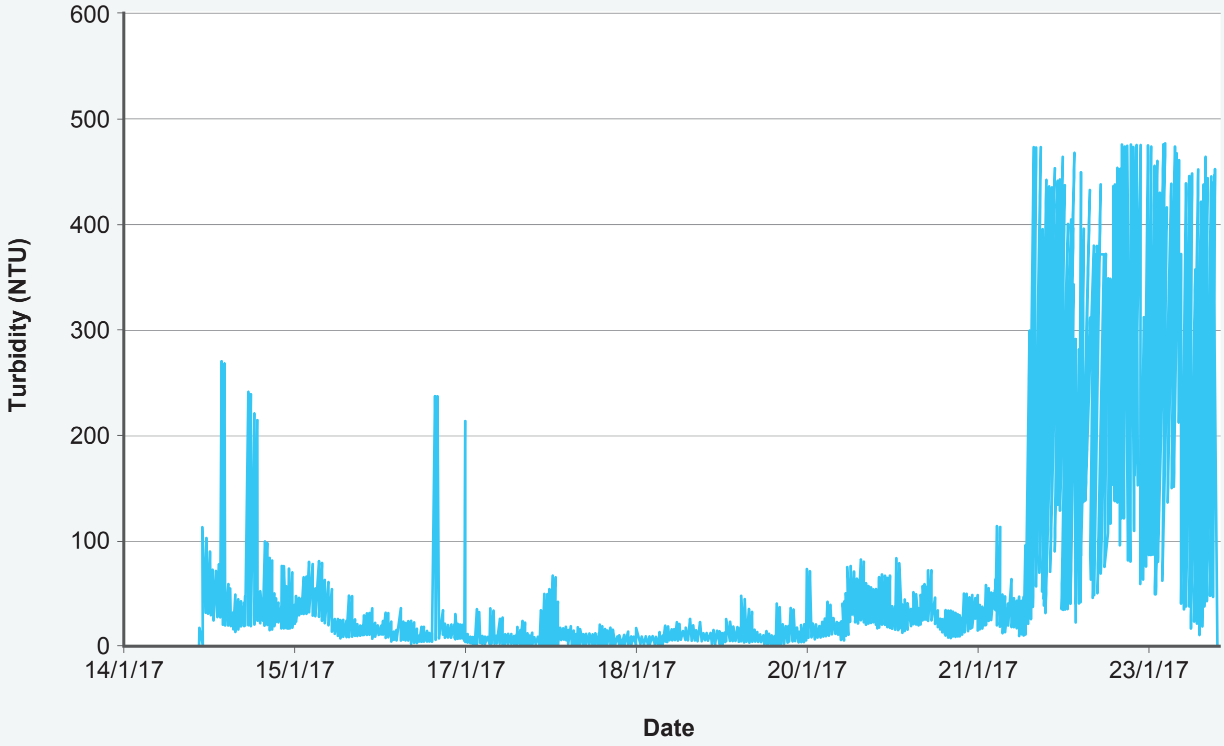
FIGURE 8.14

Site B (Reef)



Site C (Purari River Mouth)



Strontium is a constituent of seawater present in naturally high concentrations. During the southeast trade wind season, notably lower concentrations of this element were present in surface water compared to concentrations in deeper water and near the river mouth, indicating the presence of a freshwater lens across the bay. Total metal/metalloid concentrations were generally similar to dissolved concentrations except for aluminium and iron, which were higher, particularly in bottom waters during the southeast trade wind season and at the site nearest the Purari River mouth. This can be attributed to the higher suspended sediment levels in these samples. Aluminium and iron are major soil constituents, hence are present at naturally high concentrations in suspended sediment.

Concentrations of all hydrocarbon contaminants (i.e., PAHs, TPHs and BTEX) at all sites during both seasons were below the laboratory limits of reporting and relevant ANZECC/ARMCANZ (2000) guideline values.

8.4.2.3 Offshore Export Pipeline Corridor

Water quality profiling measurements of temperature, salinity, turbidity and dissolved oxygen were taken at each of the sampling sites during the southeast trade wind season and northwest monsoon season surveys (Figures 8.15 and 8.16).

Stratification of the water column was not noticeable during the southeast trade wind season; but during the northwest monsoon season survey, surface water temperatures were up to 3ºC higher, and there was lower salinity in the surface waters, extending to a depth of about 30 m.

Turbidity levels along the offshore export pipeline corridor are generally low and mostly less than 5 NTU throughout the water column in both seasons. Total suspended solids levels were less than 10 mg/L during the southeast trade wind season survey except for one bottom water sample (14 mg/L). Lower TSS levels were measured during the northwest monsoon season survey with most results less than 1 mg/L.

The upper 20 m of the water column was well oxygenated during both seasons, with dissolved oxygen levels being greater than 95% saturation. Levels progressively decreased below this depth to as low as 80% saturation in bottom waters, less than the ANZECC/ARMCANZ (2000) guideline value of 90%.

Nutrient concentrations along the offshore export pipeline corridor were low and below the limit of reporting at all sites, except for ammonia, which was present at levels similar to Orokolo Bay. Low levels of total phosphorus (0.07 mg/L to 0.13 mg/L) were also detected at some sites during the northwest monsoon season. Chlorophyll-a was not detected at any site, indicating that there was no nuisance algal growth.

Metal and metalloid concentrations along the corridor were generally similar between sites, depths and seasons. Results were below water quality guideline values at all sites during both seasons. Total metal/metalloid concentrations were generally similar to dissolved concentrations, and concentrations were generally similar throughout the water column. Similar to Orokolo Bay, the exceptions were aluminium and iron, which had higher total concentrations in some bottom samples during the southeast trade wind season survey, reflecting the higher level of suspended sediment present in these samples due to sediment remobilization from the seabed.

Strontium concentrations were similar throughout the water column during the southeast trade wind season survey but lower in the surface water samples during the northwest monsoon season survey, which is the converse of the seasonal conditions observed in Orokolo Bay. This indicates the presence of a surface fresher water lens along the corridor during the monsoon

TEMPERATURE AND SALINITY PROFILES ALONG THE OFFSHORE EXPORT PIPELINE CORRIDOR

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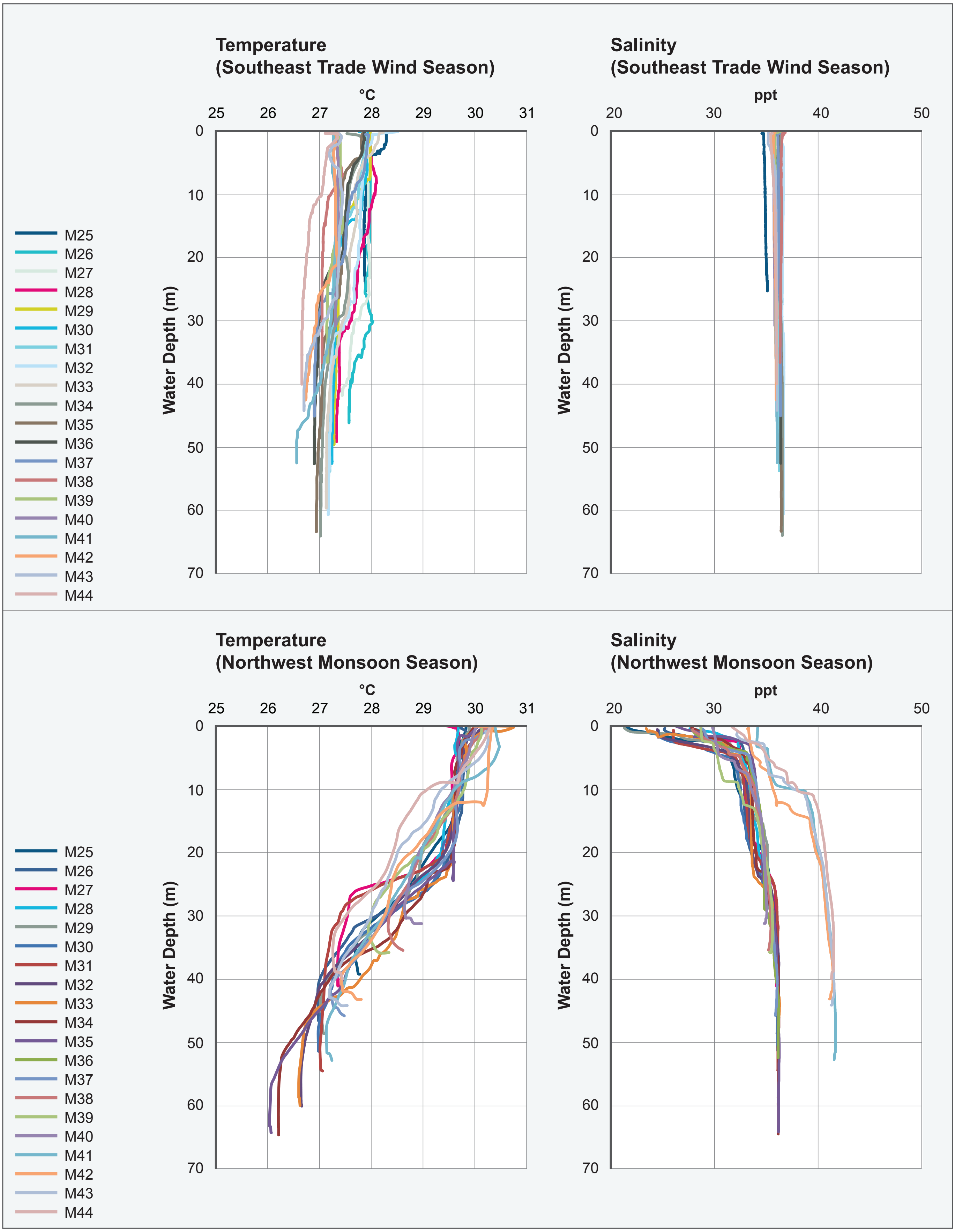
FIGURE 8.15



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TURBIDITY AND DISSOLVED OXYGEN PROFILES ALONG THE OFFSHORE EXPORT PIPELINE CORRIDOR

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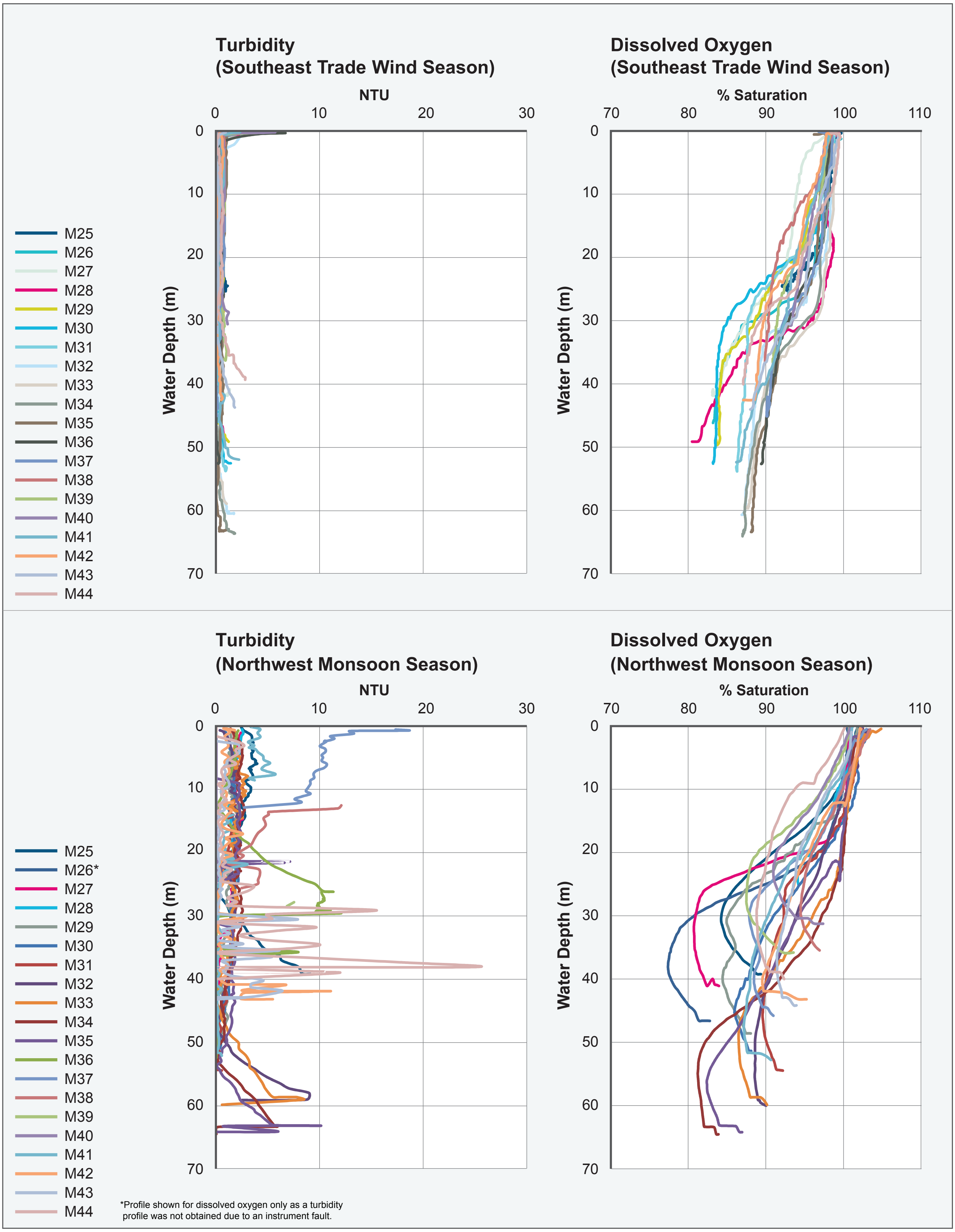
FIGURE 8.16



season. This riverine influence on surface water is also indicated by the higher total aluminium and iron concentration in the surface water samples during the monsoon season.

Concentrations of PAHs, TPHs and BTEX were below the laboratory limits of reporting and relevant ANZECC/ARMCANZ (2000) guideline values at all sites during both seasons.

8.4.2.4 Caution Bay

Water quality profiling measurements of temperature, salinity, turbidity and dissolved oxygen were taken at each of the sampling sites during the southeast trade wind season and northwest monsoon season surveys (Figures 8.17 and 8.18).

Water quality properties in Caution Bay were relatively uniform throughout the water column during the 2016 southeast trade wind season survey and typical of conditions expected for marine waters.

During the 2017 northwest monsoon season survey, some stratification was evident, with water temperature about 2ºC warmer and salinity around 5 ppt lower in the upper 20 m of the water column. The pH was 0.1 units higher in surface waters, at around pH 8.2.

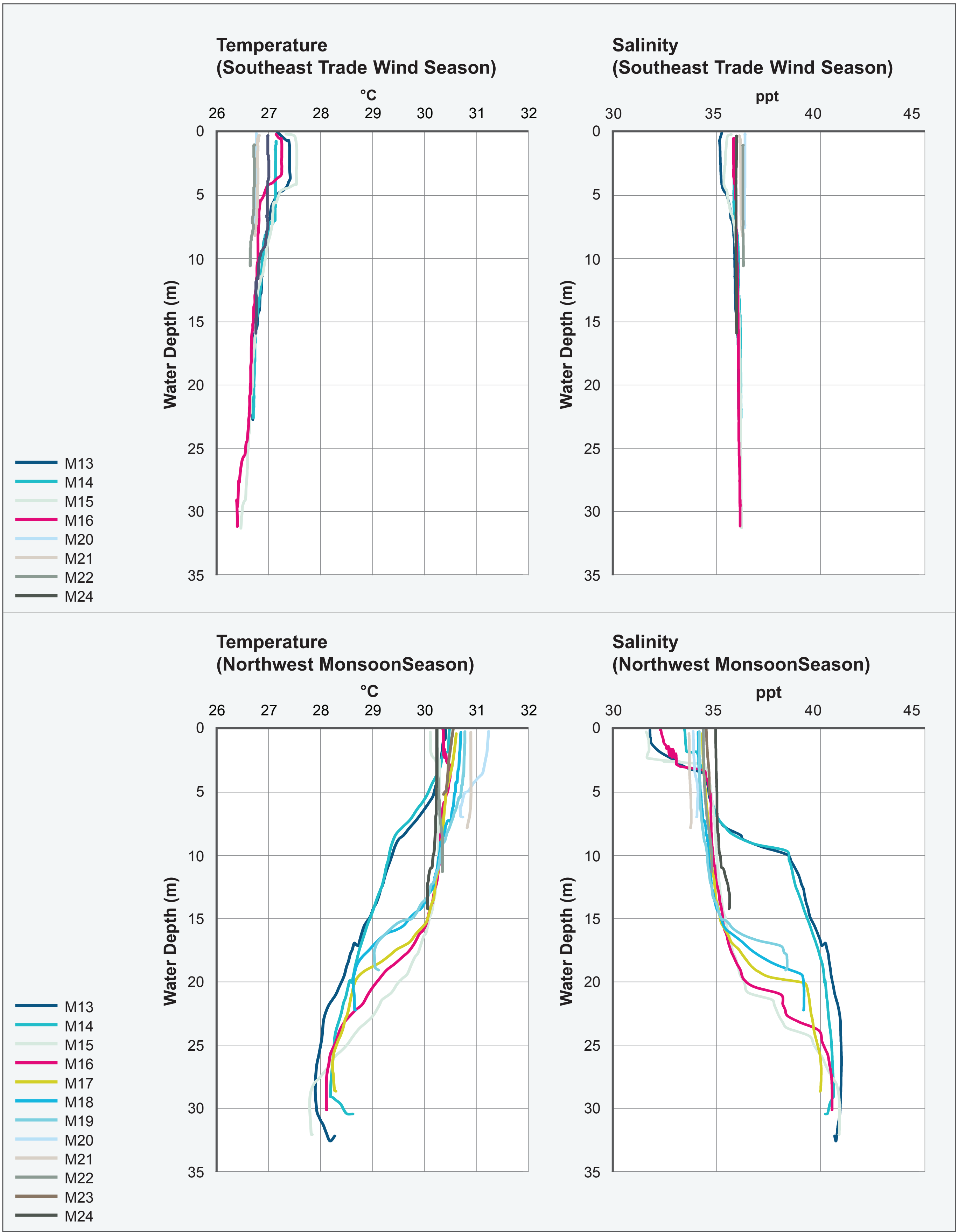
During the southeast trade wind season, turbidity levels were low (less than 2 NTU). In the northwest monsoon season, turbidity was higher but mostly less than 5 NTU although with some higher levels measured in deeper waters (i.e., sites M16, M17 and M20). This suggests that turbidity is increased due to remobilization of bed sediment by wind-driven waves. As described in Section 8.3, higher wave heights occur during the northwest monsoon season due to a higher incidence of waves from the less protected westerly direction. Shoals and a coral cay protect the bay from waves approaching from the south during the southeast trade wind season. This is consistent with previous studies conducted for the PNG LNG Project EIS, which reported higher water turbidity in Caution Bay during the northwest monsoon season than observed during the southeast trade wind season (CNS, 2008a).

Dissolved oxygen concentrations were greater than 90% saturation throughout the water column in the southeast trade wind season. Dissolved oxygen levels decreased from over 100% saturation near the surface to about 90% saturation in bottom waters in the northwest monsoon season.

Total suspended solids were less than 8 mg/L at all sites in Caution Bay in both the 2016 southeast trade wind season survey and the 2017 northwest monsoon season survey. Previous studies in Caution Bay reported TSS levels between 2 and 17 mg/L in December 2007 during the northwest monsoon season and 26 to 68 mg/L in April 2008 during the southeast trade wind season. The higher TSS results in April were considered to be contrary to the higher visibility noted by divers and lower turbidity results compared with December (CNS, 2008a).

Previous studies in Caution Bay found nutrient levels varied seasonally, with higher levels in the southeast trade wind season, when ammonia ranged from 0.01 to 0.055 mg/L and was below the ANZECC/ARMCANZ (2000) guideline value of 0.91 mg/L (CNS, 2008a). In the current study, ammonia levels were found to be higher (i.e., 0.09 to 0.83 mg/L at most sites) but were still below the ANZECC/ARMCANZ (2000) guideline value. An ammonia concentration of 0.96 mg/L was recorded at site M13 (see Figure 8.5), which was above the guideline value (0.91 mg/L). Total phosphorus concentrations were also found to be higher in the current study, from less than 0.05 to 0.49 mg/L compared with 0.01 to 0.13 mg/L reported in CNS (2008a). In contrast to the previous studies, the current study found nutrient concentrations to be higher during the northwest monsoon season survey. Concentrations of all other nutrients in the current study were

FIGURE 8.17


Temperature
(Southeast Trade Wind Season)
°C
26 27 28 29 30 31 32
Water Depth (m)
0 5 10 15 20 25 30 35
Salinity
(Southeast Trade Wind Season)
ppt
30 35 40 45
Water Depth (m)
M13
M14
M15
M16
M20
M21
M22
M24
Temperature
(Northwest MonsoonSeason)
°C
Salinity
(Northwest MonsoonSeason)
ppt
M13
M14
M15
M16
M17
M18
M19
M20
M21
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M23
M24

TURBIDITY AND DISSOLVED OXYGEN PROFILES IN CAUTION BAY

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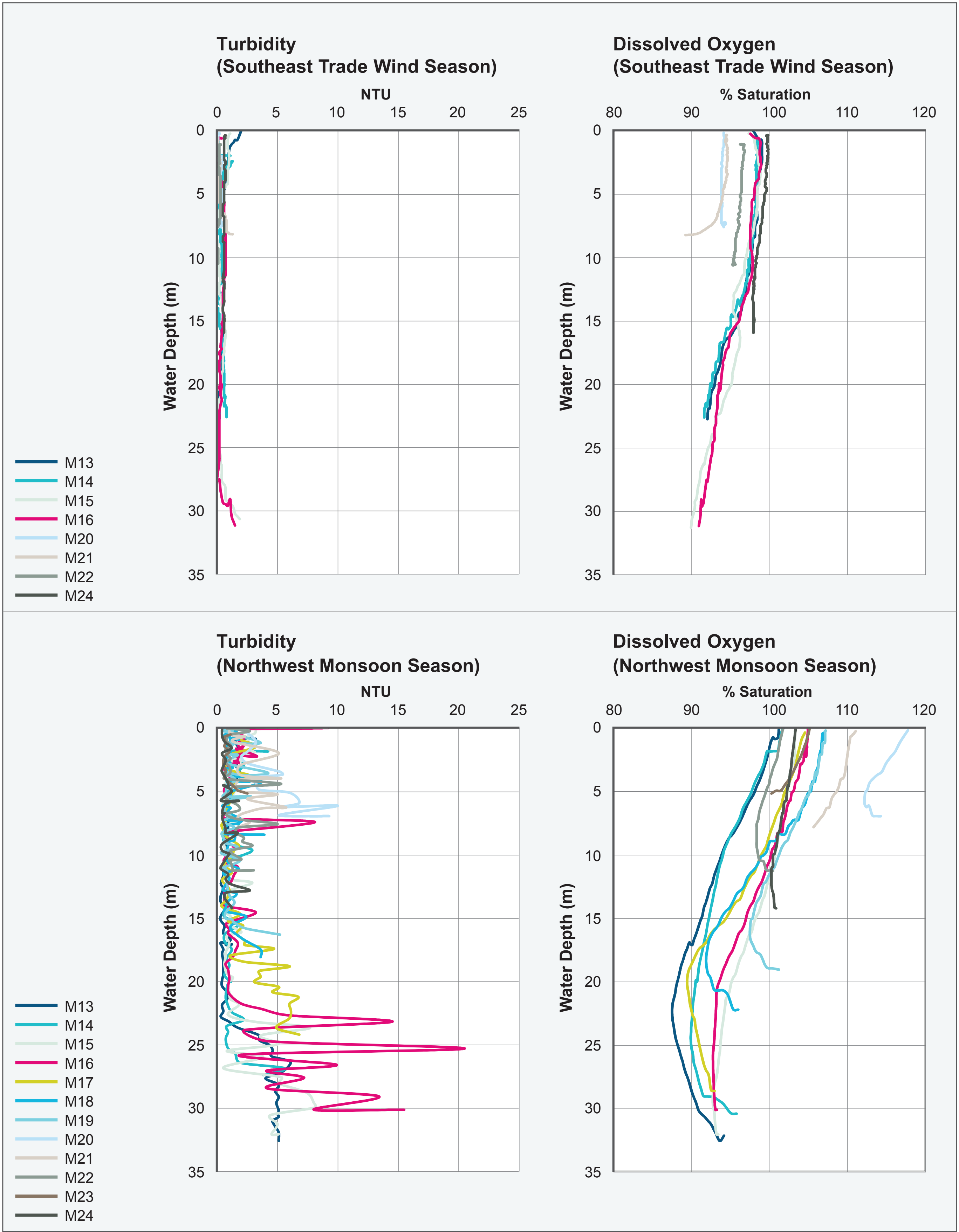
FIGURE 8.18



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below the limit of reporting at all sites during both seasons. Chlorophyll-a was not detected above the reporting limit at any site during both surveys, indicating that there was no nuisance algal growth.

Metal and metalloid concentrations were generally similar between sites, depths and seasons; and all samples were below relevant water quality guidelines. Previous studies also found metal and metalloid concentrations to be below PNG water quality criteria and ANZECC/ARMCANZ (2000) guidelines (CNS, 2008a).

Concentrations of PAHs, TPHs and BTEX were below the laboratory limits of reporting and relevant ANZECC/ARMCANZ (2000) guideline values at all sites during both seasons.

8.4.3 Marine Sediment Baseline Characterization

8.4.3.1 Study Overview

Sediment sampling in the study area was completed during the 2016 and 2017 marine surveys with samples collected from 18 sites. Sampling sites are shown in Figure 8.11.

Results from laboratory analyses of these samples were considered, in conjunction with available information from previous studies, to describe existing marine sediment characteristics in the study area, incorporating Orokolo Bay, the offshore export pipeline corridor and Caution Bay. To provide a benchmark for assessment of sediment quality, contaminant levels are compared to sediment quality guidelines contained in Schedule 2 of the *PNG Marine Pollution (Sea Dumping) Regulation 2013* and Simpson et al. (2013), which respectively provide Papua New Guinean and good international industry practice for assessing sediment contamination.

8.4.3.2 Orokolo Bay

Particle size analyses show that silts and clays comprise more than 90% of surface sediments in Orokolo Bay (Figure 8.19). This can be attributed to the influence of the Purari and Vailala rivers, which deliver large volumes of fine sediment to the gulf. Sediment is coarser in higher energy areas nearer the river mouth, with a site in the Purari River mouth (M45) having 90% sand and an inshore site nearest to the river mouth (M7) having 55% sand. Plate 8.6 shows an example of the typical, predominantly silty sediment found in Orokolo Bay.

Plate 8.6 – Typical Sediment of Orokolo Bay (Site M9)

Photo: BMT WBM.

SEDIMENT PARTICLE SIZE DISTRIBUTION AND NUTRIENT AND ORGANIC MATTER CONTENT OF SEDIMENT

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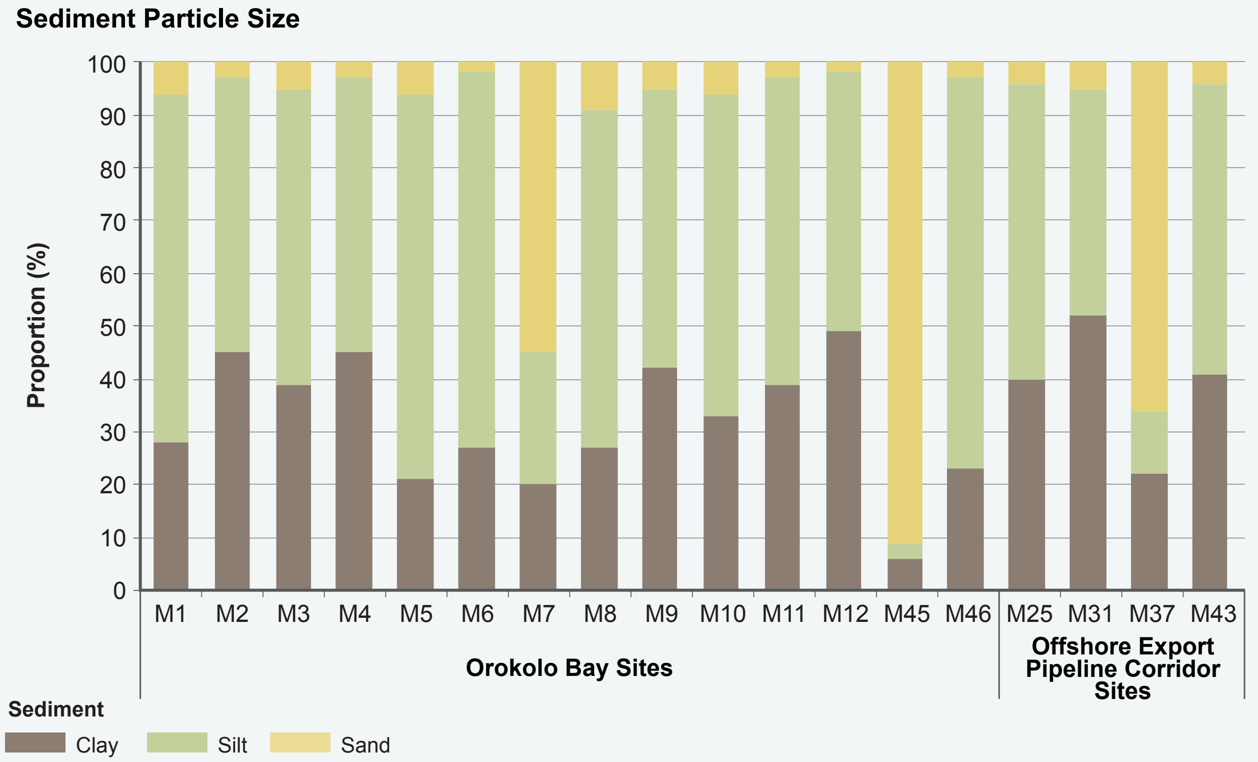
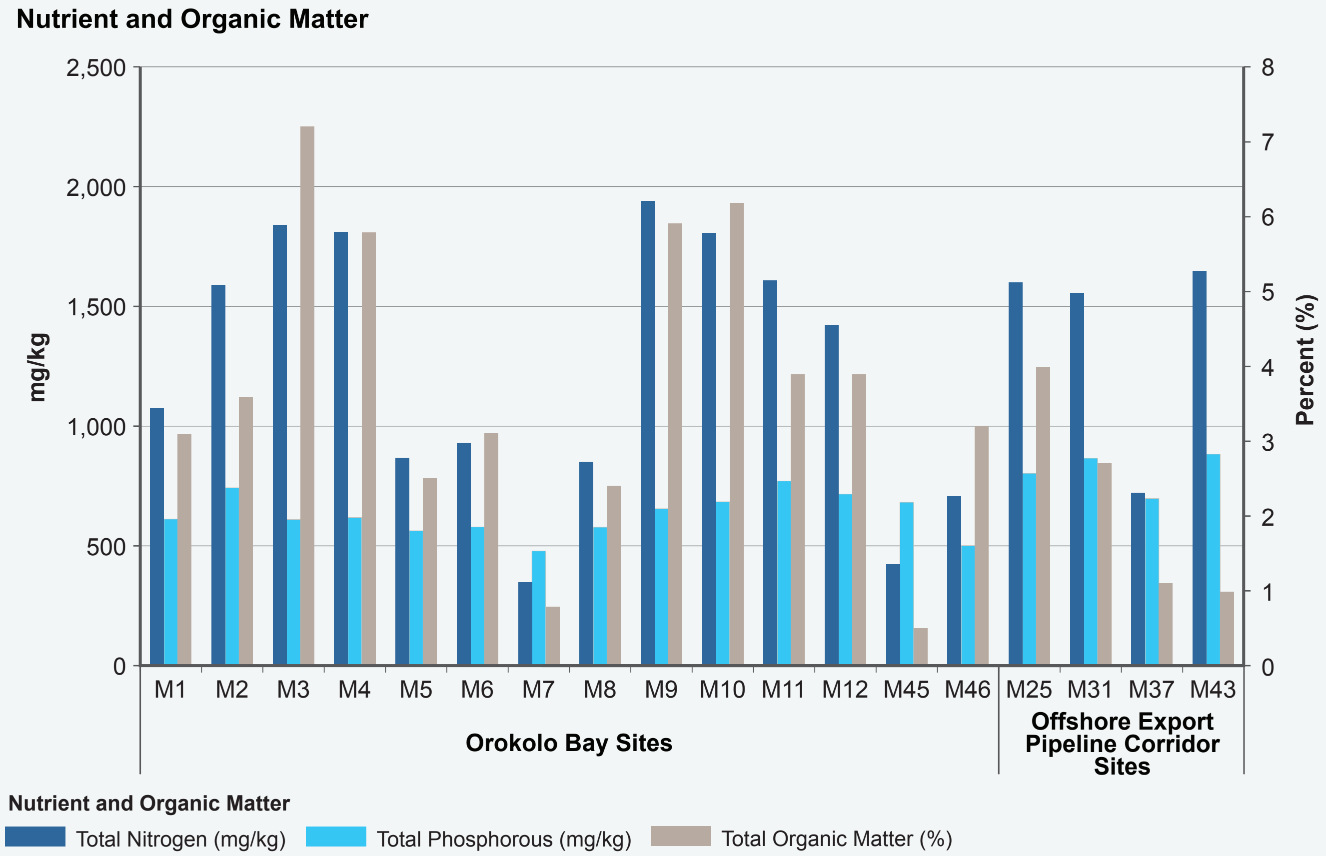
FIGURE 8.19





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Nutrient and organic content in sediments varies between sites according to the proportion of sand, silt and clay. Sediments with a higher clay proportion (e.g., sites M2, M3, M4, M9, M11 and M12) have higher total nitrogen and phosphorus concentrations ranging from 1,420 to 1,940 mg/kg and 608 to 773 mg/kg, respectively (see Figure 8.19). Total organic matter and total organic carbon concentrations are also higher at sites with greater amounts of silts and clay and are much lower at sites predominantly comprising sand (sites M7 and M45) with less than 0.8% total organic matter and less than 0.5% total organic carbon found at these sites.

Metal and metalloid concentrations are generally similar between sites and below sediment quality guidelines, with the exception of nickel. Nickel concentrations are similar at all sites (around 40 to 50 mg/kg), compared to the sediment guideline value of 21 mg/kg. Background nickel concentrations in sediments in Papua New Guinea are often found to be above this guideline value, reflecting the geology of the region (i.e., naturally high background nickel levels).

Metal (e.g., aluminium, copper, iron and nickel) concentrations are also notably lower at sites that contained higher amounts of sand (e.g., sites M7 and M45). This reflects the tendency for metals to be associated with finer sediment fractions due to the greater surface area available for adsorption, compared with coarser grained sands.

All hydrocarbon contaminant (i.e., PAHs, TPHs and BTEX) concentrations were below the laboratory limits of reporting and relevant sediment guideline values at all sites.

8.4.3.3 Offshore Export Pipeline Corridor

Similar to Orokolo Bay, sediments along the offshore export pipeline corridor are also predominantly silts and clays, which accounted for over 90% of sediment at most sites (see Figure 8.19). The exception was due west of Yule Island (site M37), where there is a high amount of sand-sized sediment (66%), which is likely attributable to the presence of shoals at Yule Island. An example of the typical silty clay sediment along the offshore export pipeline corridor is shown in Plate 8.7.

Plate 8.7 – Example of Typical Sediment Along the Offshore Export Pipeline Corridor (Site M31)

Photo: BMT WBM.

Sediment nutrient and organic content was similar between most sites and comparable to levels measured at Orokolo Bay (see Figure 8.19). Lower concentrations were present in sediment offshore from Yule Island, where sediment had a higher proportion of sand, and less silts and clays.

Metal and metalloid concentrations along the corridor were generally similar between sites. Concentrations were below sediment quality guidelines, except nickel concentrations, which were similar to those at Orokolo Bay from 38 to 50 mg/kg.

Concentrations of PAHs, TPHs and BTEX were below the laboratory limits of reporting and relevant sediment guideline values at all sites.

8.4.3.4 Caution Bay

No sediment samples were collected in Caution Bay during the 2016 and 2017 surveys, due to the safety risk from unexploded ordnances from a World War II battery at Boera that are possibly present in the study area. Surveys undertaken in Caution Bay for the PNG LNG Project (CNS, 2008a) indicate that, while the substrate predominantly comprises sandy sediments (Plate 8.8), there is a range of sediment types. In coral-dominated areas, sediments are characterized by larger particle size fractions associated with coral rubble and shell debris (Plate 8.9).

Plate 8.8 – Example of Sandy Sediment in Caution Bay (Site M21)

Photo: BMT WBM.

Plate 8.9 – Example of Coral Rubble and Shell Debris in Caution Bay (Site M20)

Photo: BMT WBM.

The deeper areas of Caution Bay are characterized by muddy terrigenous silt and clay sediments. The shallowest nearshore and intertidal areas, particularly in the vicinity of the Vaihua River estuary, are predominantly mudflats (CNS, 2008a).

The proportion of organic carbon in sediments in Caution Bay has previously been reported to be between 2.2 and 10%, while the total inorganic carbon was from 1.17 to 10.7% (CNS, 2008a). Nutrients were not analyzed in sediment samples collected in Caution Bay for the PNG LNG Project.

The 16 sites sampled in Caution Bay for the PNG LNG Project showed a considerable range in metal concentrations. This reflects the range of sediment particle sizes at different locations, with much higher concentrations at sites having higher amounts of silts and clays. The survey found that metal and metalloid concentrations were less than sediment quality guidelines, except nickel concentrations, which were close to or exceeded the guideline value of 21 mg/kg at some sites with results of up to 47 mg/kg (CNS, 2008a). This is consistent with the finding of high nickel concentrations in the 2016 and 2017 surveys at Orokolo Bay and the offshore export pipeline corridor, where nickel exceeded the sediment quality guideline at all sites.

Hydrocarbon contaminants were not analyzed in sediment samples collected in Caution Bay for the PNG LNG Project.

8.4.4 Summary of Water and Sediment Quality

Overall, water and sediment quality is high in the study area, and does not show evidence of anthropogenic contamination, although there are some naturally elevated nickel concentrations in sediment. Turbidity and physicochemical water properties vary across seasons and the water column due to changes in sea state conditions and fluvial inflows, and also vary based on proximity to the Purari, Vailala and Vaihua river mouths in the study area.

8.5 Marine Biodiversity

8.5.1 Regional Context

Papua New Guinea forms part of the Coral Triangle, a region that is home to the highest coral diversity in the world and is the center of marine biodiversity worldwide (Allen, 2006). Based on the Spalding et al. (2001) classification of marine ecoregions of the world, the study area encompasses the Gulf of Papua ecoregion, which covers Orokolo Bay and the western extent of the offshore export pipeline corridor, and the Southeast Papua New Guinea ecoregion, which covers Caution Bay and the eastern extent of the offshore export pipeline corridor (Figure 8.20). The Gulf of Papua and Australia share a strong biogeographic affinity due to their close proximity and recent geographic affinity; consequently, few endemic marine species are found in southern Papua New Guinea (Sekhran & Miller, 1996).

The study area contains no marine protected areas. The closest protected area is Paga Hill National Park Scenic Reserve, which covers part of Port Moresby harbor but is not considered relevant to the study area. This site is approximately 13 km southeast of Caution Bay.

8.5.2 Marine Habitat Baseline Characterization

8.5.2.1 Study Overview

Field surveys for the marine biodiversity study were completed during the 2016 southeast trade wind season and the 2017 northwest monsoon season.

The surveys involved (Part 23 of Volume 2):

- Mapping benthic habitats, including sensitive receptors such as coral reefs, rocky reefs and seagrasses.
- Sampling benthic macroinvertebrates in different substrate types.
- Surveying reef fish assemblages in Caution Bay by baited remote underwater video.
- Assessing the occurrence of threatened or protected marine species or potential sensitive habitat in the study area.

ECOREGIONS OF SOUTHERN NEW GUINEA

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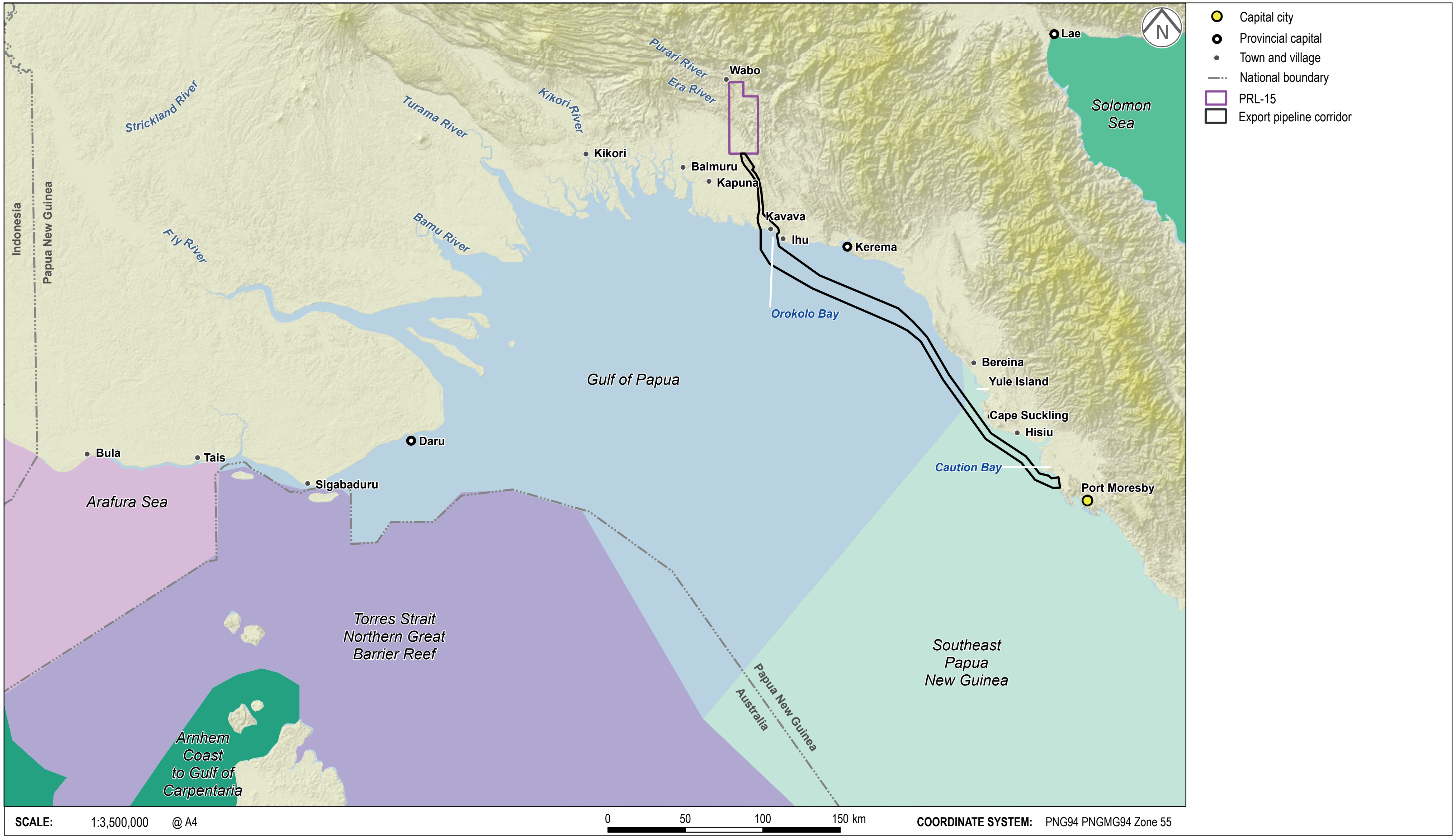
FIGURE 8.20



Survey sites are shown in Figure 8.11. The field survey data was used, in conjunction with existing information from previous studies in the area, scientific literature and databases, to provide a description of marine habitat types in the study area and to identify potential sensitive marine habitat and threatened, rare, or otherwise noteworthy species likely to be present.

Four major marine benthic habitat types were identified in the study area, including beach and intertidal flats, seagrass meadows, subtidal coral and rocky reefs, and soft sediments. The relevance of each of these benthic habitat types in the three sectors of the study area is described in the following sections. Mangrove communities, which dominate the coastline throughout the Purari River delta and the eastern coast of Caution Bay, are considered as part of estuarine communities in Section 7.6. The pelagic environment (i.e., the water column) of the study area is discussed in Section 8.5.2.5.

Beaches and intertidal flats are generally unvegetated habitats and are predominantly found along the north and east coastlines of the Gulf of Papua. Invertebrates, such as crustaceans and mollusks, can be found as permanent inhabitants, while birds can be found feeding opportunistically during low tides on intertidal flats and along the beaches.

Seagrass meadows are typically found in shallow, soft-bottomed marine coastlines and estuaries with the availability of light, tidal exposure, salinity, temperature and turbidity being some of the factors that determine their distribution (Seagrass Watch, 2015a). Seagrass meadows are found in Papua New Guinea growing on fringing reefs, in protected bays and inlets, and on the protected side of barrier reefs and islands (Seagrass Watch, 2015b).

All major coral reef types are found in Papua New Guinea, including fringing, patch and barrier reefs. Extensive barrier reefs are found southeast of Port Moresby along the south coast, around to East Cape on the eastern coast and around the Louisidae Archipelago located about 200 km southeast of East Cape. In the Gulf of Papua, no coral reefs are found to the west and north due to high sediment loads discharged from rivers to this part of the gulf. Coral reefs are found along parts of the eastern coastline, where there are fewer major river mouths and water clarity is higher. Soft sediment habitats are the major marine habitat type found throughout the Gulf of Papua due to the presence of the continental shelf and the delivery of large amounts of sediment from the rivers to the north and west of the gulf.

The occurrence of marine fauna, including benthic macroinvertebrates, fishes, macrocrustaceans, marine mammals and marine reptiles, in the study area is described in Section 8.5.3.

8.5.2.2 Orokolo Bay

Beaches and Intertidal Flats

Sandy beaches occur intermittently between tidal inlets and river mouths along the Purari River delta but are more continuous east of the delta in Orokolo Bay (Plate 8.10). These beaches comprise dark sandy material, with fine sand near the Purari River mouth grading to coarser sands and gravel toward the Vailala River.

Plate 8.10 – Example of a Dark Sandy Beach at Orokolo Bay

Photo: Iain Woxvold.

Seagrass Meadows

No seagrass meadows were identified in the shallow tidal waters of Orokolo Bay or close to the Purari River mouth. This is attributable to unsuitable environmental conditions, including:

- Bed mobilization by wave disturbance and fluvial discharges.
- High sediment loads and associated low light that reduces photosynthesis, and high sediment deposition associated with fluvial discharges and bed remobilization.
- Low salinity in nearshore waters due to fluvial discharges.

Subtidal Reefs

No coral reefs or intertidal rocky shores were recorded in the nearshore environments at Orokolo Bay near the Purari River mouth nor have they been previously noted.

A subtidal rocky reef was identified at site M6, approximately 10 km southeast of the Vailala River mouth, just outside of the offshore export pipeline corridor (see Figure 8.6). This reef supports an assemblage of filter feeding soft corals, sponges, colonial ascidians, crinoids, hydroids and other encrusting organisms (Plate 8.11). These species are known to tolerate the fluctuating salinity and turbidity associated with fluvial discharges and remobilization of bed sediment.

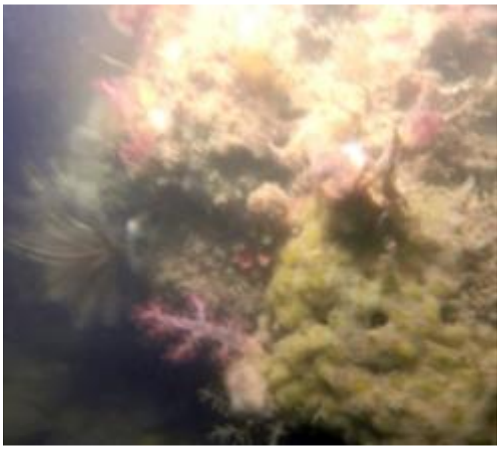
West of this location in the offshore export pipeline corridor and Orokolo Bay, the seabed was found to be flat and featureless with no subtidal reefs present.

Plate 8.11 – Rocky Reef Benthos Examples (Site M6)

Crinoids

Polychaete tube worms, crinoids and *Dendronephthya* sp.

Mixed community with crinoid, *Dendronephthya* sp. and colonial ascidian



Hydroids

Photos: BMT WBM.

Soft Sediments

Substrates in subtidal areas of Orokolo Bay mostly comprise clay and silt, with less than 10% sand. Plates 8.6 and 8.12 show examples of the typical sediment and substrate, respectively. Fluvial sediment inputs from nearby rivers represent a major source of fine material to these nearshore environments, and overlying waters can be highly turbid. This was indicated by a suspended fluid mud layer observed above the seabed in Orokolo Bay in water 10 to 15 m deep during the survey undertaken during the southeast trade wind season.

Habitat mapping found featureless soft sediments to be the dominant habitat type in Orokolo Bay, with no sensitive features, such as seagrass meadows or coral reefs, present. Mangroves found along the Orokolo Bay coastline around the mouth of the Purari River are discussed in Section 7.

Plate 8.12 – Typical Flat and Featureless Seabed Substrate in Orokolo Bay (Site M12)

Photo: BMT WBM.

8.5.2.3 Offshore Export Pipeline Corridor

Seagrass Meadows

Similar to Orokolo Bay, no seagrass meadows were identified along the offshore export pipeline corridor, consistent with the findings of surveys conducted along the PNG LNG Gas Pipeline in 2008 (CNS, 2008b). Water depths along the corridor are considered too deep to support the growth of seagrasses, which are generally found in less than 20 m of water, although some *Halophila* species can be found at depths greater than 50 m (Waycott et al., 2004).

Subtidal Reefs

No subtidal reefs were identified along the offshore export pipeline corridor during the present or historical surveys. Outside of the study area, subtidal reefs have been recorded between the pipeline corridor and the coastline, particularly near Kerema and Yule Island (CNS, 2008b).

Soft Sediments

As described in Section 8.4.3, sediments sampled along the offshore export pipeline corridor predominantly comprise silt and clay, except near Yule Island, where the sediment was found to be predominantly sand.

Similar to Orokolo Bay, featureless soft sediments are the dominant habitat type along the offshore export pipeline corridor, with no sensitive features such as seagrass meadows or coral reefs present.

8.5.2.4 Caution Bay

Beaches and Intertidal Flats

In Caution Bay, sandy beaches occurring particularly to the north, and small pockets of intertidal mudflats associated with mangroves around the Vaihua River estuary (Figure 8.21) both provide habitat, including feeding grounds, for fish, birds and invertebrates. Saltpan mudflats are found behind the mangroves (Figure 8.21) beyond the high tide level and also provide habitat, including feeding grounds for birds and invertebrates.

NEARSHORE MARINE HABITATS IN CAUTION BAY

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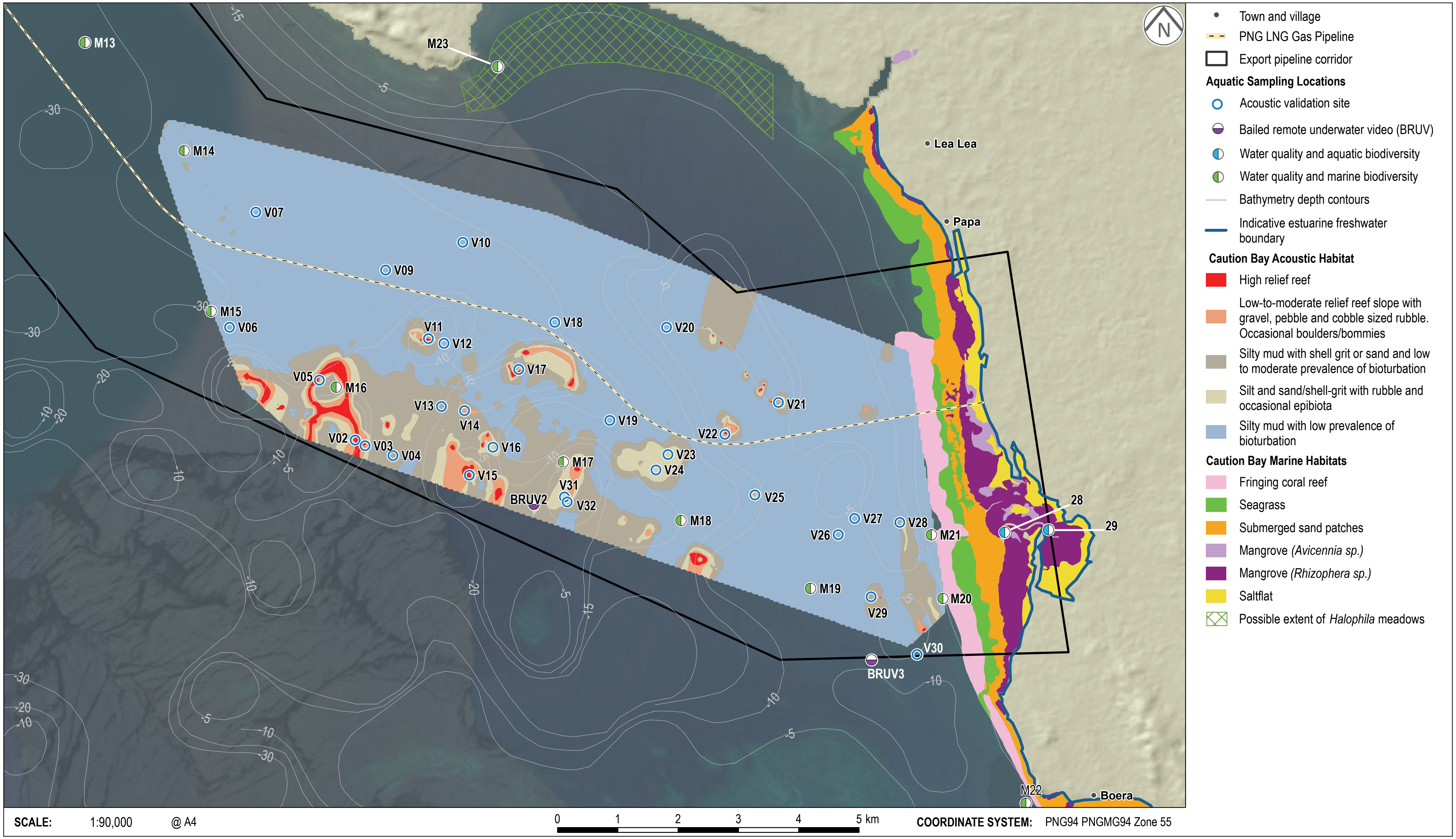
FIGURE 8.21



SCALE: 1:90,000 @ A4 0 1 2 3 4 5 km COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Seagrass Meadows

Dense seagrass meadows have been previously mapped in Caution Bay and occur on the flat, sandy seafloor between the mangrove-lined shore and the fringing reefs (CNS, 2008a). Seagrass meadows were not observed seaward of the fringing reefs and, although dense where they were found, seagrass meadows are not extensive. *Enhalus acroides*, *Syringodium isoetifolium* and *Cymodocea* spp. have been recorded in Caution Bay (CNS, 2008a). The present study confirmed these seagrass meadows are still present (see Figure 8.21). This study also identified additional, sparse seagrass meadows comprising *Halophila* species, with cover less than 5%, in the northern part of Caution Bay. Seagrass meadows in Caution Bay are considered to have a high ecological significance, as they stabilize the substrate and provide nursery and feeding habitats for a range of marine organisms, including prawns, lobsters, fish and turtles (CNS, 2008a).

No seagrass species known or likely to occur in the study area is listed as threatened or protected under the IUCN Red List or the *Fauna (Protection and Control) Act 1966*; however, the seagrass meadows of Caution Bay represent a high-value biotope since they may provide potential foraging habitat for threatened fauna species such as sea turtles (Section 8.5.3).

Subtidal Reefs

Fringing coral reefs are extensive in Caution Bay and are found parallel to the eastern shoreline, 200 to 500 m offshore (see Figure 8.21). A large outer barrier reef approximately 15 km wide is present in the south of Caution Bay and includes the coral cay, Idihi Island, at its western extent (see Figure 8.5). This barrier reef shelters the bay from ocean swells during the southeast trade wind season. Offshore reefs also exist around Vari Vari Island to the northwest just outside of Caution Bay (see Figure 8.5). Patch reefs, coral outcrops and low-relief rubble slopes are also present in the southern and central regions of Caution Bay.

Fringing and nearshore reefs have been previously noted to be in poor condition, most likely linked to high intensity fishing including dynamite fishing and the suspension of sediment from strong winds and waves (CNS, 2008a). The current survey found coral cover varied, with some areas having up to 100% live cover of *Acropora* species and *Pavona clavus* on some coral bomboras (Plates 8.13 and 8.14). Other areas had less than 5% live coral cover and were predominantly rubble with a sparse cover of soft corals, zoanthids, hydroids, sponges, ascidians and algae (Plate 8.15). There were also patches of cover where assemblages appeared to be recovering, with evidence of recent rapid growth rates (Plate 8.13).

Plate 8.13 – *Acropora* Bombora with High Coral Cover and Long Apical-growing Tips (Site V26)

Photo: BMT WBM.

Plate 8.14 – *Pavona clavus* Bombora with High Coral Cover (Site V30)

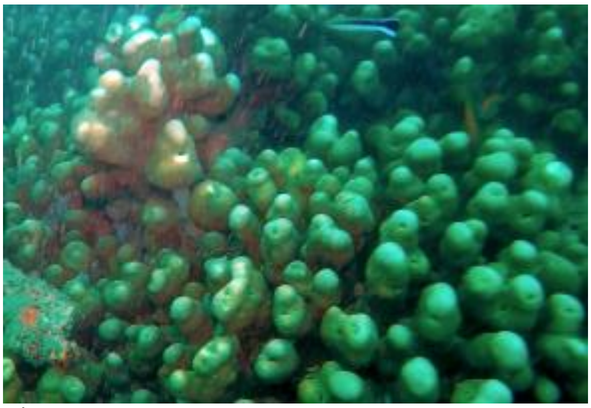
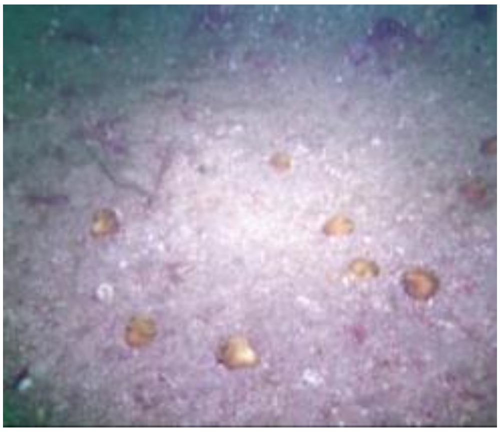


Photo: BMT WBM.

Plate 8.15 – Rubble Reef Community with Low Live Coral Cover (Site M22)

***Alveopora* sp. (stony coral)**

Free-living *Heteropsammia* sp. coral polyps



Photos: BMT WBM.

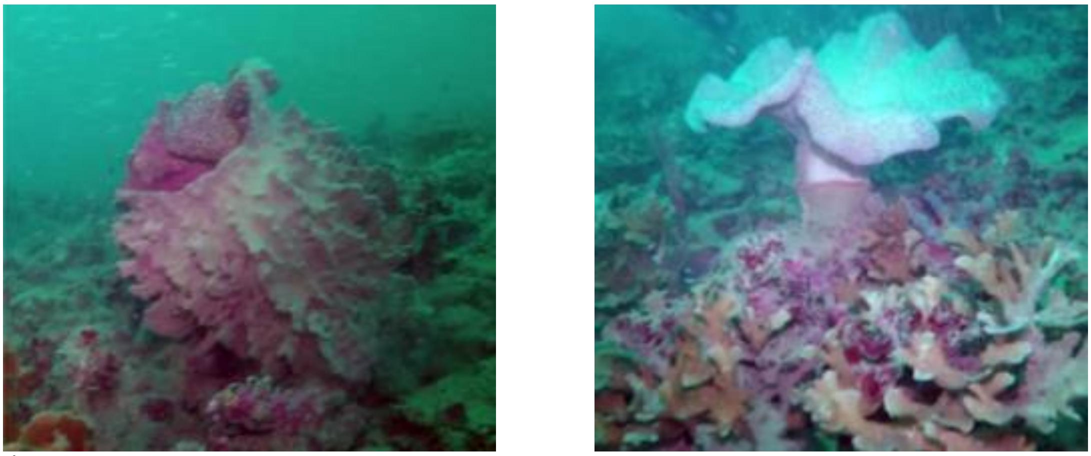
Patch reefs found in Caution Bay occur in water 5 to 25 m deep. One patch reef was found approximately 10 km west of the PNG LNG Facilities (site V02) with moderate live coral cover of 30% observed on the reef crest, which included branching and digitate *Acropora* species (Plate 8.16). Closer to shore, shallow patch reefs were also recorded 1 to 7 km northwest and southwest of the PNG LNG Facilities.

Plate 8.16 – Patch Reef Community (Site V02)

Photos: BMT WBM.

At depths greater than 25 m, reef assemblages were identified at sites V15, V16 and adjacent to site M16 (see Figure 8.21 and Plate 8.17), and were covered by octocorals (e.g., soft corals, gorgonians and sea whips), including *Sarcophyton, Sinularia, Ellisella, Viminella* and *Ctenocella* species. Hard corals were also abundant, including species of *Goniopora*, *Alveopora, Fungia, Leptoseris*, *Pavona*, and *Acropora.* Crinoids and sponges were also observed on these reefs.

Plate 8.17 – Deep Reef Community (Site V15)

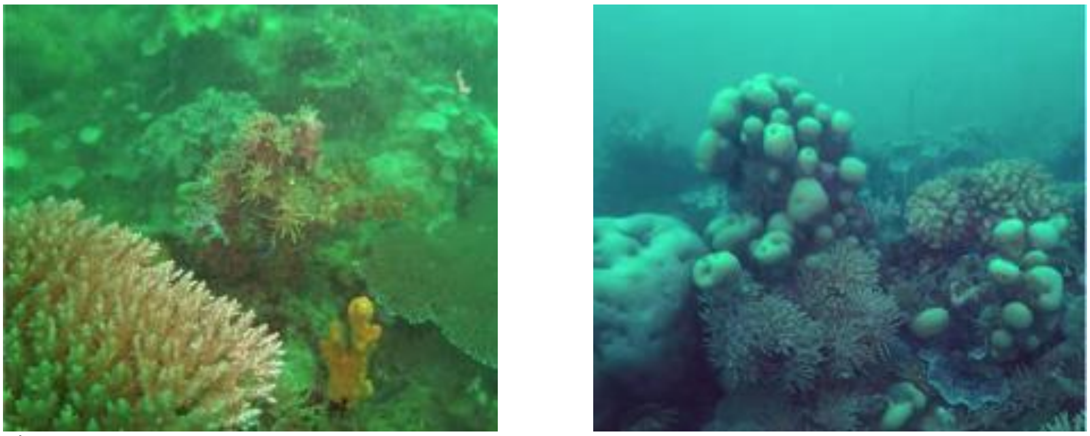


Photos: BMT WBM

The outer barrier reef and coral cay (Idihi Island), which are more extensive than the nearshore and fringing reefs, have up to 70% coral cover (Plate 8.18). These reefs, with less deposited sediment and anthropogenic disturbance, support a wider range of species. Coral at Vari Vari Island north of Caution Bay was also reported in CNS (2008a) to be in good condition with high coral cover supporting a range of species.

Coral reefs are not listed under Papua New Guinean legislation or the IUCN Red List; however, the coral reefs of Caution Bay represent a high-value biotope since they may provide habitat for threatened species, such as sea turtles and certain fish species (Section 8.5.3).

Plate 8.18 – Reef Slope Community at Idihi Island (Site M24[1])



Photos: BMT WBM.

Soft Sediments

The dominant subtidal soft substrate types in Caution Bay are muds and sands, as described in CNS (2008a) and verified during the present surveys. These soft sediments occur seaward of the fringing reef and between coral outcrops and shoals.

Based on validated acoustic habitat mapping undertaken in January 2017 (see Figure 8.21), two main types of substrate are present:

1 See Figure 5-3 in Part 12 of Volume 2.

- Substrate mostly comprising silty muds.
- Substrate between reef structures and in shallower environments in the eastern section of Caution Bay, mostly comprising silty muds with variable quantities of coarse sands, shell grit or coral rubble (see Plates 8.8 and 8.9 in Section 8.4.3.4).

8.5.2.5 Pelagic Environment

The pelagic zone, i.e., the water column of the open sea, provides habitat to marine fauna, including fish, reptiles and marine mammals, and represents the largest marine habitat in the study area by area. Conditions of the pelagic environment are controlled by fluvial runoff and coastal processes, which are described in Sections 8.2 and 8.3. Fluvial influences are also reflected in water quality conditions, which are described in Section 8.4.

Primary production in pelagic environments of the Gulf of Papua is generated from a combination of autotrophic (photosynthetic, i.e., phytoplankton) and heterotrophic (non-photosynthetic, i.e., microbial) sources. While the relative contributions from autotrophic and heterotrophic producers are thought to shift with seasonal changes and other variables, both groups form important base levels of food webs in the gulf (Robertson et al., 1998; McKinnon et al., 2007). Autotrophic production and chlorophyll-a, a surrogate for phytoplankton biomass, levels are typically greater in waters more heavily influenced by fluvial discharges, primarily due to nutrient inputs from the rivers (Davies, 2004; McKinnon et al., 2007). As discussed in Section 8.4.2.2, the survey produced no evidence of higher chlorophyll-a levels at sites closest to the Purari River mouth and therefore most influenced by fluvial discharges, with chlorophyll-a levels below or close to the limit of reporting of 1 µg/L. This likely reflects the low nutrient levels and turbid waters, which limit light penetration and together limit phytoplankton production.

The benthic-pelagic coupling in the Gulf of Papua is strong, with detrital inputs from rivers driving nearshore primary productivity (Robertson et al., 1998). The present study also recorded abundant empty planktonic skeletons in benthic samples along the offshore export pipeline corridor. This detrital material represents an energy source for benthic suspension-feeders and detrivores, which in turn support demersal fish and shellfish (e.g., prawns) of commercial fisheries significance.

8.5.3 Marine Fauna Baseline Characterization

Mobile marine fauna use different habitats during their life cycle, which, for some species, may include demersal and pelagic life stages, using freshwater, estuarine and marine environments or migrating over large distances and a variety of marine habitats. Fish, marine mammals, reptiles and crustaceans are therefore characterized in terms of the study area rather than by Project sector, as many species are expected to occur across multiple sectors. Benthic macroinvertebrates are considered in separate sectors of the study area, since they are considered to be more sedentary.

8.5.3.1 Benthic Macroinvertebrates

Orokolo Bay

A total of 3,742 individuals from 216 morphospecies were identified in sediment samples from Orokolo Bay. Benthic assemblages were numerically dominated by:

- Polychaete worms (82 taxa, 1,295 individuals).
- Decapod crustaceans (24 taxa, 1,390 individuals).
- Amphipod crustaceans (13 taxa, 255 individuals).

Plate 8.19 shows examples of these taxa.

Common and widespread groups included decapod crustaceans (the yabby (*Callianassa* sp.) and crab (*Xenophthalmus* sp.)), polychaete worms (from the genera *Sternaspis*, *Terebellides* and

Paraprionospio and the species *Prionospio ehlersi*), and Ampeliscidae amphipods. One crab species (*Xenophthalmus* sp.) accounted for 31% of all benthic fauna. Only single individuals were recorded for 67 of the 216 morphospecies observed. As shown in Figure 8.22, site M45, which was closest to the Purari River mouth and had the highest proportion of sand (see Figure 8.19), had the lowest species richness and lowest abundance of benthic fauna. The depauperate benthic assemblages in this area are likely due to multiple natural stressors, including low and temporally variable salinity, and the physical disturbance and remobilization of bed sediments by waves and fluvial discharges.

Plate 8.19 – Examples of Numerically Dominant Taxa

Polychaete Worm

Decapod (free swimming larval stage)

Amphipod

Photos: BMT WBM.

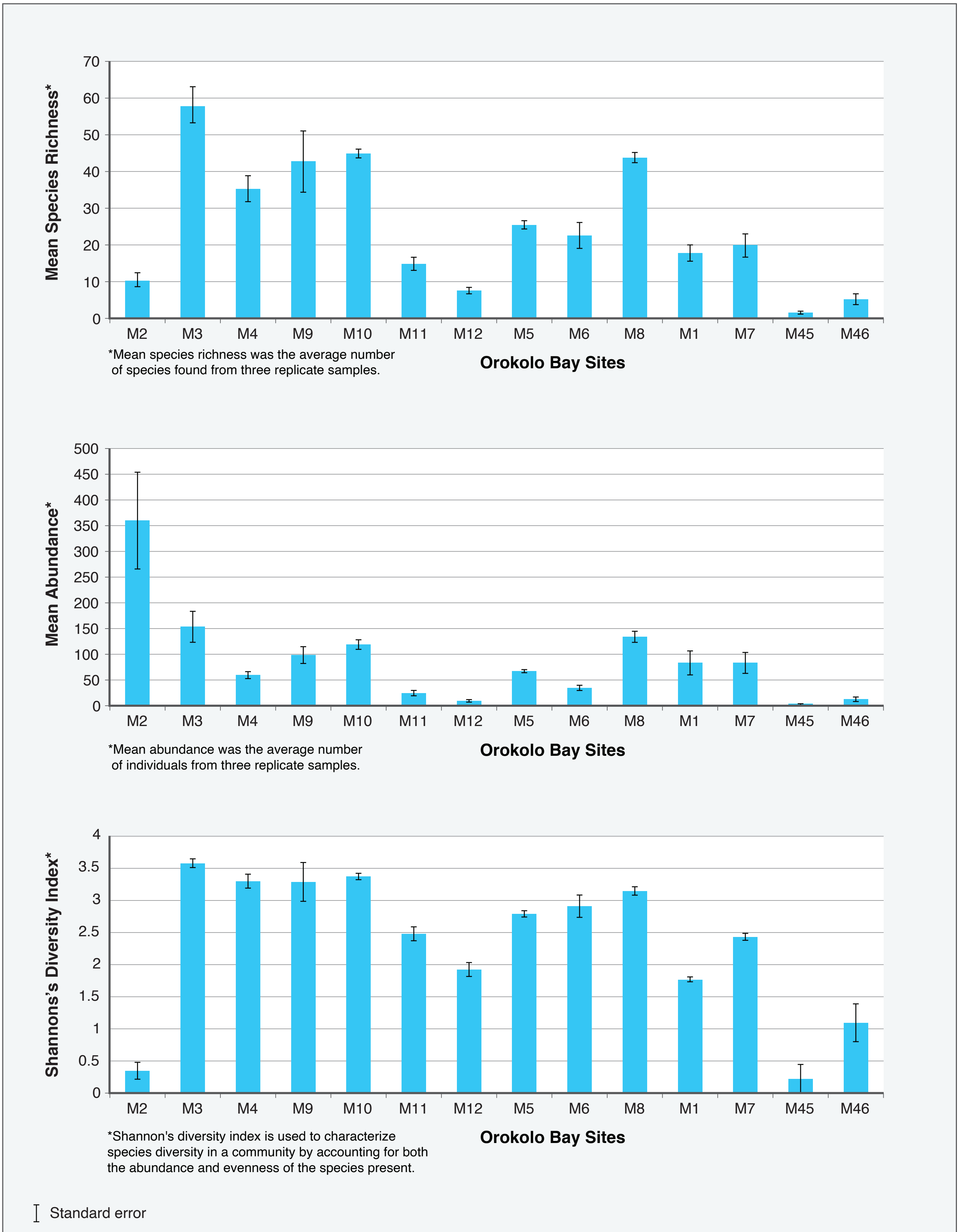
Offshore Export Pipeline Corridor

A total of 181 morphospecies of benthic infauna was identified, with polychaete worms and crustaceans (i.e., isopods, amphipods, shrimps and crabs) being the most abundant species. Previous surveys identified 137 species along the PNG LNG Gas Pipeline (CNS, 2008b).

OROKOLO BAY BENTHIC MACROINVERTEBRATE COMMUNITY METRICS

Papua LNG Project I Environmental Impact Statement

FIGURE 8.22



Species richness, diversity and abundance was highest at one site west of Yule Island, where the sediment was predominantly sand with shell grit, which may explain the differences in benthic assemblages at this site (i.e., potential species preference for this habitat type). Similar to Orokolo Bay, the majority of species were observed in low abundance, with less than five individuals for 67% of species recorded. Just three taxa were widespread and abundant; heart urchins (7.7% of the catch), the amphipod *Cheiriphotis* sp. 1 (5% of the catch) and the polychaete worm *Paraprionospio* sp. (3% of the catch).

A sparse cover of epibenthic macrofauna (i.e., animals living on top of the seabed) was observed along the offshore export pipeline corridor, with video footage recording burrowing gobies, crinoids, sponges, sea pens, cerianthid anemones and polychaete worms.

Caution Bay

No sediment samples were collected in Caution Bay during the 2016 and 2017 surveys, due to the risk from unexploded ordnances.

Sampling of benthic infauna undertaken for the PNG LNG project identified 68 morphospecies in Caution Bay (CNS, 2008a). The majority of these were crustaceans and polychaetes, with lesser numbers of gastropods, bivalves and echinoderms. While the taxa numbers differed across samples, polychaete worms and crustaceans were numerically dominant in all samples.

8.5.3.2 Fish

Much of the information on the structure and characteristics of fish and shellfish assemblages of the Gulf of Papua is based on commercial fishing data, including by-catch. Part 12 of Volume 2 identifies that the following species numerically dominate the bycatch of prawn trawls from the Gulf of Papua (Gulf Province), Orangeria Bay (Milne Bay Province) and Torres Strait (Western Province):

- Clupeidae (sardines and herrings) (20% of total fish catch).
- Leiognathidae (ponyfishes) (15% of total fish catch).
- Engraulidae (anchovies) (10% of total fish catch).
- Lutjanidae (snappers) (8% of total fish catch).
- Mullidae (goatfishes) (4% of total fish catch).

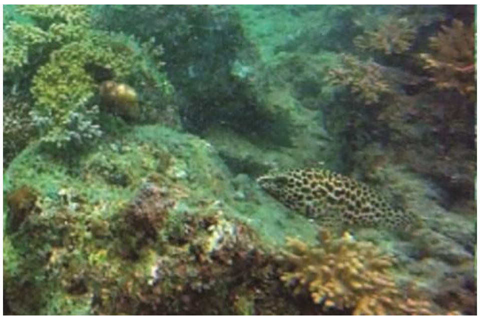
Studies undertaken near the Purari River delta identified 143 fish species from 58 families (Haines, 1979). Gulf fish assemblages can vary greatly both spatially and temporally. Historical studies report higher numbers of ariids (catfishes), sciaenids (croakers), polynemids (threadfins), engraulids (anchovies) and synodontids (lizardfishes) in the west of Orokolo Bay, while the east was dominated by leiognathids (ponyfishes), theraponids (grunters), carangids (trevallies), synodontids, priacanthids (bigeyes) and mullids (goatfishes) (Kailola & Wilson, 1978, in Watson, 1984). This was attributed to habitat conditions, with areas in the west having a muddier substrate and being more strongly influenced by fluvial inputs than areas in the east.

Studies in Caution Bay identified fish from 14 predominantly reef fish families, with Pomacentrids (damselfishes) accounting for more than half of all fish observations (CNS, 2008a). An absence of larger fish such as snappers, emperors and sharks has also been previously noted, with observations of mainly small-bodied fish less than 10 cm long recorded, which may have been due to fishing pressure in the area (CNS, 2008a).

Fish surveys conducted at three reef sites in Caution Bay in January 2017 are described in Part 12 of Volume 2. These surveys identified 42 species, with Chaetodontids (butterflyfishes), Pomacentrids (damselfishes) and Labrids (wrasses) accounting for over half of the species observed (Figure 8.23 and Plate 8.20). More, larger-bodied species were identified in these surveys than in the CNS (2008a) studies, with species of Carangids (trevallies), Lutjanids (snappers), Serranids (groupers and rockcods), Acanthurids (surgeonfishes) and Caesionids (fusiliers) recorded (Plate 8.21). This is likely due to the different survey method adopted for the present study, which used baited remote underwater video stations to survey fishes rather than visual observations by divers. This survey technique favors identification of larger predatory fish, which are attracted to the baited station but evade divers (Kulbicki, 1998).

Plate 8.20 – Examples of Reef Fish

Bird-wire cod (*Epinephelus merra*)

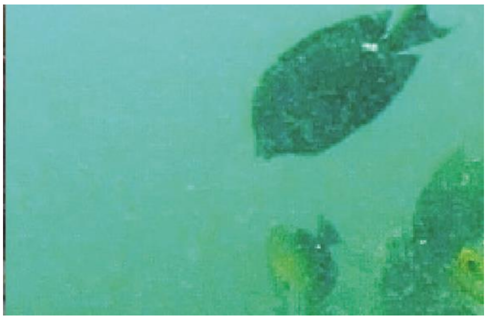


Saddled butterflyfish (*Chaetodon ephippium*)

Moorish idol (*Zanculs cornutus*)

Dot-dash goatfish (*Purapeneus barberinus*)

Surgeonfishes (Acanthuridae)



Brown-barred rock cod (*Cephalopholis boenak*) and doublebanded soapfish (*Diploprion bifasciatum*)

Photos: BMT WBM.

NUMBER OF FISH SPECIES RECORDED PER FAMILY IN CAUTION BAY

Papua LNG Project | Environmental Impact Statement

FIGURE 8.23

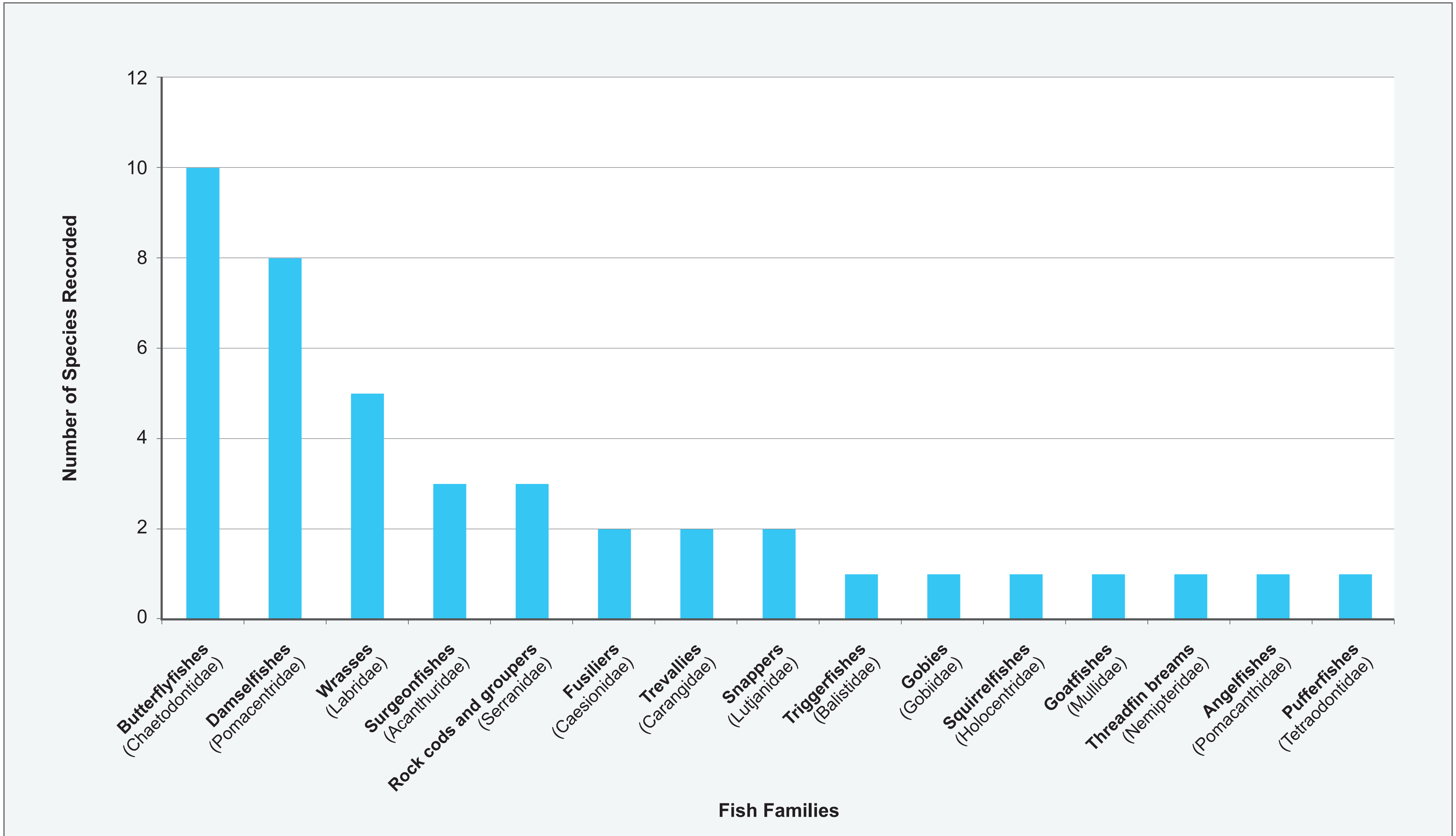


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Plate 8.21 – Examples of Larger-bodied Fish (Bigtail Fusiliers, *Pterocaesio marri*) Observed in Caution Bay

Photo: BMT WBM.

Several species of elasmobranchs, a subclass of cartilaginous fish with five to seven pairs of gills, which includes many shark and ray species, are considered likely to occur in the study area, including:

- Two sawfish species (*Anoxypristis cuspidata* and *Pristis pristis*).
- Seven shark species (*Carcharhinus leucas, C. macloti, Glyphis garricki, G. glyphis, Hemiscyllium hallstromi, Rhizoprionodon acutus* and *Eusphyra blochii*).
- Five ray species (*Glaucostegus typus, Aetobatus narinari, Manta birostris, M. alfredi* and *Mobula eregoodootenkee).*

As further described in Part 12 of Volume 2, many of these species are considered to be sensitive species (Section 8.5.4.1). Table 8.1 summarizes information on threatened or important marine fauna and the likelihood of their occurrence in the study area.

8.5.3.3 Marine Mammals and Reptiles

Marine mammals, including whales, dolphins and marine reptiles such as sea turtles, crocodiles and sea snakes, potentially occur in the study area. Dugongs are not known to occur in the study area, although some suitable foraging habitat may exist in Caution Bay, particularly to the north where sparse beds of the seagrass *Halophila* spp. are present. Further detail is provided in Part 12 of Volume 2.

Seven dolphin species are known to or are likely to occur in the study area, and these include two threatened species, the Australian snubfin (*Orcaella heinsohni*) and Australian humpback dolphin (*Sousa sahulensis*), as described in Table 8.1. Whales are not often reported in the Gulf of Papua (CNS, 2008b).

Six turtle species are known to occur in PNG waters and are all considered to potentially be present in the study area. In particular, the coral reefs and seagrass meadows of Caution Bay may provide sea turtle foraging habitat. Five of these six species are considered threatened (Table 8.1). No major turtle nesting sites are known to occur in the Gulf of Papua; however, low-density nesting of green turtles (*Chelonia mydas*) has been reported to occur along the beaches

Table 8.1 – Sensitive Marine Fauna Potentially Present in the Study Area

Group	Species Name	Common Name	IUCN Listing*	CITES Listing[#]	Other	Habitat Used	Orokolo Bay	Offshore Export Pipeline Corridor	Caution Bay
Sawfish (Pristidae)	*Pristis pristis*	Largetooth sawfish	CR	I	Migratory	Coastal waters alongside mangrove-dominated coastlines Coastal waters near large river mouths	Likely	Possible	Unlikely
	Pristis zijsron	Green sawfish	CR	I	Migratory	Shallow coastal waters near large river mouths	Possible	Unlikely	Unlikely
	Anoxypristis cuspidata	Narrow sawfish	EN	I	Migratory	Coastal waters near large river mouths	Known	Possible	Unlikely
Requiem sharks (Carcharhinidae)	*Glyphis glyphis*	Speartooth shark	EN	-	-	Coastal waters near large river mouths	Likely	Unlikely	Unlikely
	Glyphis garricki	Northern river shark	CR		-	Coastal waters near large river mouths	Possible	Unlikely	Unlikely
	Carcharhinus leucas	Bull shark	NT	-	-	Coastal waters to the edge of the continental shelf	Likely	Likely	Likely
	Carcharhinus macloti	Hardnose shark	NT	-	-	Coastal waters to the edge of the continental shelf	Likely	Likely	Known
Hammerhead sharks (Sphyrnidae)	*Eusphyra blochii*	Winghead shark	EN	-	-	Coastal waters to the edge of the continental shelf	Known	Likely	Likely
Bamboo sharks (Hemiscyllidae)	*Hemiscyllium hallstromi*	Papuan epaulette shark	V	-	Endemic	Coastal waters near coral reefs and seagrass meadows	Unlikely	Unlikely	Likely
Giant guitarfish (Glaucostegidae)	*Glaucostegus typus*	Giant shovelnose ray	V	-	-	Coastal waters to the edge of the continental shelf	Likely	Unlikely	Likely
Eagle rays (Aetobatidae)	*Aetobatus narinari*	Spotted eagle ray	NT	-	-	Coastal waters, especially near coral reefs	Likely	Possible	Likely
Whiptail stingrays (Dasyatidae)	*Pastinachus sephen*	Cowtail ray	NT	-	-	Coastal waters, especially near coral reefs	Likely	Possible	Likely

Table 8.1 – Sensitive Marine Fauna Potentially Present in the Study Area (cont'd)

Group	Species Name	Common Name	IUCN Listing*	CITES Listing[#]	Other	Habitat Used	Orokolo Bay	Offshore Export Pipeline Corridor	Caution Bay
Rays (mantas and mobulas)	*Manta birostris*	Giant manta ray	V	II	Migratory	Pelagic waters	Unlikely	Possible	Unlikely
	Manta alfredi	Reef manta ray	V	II	Migratory	Nearshore to pelagic waters	Possible	Possible	Likely
	Mobula eregoodootenkee	Pygmy devilray	NT	II	Migratory	Nearshore to pelagic waters	Possible	Possible	Possible
Mackerels (Scombridae)	*Scomberomorus multiradiatus*	Papuan seerfish	-	-	Restricted-range	Coastal waters to the edge of the continental shelf	Known	Likely	Likely
	Scomberomorus commerson	Narrow-barred Spanish mackerel	NT	-	Migratory		Likely	Likely	Likely
Serranidae (groupers and rockcods)	*Epinephelus fuscoguttatus*	Brown marbled grouper	V	-	-	Coastal waters near coral reefs and seagrass meadows	Likely	Possible	Likely
Sea cucumbers (Holothuridae)	*Actinopyga echinites*	Deepwater redfish	V	-	-	Coastal waters, estuaries, reef flats, seagrass meadows	Known	Unlikely	Known
	Actinopyga mauritana	Surf redfish	V	-	-				
	Actinopyga miliaris	Hairy blackfish	V	-	-				
	Holothuria fuscogilva	White teatfish	V	-	-				
	Holothuria lessoni	Golden sandfish	EN	-	-				
	Holothuria nobilis	Black teatfish	EN	-	-				
	Holothuria scabra	Sandfish	EN	-	-				
	Stichopus herrmanni	Curryfish	V	-	-				
	Thelenota ananas	Prickly redfish	EN	-	-				

Table 8.1 – Sensitive Marine Fauna Potentially Present in the Study Area (cont'd)

Group	Species Name	Common Name	IUCN Listing*	CITES Listing#	Other	Habitat Used	Orokolo Bay	Offshore Export Pipeline Corridor	Caution Bay
Rock Lobsters (Paniluridae)	*Panulirus ornatus*	Ornate rock lobster	-	-	Migratory/ congregatory	Usually occur in shallow waters (less than 8 m deep) near the coast Migration in waters 40 to 80 m deep through the northern gulf to Yule Island Spawning near Yule Island	Possible	Known	Likely
Dugong (Dugongidae)	*Dugong dugon*	Dugong	V	I	Migratory Protected (*Fauna (Protection and Control) Act 1966)*	Coastal waters near seagrass meadows	Unlikely	Unlikely	Possible
Dolphins (Delphinidae)	*Tursiops aduncus*	Indo-Pacific bottlenose dolphin	-	II	Migratory	Pelagic waters	Likely	Likely	Likely
	Tursiops truncatus	Common bottlenose dolphin	-	II	Migratory	Pelagic waters	Likely	Likely	Likely
	Delphinus delphis	Short-beaked common dolphin	-	II	Migratory	Pelagic waters	Likely	Likely	Likely
	Stenella longirostris	Spinner dolphin	-	II	Migratory	Pelagic waters	Likely	Likely	Likely
	Stenella attenuata	Pantropical spotted dolphin	-	II	Migratory	Pelagic waters	Likely	Likely	Likely

Table 8.1 – Sensitive Marine Fauna Potentially Present in the Study Area (cont'd)

Group	Species Name	Common Name	IUCN Listing*	CITES Listing#	Other	Habitat Used	Orokolo Bay	Offshore Export Pipeline Corridor	Caution Bay
Dolphins (Delphinidae) (cont'd)	*Orcaella heinsohni*	Australian snubfin dolphin	V	I	Migratory	Coastal waters near large river mouths Coastal waters near seagrass meadows	Likely	Unlikely	Likely
	Sousa sahulensis (as S. chinensis)	Australian humpback dolphin	V	I	Migratory	Coastal waters near large river mouths	Likely	Unlikely	Likely
Sea Turtles (Cheloniidae and Dermochelyidae)	*Chelonia mydas*	Green turtle	EN	I	Migratory	Coastal waters near seagrass meadows Low-gradient sandy beaches	Possible	Likely	Likely
	Eretmochelys imbricata	Hawksbill turtle	CR	I	Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
	Caretta caretta	Loggerhead turtle	V	I	Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
	Dermochelys coriacea	Leatherback turtle	CR (West Pacific Ocean subpopulation)	I	Migratory Protected (*Fauna (Protection and Control) Act 1966)*	Pelagic waters	Unlikely	Possible	Unlikely

Table 8.1 – Sensitive Marine Fauna Potentially Present in the Study Area (cont'd)

Group	Species Name	Common Name	IUCN Listing*	CITES Listing#	Other	Habitat Used	Orokolo Bay	Offshore Export Pipeline Corridor	Caution Bay
Sea Turtles (Cheloniidae and Dermochelyidae) (cont'd)	*Lepidochelys olivacea*	Olive ridley turtle	V	II	Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
	Natator depressus	Flatback turtle	-	I	Migratory	Coastal waters near coral reefs and seagrass meadows	Possible	Likely	Likely
Elapid Snakes (Elapidae)	*Laticauda guineai*	Guinea's sea krait	NT	-	Endemic	Coastal waters near coral reefs	Does not occur	Possible	Likely
Water Snakes (Homolopsidae)	*Cantoria annulata*	Banded water snake	-	-	Restricted-range	Coastal waters near mangroves and nipa palm wetlands	Possible	Unlikely	Unlikely
Crocodiles (Crocodylidae)	*Crocodylus porosus*	Saltwater crocodile	-	II	Migratory	Coastal waters near large river mouths	Known	Unlikely	Possible

*International Union for Conservation of Nature (IUCN) where CR – critically endangered, EN – Endangered, V – Vulnerable, NT – Near Threatened, LC – least concern. Based on the 2018 IUCN Red List.

Convention on the International Trade in Endangered Species (CITES) of Wild Fauna and Flora where I refers to CITES Appendix I (species threatened with extinction); II refers to CITES Appendix II (species in which trade must be controlled).

in Kerema Bay, located approximately 50 km to the east of Orokolo Bay. Other sandy beaches in the north of the gulf also possibly support turtle nesting.

Village surveys undertaken at Orokolo Bay in 2016 for the Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2) found that marine turtles are encountered only infrequently, and no reports of them nesting at Orokolo Bay existed. CEPA (2015) reports a green turtle aggregation site around Cape Suckling north of Caution Bay, which overlaps with part of the offshore export pipeline corridor (Section 8.5.4.2).

Twenty-three sea snake species are known to occur in the waters of Papua New Guinea of which two are considered threatened, the banded watersnake (*Cantoria annulata)* and Guinea's sea krait (*Laticauda guineai*) (see Table 8.1). A small-banded sea krait (*Laticauda* sp.*)* was observed along the offshore export pipeline corridor during the 2016 southeast trade wind season field survey. Sea snakes are considered likely to occur in the study area, both in nearshore and offshore waters.

Saltwater crocodiles *(Crocodylus porosus*) are known to occur in the Purari River, with one observed in the Purari River during the northwest monsoon season survey (Plate 8.22). They are considered likely to be found in highest abundance in the nearshore, wetland and riverine environments in the study area.

Plate 8.22 – Saltwater Crocodile (*Crocodylus porosus*) in the Purari River

Photo: TEP PNG.

8.5.3.4 Crustaceans

In the Gulf of Papua, banana prawns (*Fenneropenaeus merguiensis* and *F. indicus*), black tiger prawns (*Penaeus monodon* and *P. semisculcatus*) and endeavor prawns (*Metapenaeus ensis, M. endeavouri* and *M. demani*) inhabit coastal waters with muddy and sandy bottoms. Ornate rock lobster (*Panulirus ornatus*) are also found in the gulf, migrating annually from northern Torres Strait to the Gulf of Papua, to spawning grounds offshore from Yule Island. Both banana prawn species and the ornate rock lobster are of important commercial or artisanal value and are discussed in more detail in Section 8.6.

8.5.4 Sensitive Species, Ecosystems and Habitat Features

8.5.4.1 Sensitive Species

Table 8.1 presents 45 sensitive marine fauna species potentially occurring in the study area, sets out their likelihood of occurrence and categorizes each under the following:

- Species listed under the *Fauna (Protection and Control) Act 1966*.
- Species trade-restricted under CITES or the *International Trade (Fauna and Flora) Act 1979*.
- Species with a threatened status under the IUCN Red List of Threatened Species.
- Endemic or restricted-range species.
- Migratory and congregatory species.

Alien and native invasive species are not considered sensitive fauna, even when they occur in one of the above categories. This reflects the negative impact such species have on the ecosystem.

Further details on these categories and the process of classifying species are provided in Part 12 of Volume 2. The study area is expected to support 35 threatened species. These consist of the following, which are grouped based on the threatened status on the International Union for the Conservation of Nature (IUCN) Red List:[2]

- Five species listed as Critically Endangered on the IUCN Red List, two of which are likely to occur in part of the study area while three may possibly occur. These include sea turtles and species of elasmobranchs (i.e., cartilaginous fish), such as sharks, rays and sawfish.
- Eight species listed as Endangered, six of which are known to occur in the study area and two of which are likely to occur. These include species of elasmobranchs, sea turtles and sea cucumbers.
- Fifteen species listed as Vulnerable, five of which are known to occur in the study area, eight of which are likely to occur and two of which may possibly occur. These include species of elasmobranchs, sea turtles, sea cucumbers, dugong and dolphins.
- Seven listed as Near Threatened, one of which is known to occur in the study area, five of which are likely to occur and one of which may possibly occur. These include species of elasmobranchs, stingrays, sea turtles, fish and sea krait.

The Vulnerable listed dugong (*Dugong dugon*) and the Critically Endangered leatherback turtle (*Dermochelys coriacea*) are also listed as protected species under the PNG *Fauna (Protection and Control) Act 1966.*

The remaining 10 species listed in Table 8.1, while not listed as threatened on the IUCN Red List, are sensitive, as they are endemic species, have a restricted range or a migratory or congregatory status, or are restricted from trade under CITES or the *International Trade (Fauna and Flora) Act 1979.*

2 The following changes have been made to the IUCN rankings of recorded or potentially occurring species since undertaking the marine biodiversity baseline study: The orange-spotted grouper (*Epinephelus coioides*) has had its status downgraded from Near Threatened to Least Concern; the brown marbled grouper (*Epinephelus fuscoguttatus*) and Australian snubfin dolphin (*Orcaella heinsohni*) have had their status upgraded from Near Threatened to Vulnerable; and the cowtail ray (*Pastinachus sephen*) has had its status upgraded from Not Evaluated Deficient to Near Threatened. There are no changes to nationally Protected status.

8.5.4.2 Sensitive Ecosystems and Habitat Features

As described in Section 8.5.2, the study area supports a range of marine habitat types, which include important areas for the spawning, aggregation and migration of marine fauna, areas that provide habitat for a high diversity of marine species or particular threatened species, or areas that may promote species endemism. Such areas are considered to be sensitive. Marine habitats found in the study area include:

- Coral reefs.
- Ornate rock lobster migratory path (northern gulf between Purari River and Yule Island, between 40 and 80 m deep).
- Ornate rock lobster (*Panulirus ornatus)* spawning ground (Yule Island).
- Green turtle (*Chelonia mydas*) aggregation site (Cape Suckling).
- Seagrass meadows (Caution Bay).
- Highly turbid waters adjacent to the Purari and Vailala rivers.
- Turtle nesting beaches.
- Soft sediment benthic substrate, including sand, silts and mud.
- Rocky reefs.

The sensitivity of these habitat types is categorized in Table 8.2, based on their vulnerability and irreplaceability. The methods and criteria used in this assessment are further described in Part 12 of Volume 2[3].

Table 8.2 – Sensitivity Rating of Marine Habitats

Marine Habitat	Sensitivity Rating	Comments/Applicable Criteria
Coral reefs	High	Potentially supports coral species with extreme vulnerability. Provides habitat used by non-coral species with moderate, high and extreme vulnerability, although not considered to be critical to the survival or life cycle functions of these species. Due to uncertainty regarding the presence of coral species with extreme vulnerability, the overall sensitivity rating is high rather than extreme.
Panulirus ornatus migratory path	High	Area in the migration route for migratory species (*P. ornatus*) that occurs only in the Gulf of Papua and Southeast Papua New Guinea ecoregions.
P. ornatus spawning ground	High	Area in the spawning ground for migratory species (*P. ornatus*) that occurs only in the Gulf of Papua and Southeast Papua New Guinea ecoregions.
Chelonia mydas aggregation site	High	Area used by congregatory species (*C. mydas*) that is of extreme vulnerability but is represented in other parts of the ecoregions of the study area and surrounds.

3 Sensitivity is redefined in Chapter 12 consistent with ratings in Chapter 3. The different rating terminology used in baseline reflects the approach at the time the baseline was undertaken.

Table 8.2 – Sensitivity Rating of Marine Habitats (cont'd)

Marine Habitat	Sensitivity Rating	Comments/Applicable Criteria
Seagrass meadows	Moderate	Supports seagrass species (including *Enhalus acoroides*, which has a decreasing global population) with moderate vulnerability. Provides habitat used by non-seagrass species with moderate, high and extreme vulnerability, although not considered critical to the survival or life cycle functions of these species.
Highly turbid waters adjacent to large rivers	Moderate	Provides primary feeding habitat for species with high (*O. heinsohni*, *S. sahulensis*) and extreme (*G. glyphis*) vulnerability.
Turtle nesting beaches	Moderate	Potentially provides habitat important to life-cycle functions of a species with moderate, high or extreme vulnerability (*C. mydas*). Due to the uncertainty regarding the use of specific locations for nesting, the overall rating for all possible nesting beaches is moderate rather than high or extreme.
Soft sediment benthic substrate	Low	Habitat type does not provide suitable habitat for species of moderate, high or extreme vulnerability and is not considered to be unique.
Rocky reefs	Low	Habitat type does not support specific life-cycle functions of species with moderate, high or extreme vulnerability and is not considered to be unique.

As shown in Table 8.2, some marine habitats in the study area are considered to be of moderate to high sensitivity, due to their intrinsic value or support of threatened species. These more sensitive environments of the study area include the coral reefs and seagrass meadows in Caution Bay, the highly turbid waters adjacent to large rivers in Orokolo Bay the ornate rock lobster migratory path and spawning ground that overlaps the offshore export pipeline corridor and the Cape Suckling aggregation area for green turtles that also overlaps the offshore export pipeline corridor (Figure 8.24). Mangrove habitats are considered in Section 7.6.4.

8.5.5 Introduced and Invasive Species

Few invasive or introduced species have been documented in Papua New Guinea; however, many of the reef-associated species of northern Australia and the Great Barrier Reef are common to Papua New Guinea and move between the Torres Strait, the northern Great Barrier Reef and fringing reefs of Papua New Guinea. Current marine pests of northern Australia include the Asian green mussel (*Perna viridis*) and Caribbean tubeworm (*Hydroides sanctaecrucis*). These species have not yet been recorded outside of port areas, but may be present in Port Moresby given shipping movements between it and Cairns.

Acanthaster planci (crown-of-thorns seastar), although native to the Indo-Pacific reefs, can be considered an invasive species when in high abundance and can devastate coral reefs. *A. planci* has been recorded in Bootless Bay, approximately 15 km southeast of Port Moresby. Up to 85% coral mortality has been recorded in the bay, with an average density of 162 *A. planci* per hectare (Pratchett et al., 2009). Given the relatively close proximity of this outbreak to Caution Bay, the area may be prone to a future outbreak.

SENSITIVE MARINE AREAS

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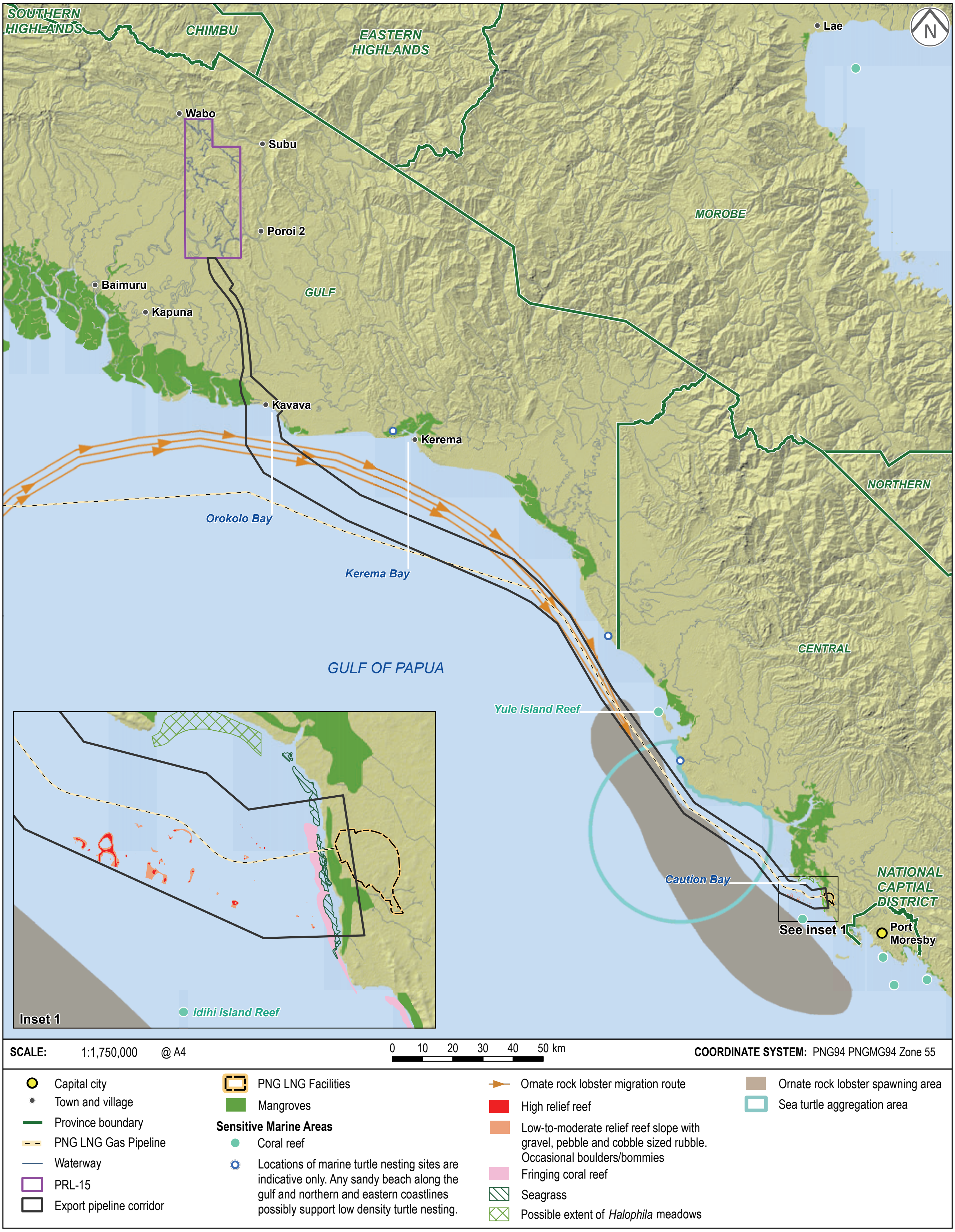
FIGURE 8.24



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8.6 Marine Fisheries and Resources

8.6.1 Regional Context

Two broad types of fisheries exist in Papua New Guinea: the larger-scale offshore operations, which primarily target finfish and shellfish, and the small-scale subsistence and artisanal (i.e., small-scale trade) fisheries that target reef fish and invertebrates found primarily in the coastal zone that extends three nautical miles offshore.

The Gulf of Papua is a biologically diverse area that supports commercial prawn, lobster, finfish and, to a lesser extent, bêche-de-mer (sea cucumber) fisheries, and subsistence and artisanal fisheries.

8.6.2 Marine Fisheries and Resource Baseline Characterization

8.6.2.1 Study Overview

The description of marine fisheries and resources in the study area draws on a wide variety of historical and contemporary literature sources, industry databases, fisheries data and reports, and data collected for the current study from marine, estuarine and freshwater biodiversity (Sections 8.5 and 7.6, respectively), and land and natural resource use surveys (Section 9.8).

8.6.2.2 Commercial Fisheries of the Gulf of Papua

Several commercial fisheries in the Gulf of Papua and Torres Strait are relevant to the offshore export pipeline corridor. These are described in the following sections. Figure 8.25 shows the environmental setting of these commercial fisheries.

Gulf of Papua Prawn Fishery

The Gulf of Papua Prawn Fishery (GOPPF) is one of the largest fisheries in Papua New Guinea, with an estimated value of PGK10 million (approximately US$3 million[4]) (Liviko et al., 2016). The fishery covers 9,600 km^2 and extends from about 60 km southeast of Kerema to 30 km east of the Fly River mouth, from three nautical miles from shore to around the 40 m depth contour offshore (Figure 8.25). The coastal waters zone, extending from the shore to the three nautical mile limit, is reserved for subsistence and artisanal fishing; however, Kompas & Kuk (2009) report that about one third of the total catch from the GOPPF comes from this zone, primarily as a result of resource sharing agreements with customary resource owners.

Twenty prawn species have been identified in the GOPPF, with banana shrimp (*Fenneropenaeus merguiensis*) and the Indian banana prawn (*F. indicus*) being the most valuable species, contributing around 50 to 60% of the prawn catch (Plate 8.23).

The mangrove-lined estuaries of the Kikori and Purari rivers are known to be major nursery areas for juvenile prawns where they reside before migrating to deeper water and, as such, maintenance of the ecosystem processes supporting the prawn life cycle is key to maintaining the commercial fishery (Liviko, 2012). The highest abundance of the target prawn species in the GOPPF occurs between April and September, with the peak in April to May (Liviko, 2012). The fishery is closed from 1 December to 31 March to protect brooding females.

4 Currency conversion undertaken at a rate of PGK1 = US$0.30.

ENVIRONMENTAL SETTING OF MARINE FISHERIES

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FIGURE 8.25

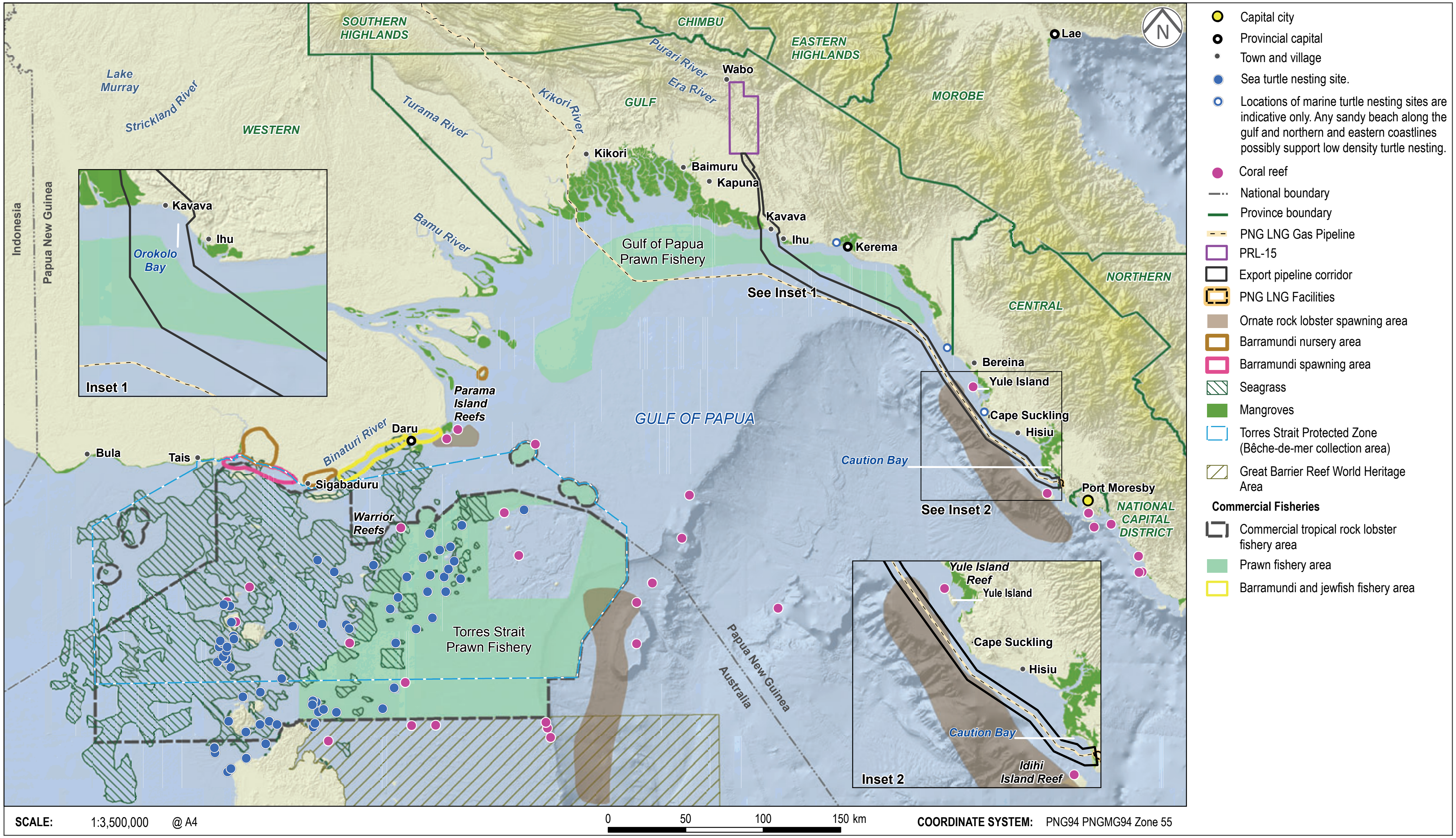

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Plate 8.23 – Banana Prawn Catch

Photo: Raptis, 2015.

The National Fishery Authority divides the GOPPF into eight reporting areas, and catch data is reported on the basis of these areas. Vessel positioning data was used to determine the areas where trawling activities were undertaken, using the speed of vessels to distinguish between trawling and transiting activities. Part 13 of Volume 2 provides further detail. The final dataset included 26,600 vessel positions that represented the location of all vessels in the prawn fishery reporting area over all times for which data was available between 2010 and 2016. The density of vessel position data points was visualized as a heat map with warmer colors representing higher density and therefore greater trawling activity (Figure 8.26).

As shown in Figure 8.26, trawling activity is highest in the inshore areas around Kerema Bay and Freshwater Bay, with other high-activity areas occurring around the Purari River and Cape Blackwood. The offshore export pipeline corridor overlaps an area of relatively low prawn trawling activity in Orokolo Bay and an area of moderate activity in West Kerema Bay, neither of which is considered a high productivity area. Marine transport routes to the Purari River delta will also traverse areas of the GOPPF, potentially traversing high productivity areas of the Cape Blackwood, Purari and Orokolo Bay reporting areas.

Rock Lobster

Papua New Guinea shares the Torres Strait Tropical Rock Lobster Fishery with Australia. The fishery targets the ornate rock lobster (*Panulirus ornatus*) (Plate 8.24) in the Torres Strait Protected Zone (TSPZ), specifically in the Australian jurisdiction (see Figure 8.25), and is estimated to have a total annual export value of about PGK4 million (approximately US$1.2 million[5]) (Jogo, 2015).

Divers are used to collect lobsters from the reefs in the TSPZ, particularly from the Warrior Reefs about 300 km southwest of the Purari River mouth (see Figure 8.25). Daru, 50 km north of the Warrior Reefs, in Western Province, is the main port used in Papua New Guinea for exporting lobsters, which are mostly frozen and sent mainly to the United States.

Lobster catches and the number of active freezer vessels operating have reportedly declined in recent years, with 192 t, amounting to 66% of the total allowable catch, exported in 2014 to 2015 (Williams & Mazur, 2016) and with only one of the seven licensed freezer vessels reportedly active (Jogo, 2015).

5 Currency conversion undertaken at a rate of PGK1 = US$0.30.

DENSITY OF PRAWN TRAWLER POSITIONS IN THE GOPPF REPORTING AREAS

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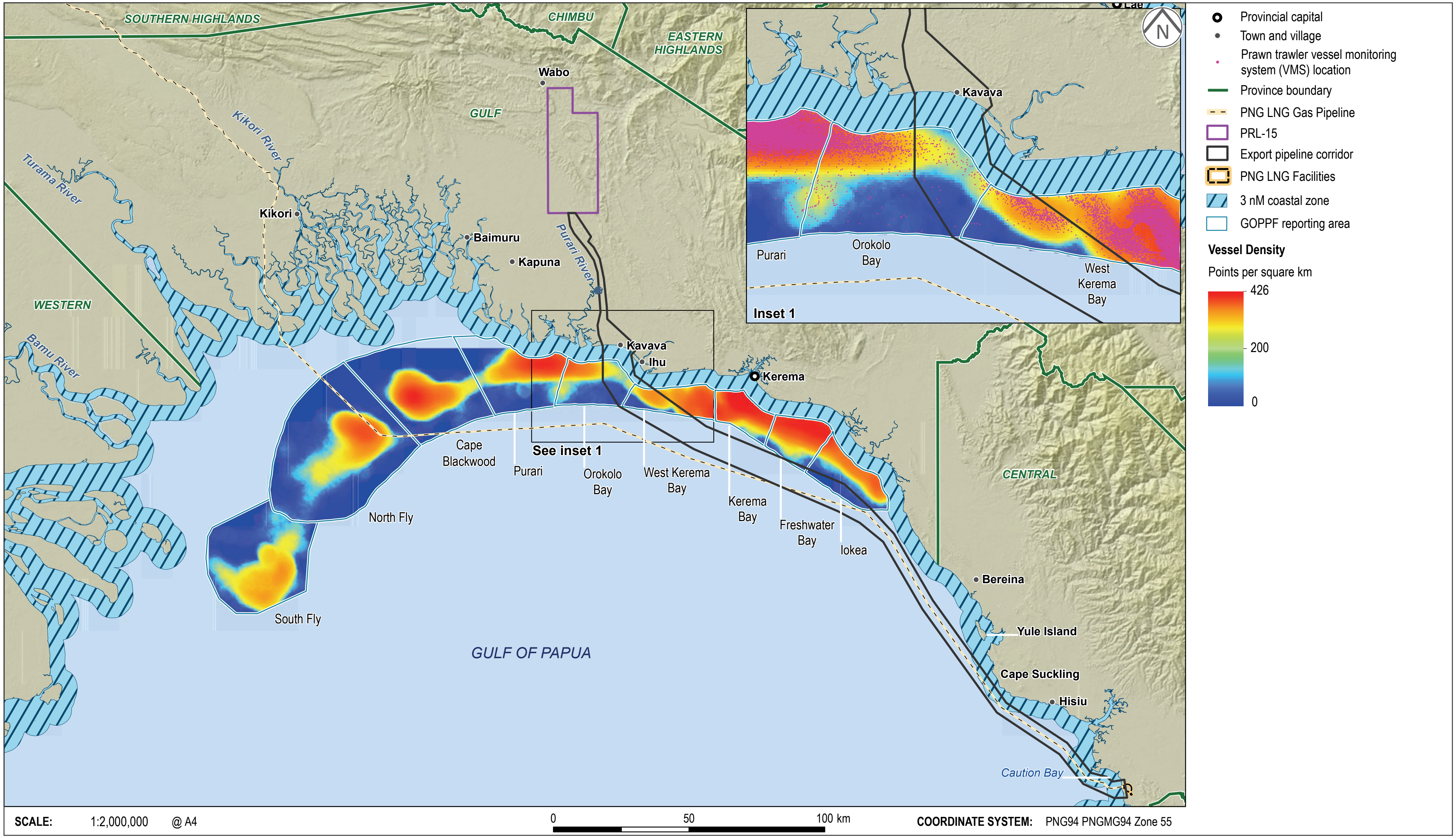
FIGURE 8.26



Color range represents scale of trawler positions per square kilometer with warm colors representing higher density.
Area 9 (South Fly) is established from the present study and Areas 1 - 8 are standard NFA reporting areas.

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Plate 8.24 – Ornate Rock Lobster (*Panulirus ornatus*)

Photo: CSIRO, 2016 (Robert Kerton).

While the focus of the fishery is in the northern Torres Strait, the ornate rock lobster undergoes a migration from this area into the Gulf of Papua (Figure 8.27). Lobsters leave the Torres Strait from early September to late November and walk up to 400 km into the Gulf of Papua to the main spawning site at Yule Island and other reefs throughout Central Province (Moore & MacFarlane, 1984), arriving between late November and early April. Parama Island near the Fly River delta is also a known spawning site. The migrating lobsters from the Torres Strait are thought to move against the prevailing bottom current and to orientate with respect to this current, rather than follow a specific depth contour or substratum type (Moore & MacFarlane, 1984). Migrating lobsters have the potential to intersect with the proposed offshore export pipeline corridor and potential marine transport routes. While Yule Island is located east of the export pipeline corridor, the corridor transects a small area of the spawning area (see Figure 8.25).

The arrival of lobsters at Yule Island and other reefs in the Gulf of Papua is the basis of a seasonal subsistence and artisanal fishery (Section 8.6.2.3). There is mass natural post-spawning mortality of lobsters in the vicinity of Yule Island, and there is no return migration from the Gulf of Papua back into Torres Strait fishery by migrating adults (Dennis et al., 1992).

Little is known about the spawning area southeast of the TSPZ (see Figure 8.25). This area is not thought to form the basis of a targeted fishery. This spawning area may be linked to lobster populations from the Great Barrier Reef rather than those from the Torres Strait. It is also unknown whether spawning lobsters return to the Great Barrier Reef from this spawning area.

Bêche-de-mer

Bêche-de-mer are collected from the Torres Strait, in the TSPZ, in the same area that supports the tropical rock lobster fishery (see Figure 8.25), with the focus of the fishery being the Warrior Reefs, and the coastal zone of Papua New Guinea such as in the Gulf of Papua (i.e., within three nautical miles of the coast; see Figure 8.26). The proposed export pipeline corridor intersects with the coastal zone in Orokolo Bay, near Cape Suckling, and to the northeast and within Caution Bay (see Figure 8.26).

In the TSPZ, the four main bêche-de-mer species of commercial interest are black teatfish *(Holothuria whitmaei)*, prickly redfish *(Thelenota ananas)*, sandfish (*Holothuria scabra*) and white

MIGRATION ROUTE OF THE ORNATE ROCK LOBSTER

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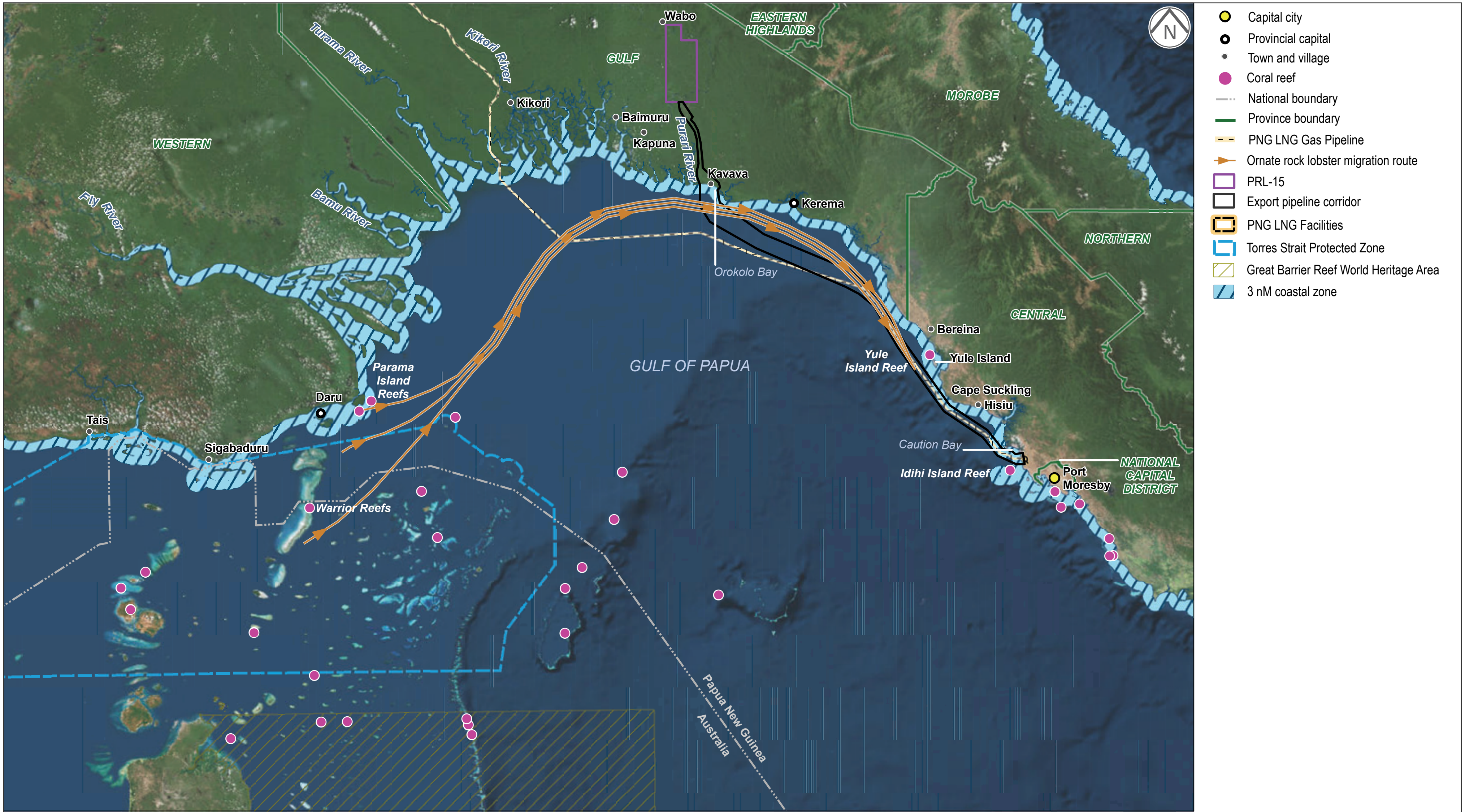
FIGURE 8.27



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teatfish (*Holothuria fuscogilva*). The current degree of participation in the fishery is unclear, but Daru is considered the major port supporting the fishery, with the Warrior Reefs being the focus area for fishing (Lokani et al., 1996; Long et al., 1996) (see Figure 8.25).

In the coastal waters of Papua New Guinea, the total annual bêche-de-mer export is estimated to average around 400 t and to be worth PGK21 million (approximately US$6.3 million[6]), which is almost double the annual average export value of prawns (ADB, 2009). Twenty-nine bêche-de-mer species are known to occur in the coastal waters of Papua New Guinea, with lollyfish (*Holothuria atra*), greenfish (*Stichopus chloronotus*) and amberfish (*Thelenota anax*) the most abundant species. These three species account for nearly 75% of the commercial fishery (Skewes et al., 2006). Milne Bay Province is the main focus of the PNG bêche-de-mer fishery, and it is the most important coastal fishery in that province (Skewes et al., 2006).

A moratorium was placed on the PNG bêche-de-mer fishery in 2009 due to concerns about overfishing; however, exploitation of the fishery continued in some areas. Associated with the fishery concerns are potential negative impacts to mangroves and other coastal forests associated with wood harvesting for bêche-de-mer smoking (Jogo, 2015). The moratorium was lifted on 1 January 2017, with a compulsory closed season from 1 October to 31 March. A catch limit will be allocated to each province in due course. Historical data indicates that the Gulf of Papua contributes relatively small catches to the bêche-de-mer fishery, with a previous total allowable catch of 1 t compared to 140 t for Milne Bay (Kinch et al., 2008). The future status of the commercial bêche-de-mer fishery in the Gulf of Papua is uncertain; but if operating, the fishery would likely focus on the reefs around Caution Bay and Yule Island, rather than to the north of the gulf. These same areas may also be used for subsistence and artisanal bêche-de-mer harvesting.

Barramundi and Jewfish

Barramundi (*Lates calcarifer*) are only found naturally in rivers in the southern part of the country. They are most abundant in rivers with substantial lake and swamp systems, and with extensive estuarine reaches, such as those of the gulf. The species migrates from adult freshwater foraging habitat to coastal spawning grounds. A spawning migration is well documented in the Gulf of Papua whereby fishes from all rivers in the gulf migrate to spawning grounds on the southern coast of Western Province, west of Daru (see Figure 8.25).

The barramundi fishery in the Gulf of Papua was historically one of the largest fisheries in Papua New Guinea, but it declined substantially in the 1990s. This is thought to be a result of overfishing and, for Fly River populations, impacts from mine waste from the Ok Tedi copper mine (Swales et al., 2000; Blaber et al., 2009). The two bases for the barramundi fishery were Daru and Baimuru. The Daru-based fishery exploited the Fly River-Lake Murray area and along the coast from the mouth of the Fly River to the mouth of the Binaturi River west of Daru. The Baimuru-based fishery exploited the northern Gulf of Papua, including the Turama, Kikori, Era and Purari rivers. On-shore freezer facilities were located at Ihu, Baimuru and Kikori.

Today the fishery is based primarily in Western Province (see Figure 8.25) and serviced out of Daru. Wild-caught barramundi are supplemented by jewfish (Sciaenidae) (Busilacchi et al., 2014). The main spawning and breeding grounds between Sigabaduru village and the Papua New Guinea/Irian Jaya border are closed during peak spawning periods from 1 October to 30 November each season. Barramundi are also an important part of the subsistence and artisanal fishery, discussed in Section 8.6.2.3.

6 Currency conversion undertaken at a rate of PGK1 = US$0.30.

Other Commercial Fisheries

A commercial shark fishery that primarily caught hammerhead shark (*Sphyrna lewini*) existed in the Gulf of Papua during the 1970s and 1980s. This fishery is not active today, but sharks are a major component of GOPPF bycatch, and the region supports significant shark populations that are an important resource in subsistence and artisanal fisheries.

Fishing trials for commercially valuable fish species, such as jewfish, snapper and emperors, were conducted in the Gulf of Papua in 2015, but no commercial fishery currently exploits these species.

8.6.2.3 Subsistence and Artisanal Fisheries

Fishing and harvesting of marine and estuarine resources are integral to subsistence lifestyles and cultural identity in most coastal areas of Papua New Guinea. The total volume and economic value of the coastal artisanal (i.e., small-scale trade) fishery is estimated to exceed that of the commercial fisheries (ADB, 2009).

Subsistence and artisanal fishing mostly occurs in the coastal zone, zero to three nautical miles offshore (see Figure 8.26), which is a zone where commercial fishing operations are prohibited. Fishing effort is highly targeted toward maximum yields from the habitats that are available to people in their customary areas and toward seasonal abundance and movements of species. As such, communities located near mangrove-lined estuaries with no coastal reef systems focus their efforts on maximizing yields from the estuarine system. The offshore export pipeline corridor comes within three nautical miles of the coast in Orokolo Bay, near Cape Suckling and to the northeast and within Caution Bay (see Figure 8.26).

Further detail regarding the social and economic value of fishing in the study area is provided in Section 9.8 and the Upstream Land and Natural Resource Baseline Report (Part 18 of Volume 2). The following sections describe the key coastal subsistence and artisanal fisheries in three relevant Project regions.

Orokolo Bay and the Purari River Delta

Community-level surveys undertaken in coastal villages at Orokolo Bay indicate that fishing is important for subsistence but that the primary motivation for fishing was commercial benefit, with direct consumption being a secondary motivation. Household-level surveys; however, showed a low volume of sales and a high volume of household consumption, indicating that most of the catch was consumed rather than sold (Part 18 of Volume 2). The survey results suggest a degree of opportunistic artisanal sale or trade during times of excess fisheries resources and when the occasion exists for cash income.

The predominant practice at Orokolo Bay appears to be one of fishers going throughout the coastal zone with a focus in and around river mouths. This fishing principally occurs during the calm period of November to April, using mainly gill nets and hook-and-line techniques to target elasmobranchs (i.e., sharks, sawfishes and rays), threadfin salmon, beach salmon, croakers and barramundi. In addition, hand-netting for small fishes and prawns is common in shallow areas.

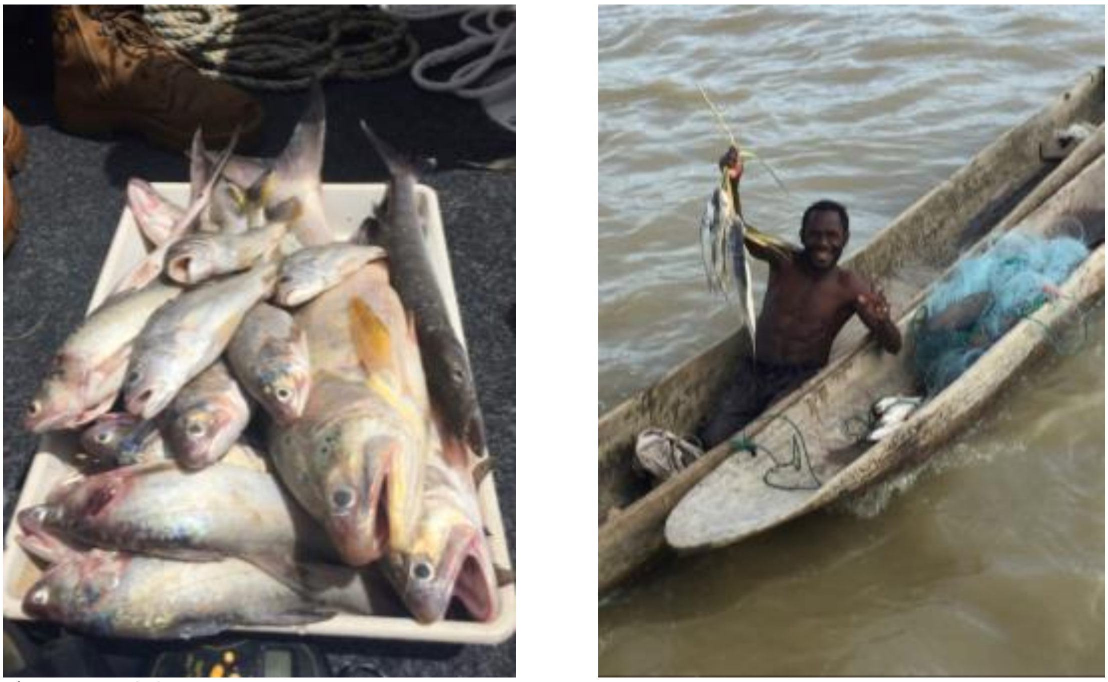
Fishing is limited in Orokolo Bay during the southeast trade wind season from May to October due to strong winds creating hazardous conditions for dugout canoes and banana boats. Household surveys estimate around 400 dugout canoes and 40 dinghies belong to the coastal villages of Aire, Apiope, Akoma/Kairu'u, Harevavo, Herekela and Iuki; however, these numbers do not necessarily reflect the numbers used for fishing (Part 22 of Volume 2). Fishing during the southeast trade wind season is restricted to the Purari River delta and occurs mainly in the smaller tributaries rather than in the main channel. Most fishing grounds are within customary lands in the Purari River delta, although the main channels of the Purari River are openly accessible by local villagers.

Traditional techniques, such as the use of *Derris* root poisoning, woven fish traps and v- and y-shaped scoop nets, are still used. More modern equipment, such as hook and line, and gill nets, are also used. Both powered and unpowered dugout canoes, banana boats and small outrigger canoes are used for fishing activities.

Villagers are also reported to purchase or trade bycatch from the prawn trawlers, the transactions of which represent at least 75% of the total biomass of trawls. This was observed at least once during field surveys (Part 18 of Volume 2).

Household surveys revealed that barramundi, prawns and sharks were the top three fisheries species consumed in Orokolo Bay coastal villages. Threadfin salmon (family Polynemidae) were reported to be seasonally abundant and particularly targeted from April to July (Plate 8.25).

Plate 8.25 – Threadfin Salmon Caught in the Purari River Delta Estuary



Photos: ERIAS Group.

Qualitative observations of subsistence catches at Orokolo Bay coastal villages in 2016 are in general agreement with historical studies of Haines and Stevens (1983) with respect to faunal composition. Elasmobranchs, barramundi, threadfin salmon (family Polynemidae) and mullet (family Mugilidae) were recorded in subsistence catches in marine and river mouth habitats (Plate 8.26). In estuarine reaches, dominant species were black bass (*Lutjanus goldiei)* and emperors (family Lethrinidae); and in the estuarine and lower freshwater zones, several catfish species dominated the catch. Prawns are widespread throughout the system and in some villages are more often consumed than finfish or sharks. These observations are also broadly consistent with previous studies in the nearby Omati-Kikori delta, which found barramundi, threadfin salmon, catfish, black bass, bream, nursery fish, ponyfish, prawns (including the giant river prawn), mudcrab and crocodile in subsistence catches (CNS, 2008c).

Plate 8.26 – Species Observed in Subsistence Fish Catches from the Orokolo Bay Region

Blue threadfin (*Eleutheronema tetradactylum*)

Juvenile sharks (family Carcharhinidae)

Lesser queenfish (*Scomberoides lysan*)

Narrow sawfish (*Anoxypristis cuspidata*)

Dorab wolf herring (*Chirocentrus dorab*)

Winghead shark (*Eusphyra blochii)*

Mackerel (*Scomberomorus* sp.)

Trevally (possibly *Caranx herberi*)

Scaly jewfish (*Nibea squamosa*)

Longfin beach salmon (*Leptobrama pectoralis*)

Photos: Ken Aplin.

Yule Island

The offshore export pipeline corridor overlaps the three nautical mile coastal zone south of Yule Island near Cape Suckling. As described in Section 8.6.2.2, ornate rock lobsters gather at the reefs around Yule Island east of the export pipeline corridor to spawn from November to April. The spawning aggregation results in a seasonal artisanal and subsistence dive fishery around Yule Island, with peak catches from mid-January to mid-February. Historically, lobsters were processed at a facility on Yule Island, with catches of nearly 1 t (whole lobster weight) reported from 1988 and 1989 (Dennis et al., 1992). The current status of the processing facility is unknown; however, the subsistence and artisanal fishery is still considered active today.

Caution Bay

The subsistence and artisanal fisheries in Caution Bay target the fringing, barrier and deep coral reefs; the pelagic environment; seagrass meadows; mangroves habitats; and beaches found throughout the area. A diverse range of equipment is used, including hook-and-line, netting, trapping and spearing techniques, with a predominance of hook-and-line fishing from non-motorized canoes. A variety of resources are targeted, including small fish, such as goatfish (Mullidae), threadfin bream (Nemipteridae) and small emperors (Lethrinidae); large-bodied fish, such as trevallies (Carangidae), mackerel and tuna (Scombridae) and long toms (Belonidae); and invertebrates, such as crabs and snails.

As described in Section 8.5.3.2, fish surveys at coral reef sites in Caution Bay using baited remote underwater video stations identified large-bodied fish species, such as trevallies, snappers (Lutjanidae), groupers and rockcods (Serranidae) and surgeonfish (Acanthuridae). This finding was in contrast to previous studies that reported an absence of these larger fish, with most observations being of small ornamental reef fish less than 10 cm long (CNS, 2008a). An interview with men from Boera village indicated that the outer deep reefs of Caution Bay were the main focus for subsistence fishing, targeting hammerhead sharks, snapper and trevally (Niniga & Madaha, pers. com., 2017).

8.7 Underwater Noise

This section describes the ambient acoustic environment, i.e., underwater noise, of the marine, estuarine and riverine areas relevant to the export pipeline corridor and marine and river transport corridors. A description of the existing underwater acoustic environment has been included in Volume 2 (ESBS Dossier), as the Project will have underwater noise sources such as those associated with marine traffic and transport and with construction activities. An understanding of the existing ambient acoustic conditions therefore forms part of the description of the existing environment and is required for the impact assessment in Chapter 13.

Technical units and terms are used to describe underwater noise levels in this section; hence, a brief explanation of each is provided below:

- Frequency: the rate of oscillation or vibration measured in cycles per second, hertz (Hz), or in kilohertz (kHz) equivalent to 1,000 cycles per second.
- Decibel (dB): used to describe the intensity of sound by comparison to a logarithmic scale. The reference pressure for freshwater and seawater is 1 micropascal (μPa) (compared to 20 μPa for air).
- Sound pressure level: the unit is the pascal (Pa), which is equivalent to a newton per meter squared (N/m^2) and is expressed in terms of decibels with reference to 1 micropascal at 1 meter, expressed as dB re 1 μPa at 1 m, where 're' denotes 'with reference to'.

In this section, noise sources levels are reported as units of dB re 1 μPa at 1 m while sound received levels are reported as units of dB re 1 μPa rms, where rms denotes root mean square. Received level is an imprecise term but is typically used to distinguish received levels from source levels and generally refers to the sound level received by a receptor such as marine fauna. For the baseline characterization, received levels have been calculated at an estimated mid-water depth[7] at each assessment location.

8.7.1 Regional Context

In the Gulf of Papua, underwater noise is predominantly ambient noise, i.e., environmental background noise, and does not have a single source or point (MMS, 2001). This ambient noise includes both natural and anthropogenic noise, which can be continuous or intermittent from both low and high frequencies. Natural variation in background noise can be as much as 20 dB per day. In the Gulf of Papua, ambient noise is expected to be highly variable and to come from a wide variety of sources.

Figure 8.28 shows the ambient noise spectra levels that are generated by natural and anthropogenic (e.g., vessel traffic) noise sources. For example, noise source levels at a frequency of 600 Hz for Beaufort scales[8] 1, 2, 3, 5 and 8 in Figure 8.28 are 46.5, 55.0, 66.0, 73.0 and 81.0 dB re 1 μPa at 1 m, respectively.

Natural sources include physical sources, such as wind, waves, rainfall, thunder and earthquakes, and biological sources, such as marine mammals, fish and macroinvertebrates. Biological sources of underwater noise are expected to be generally intermittent and of short duration, although some sources, such as snapping shrimp, may produce more continuous noise.

Ambient background noise is site-specific; however, in general, the natural background noise levels in the undisturbed ocean vary from around 90 dB re 1 μPa rms to 110 dB re 1 μPa rms, depending on ambient weather conditions (Entrix, 2004). Table 8.3 presents ambient natural underwater noise levels for a range of marine environments.

Anthropogenic underwater noise sources in the Gulf of Papua include both commercial and community vessels; oil and gas exploration activities, such as seismic surveys and sonar systems; and functioning oil terminal platforms, such as the Kumul Marine Terminal. Section 10.5 provides further detail on the coastal and river shipping routes and the types and quantity of commercial vessels in the Gulf of Papua, and in the Purari River and its distributaries.

8.7.2 Baseline Characterization

8.7.2.1 Study Overview

The main natural noise sources in the study area are snapping shrimp, soniferous fish and, to a lesser extent, wind and waves. Barges and community vessels are the main anthropogenic noise sources.

A desktop study assessed the existing underwater acoustic environments of rivers, estuaries, and nearshore and offshore areas in the study area. Seven assessment locations were selected, which included the riverine environment of the upstream onshore Project area in PRL-15, in the

7 Mid-water depth was selected as a representative point to be consistent between ambient underwater noise predictions at each location.
8 The Beaufort Scale relates wind speed to observed conditions at sea and on land on a scale from 0 to 12 for wind speeds from less than 1 knot to greater than 64 knots.

AMBIENT UNDERWATER NOISE SPECTRA LEVELS IN THE MARINE ENVIRONMENT

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FIGURE 8.28

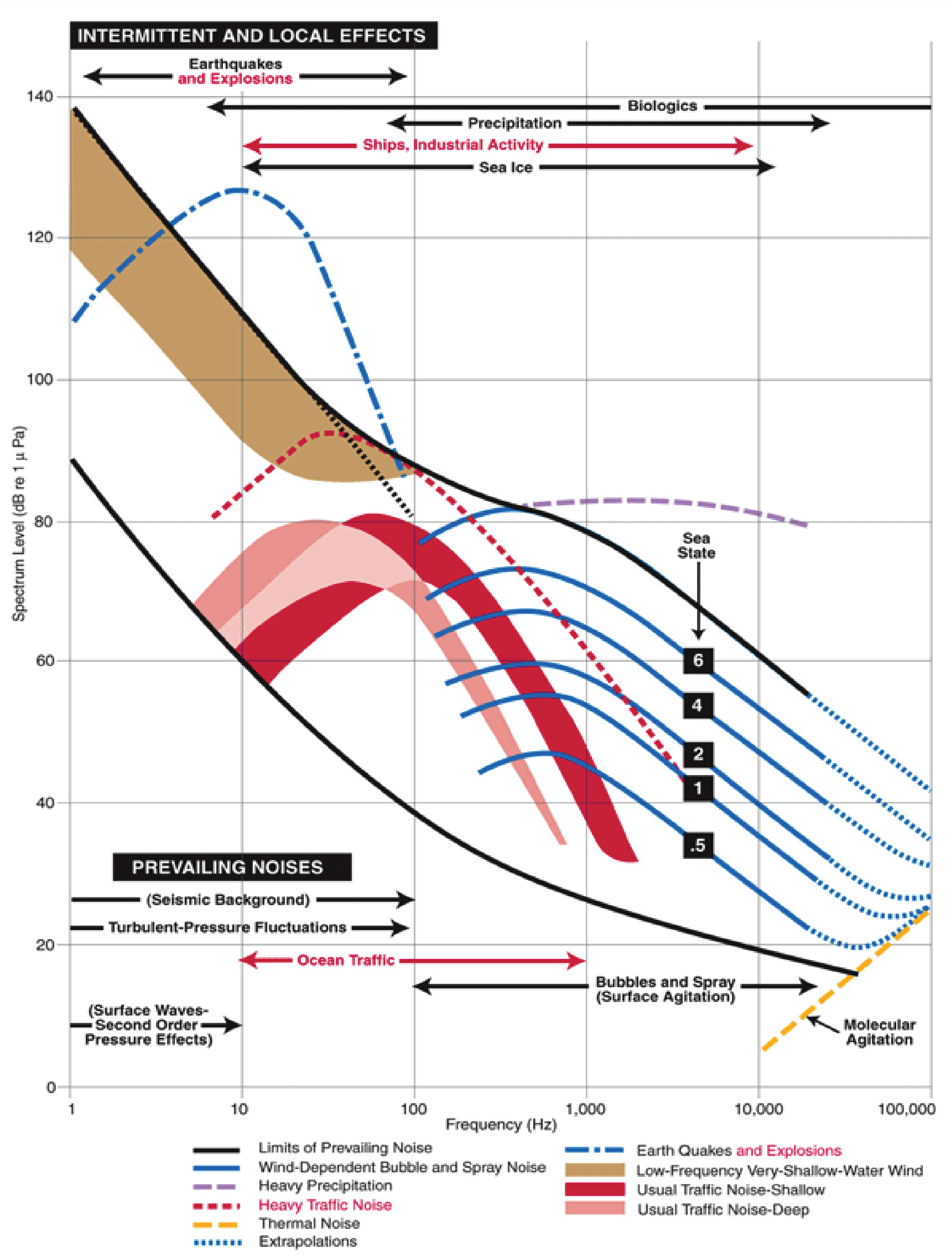

Table 8.3 – Ambient Natural Underwater Noise Levels in the Marine Environment

Location	Broadband Frequency	Broadband Ambient Level	Reference
Undisturbed ocean in general	Not stated	Range 90 to 110 dB re 1 μPa at 1 m.	Entrix (2004)
Timor Sea	Not stated	93 dB re 1 μPa at 1 m. Maximum of 110 dB in Beaufort Scale winds of between 5 and 7.*	McCauley (1998)
North Pacific Ocean	10 to 100 Hz	90 dB re 1 μPa at 1 m.	Baggeroer et al. (2005)
Open ocean (off the coast of central California)	Not stated (Wind Beaufort scale between 3 and 5*)	74 to 100 dB re 1 μPa at 1 m.	Heathershaw et al. (2001)
Open sea	10 to 100 Hz	40 to 100 dB re 1 μPa at 1 m.	Wenz (1962)
Scott Reef (Australia)	Not stated	90 to 100 dB re 1 μPa at 1 m with daily spikes by fish choruses to 120 to 130 dB re 1 μPa at 1 m.	McCauley (2008)
Exposed ocean (i.e., offshore environment without protection from land) (Otway Basin, Bass Strait)	Not stated	90 to 110 dB re 1 μPa.	APPEA (2005)

* The Beaufort Scale relates wind speed to observed conditions at sea and on land on a scale from 0 to 12 for wind speeds from less than 1 to greater than 64 knots.

proposed export pipeline corridor and in the river transport corridor (Figure 8.29). Existing underwater noise is described for the relevant Project components based on a desktop literature study. As such, existing underwater noise levels have been estimated based on known or calculated noise levels from natural and anthropogenic sources such as those listed in Tables 1, 3, 4, 5 and 6 in Attachment 8.1.

Underwater noise transmission is a complex process affected by the location of the sound source, water depth, seabed or riverbed type, bathymetry, water density and temperature, and absorption and refraction of sound energy. These are discussed in more detail in Attachment 8.1. As point source underwater sound energy propagates through the marine environment, it spreads over a larger area and the intensity of the sound energy decreases. This is known as transmission loss (Collins, 2017).

Seafloor conditions have a strong effect on shallow-water ambient noise, with generally higher levels of ambient noise where the seafloor is very reflective and lower where it is absorptive (Urick, 1983). The amount of energy lost into the bottom varies with the bottom composition, the sound frequency, and the striking angle of the sound wave. The total of these losses can vary from as low as 2 dB/bounce to greater than 30 dB/bounce. In general, bottom loss will tend to increase with frequency and with the angle of incidence. Soft bottoms, such as mud, are usually associated with high bottom losses (i.e., 10 to 30 dB/bounce); hard bottoms, such as smooth rock or sand, produce lower losses. The seafloor in the Project area varies from silty muds, (e.g., Orokolo Bay and along most of the export pipeline corridor) to sand and reef (e.g., Caution Bay and near Yule Island) with these areas expected to have high and low bottom loss, respectively.

This study used a basic underwater sound-spreading model to estimate sound levels from anthropogenic sources at each location for a mid-water depth. In all cases, a spherical spreading model (i.e., 20log10[R], where R is the radial distance from the noise source in meters) was used to assess anthropogenic noise generated in the immediate vicinity of the seven assessment

UNDERWATER NOISE DESKTOP ASSESSMENT LOCATIONS

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FIGURE 8.29

SCALE: 1:1,750,000 @ A4

0 10 20 30 40 50 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Capital city
- Town and village
- Province boundary
- PNG LNG Gas Pipeline
- Waterway
- PRL-15
- Export pipeline corridor
- Crater Mountain Wildlife Management Area
- PNG LNG Facilities
- Underwater noise desktop assessment location

locations. Natural noise levels from physical and biological sources were based on background ambient levels reported in the literature, such as those presented in Attachment 8.1.

8.7.2.2 Underwater Noise Desktop Assessment

Table 8.4 summarizes the underwater noise levels for the seven assessment locations, considering the contribution of both natural biological and physical noise sources and anthropogenic noise sources. Underwater noise levels along the offshore export pipeline corridor south of Kerema and Ihu (i.e., assessment locations 2 and 3) are assessed to be notably lower than other locations, ranging from 75 to 127 dB re 1 μPa rms at mid water depth. At these two locations, the ambient noise from natural physical and biological noise sources would include wind, waves and snapping shrimp, with distant shipping and trawlers being the main anthropogenic noise sources.

Table 8.4 – Summary of Underwater Noise Levels and Key Noise Sources at Assessment Locations

Project Area	Assessment Location	Depth (m)	Key Noise Sources	Baseline Characterization Level (dB re 1 μPa rms)
Caution Bay	1 (Caution Bay)	30	Soniferous fish, snapping shrimp, commercial shipping traffic including LNG carriers and tugboats	90 to 161
Offshore export pipeline corridor	2 (South of Kerema)	80	Wind, waves, snapping shrimp, barges and trawlers	75 to 127
	3 (South of Ihu)	50		
Orokolo Bay	4 (Orokolo Bay)	12	Wind, waves, rainfall, soniferous fish, snapping shrimp, marine mammals, barges and community vessels	85 to 163
Purari River delta	5 (Aievi Passage)	6	Rainfall, soniferous fish, marine mammals, barges and community vessels	75 to 175
	6 (Port Romilly)	8		
PRL-15	7 (Purari River)	6	Wind, rainfall, soniferous fish, barges and community vessels	75 to 170

The closer proximity of the other locations to boat and shipping traffic means these locations have higher underwater noise levels, from 75 to 175 dB re 1 μPa rms at mid water depth. Natural physical and biological noise sources would include wind, waves and snapping shrimp, with community vessels, port traffic and transiting barges the main anthropogenic noise sources.

The close proximity of the assessment locations to vessel traffic results in the upper noise levels being higher (i.e., up to 175 dB re 1 μPa rms) than the upper ambient noise levels of up to 110 dB re 1 μPa rms reported in the literature for marine locations elsewhere in the world (see Table 8.3).

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Attachment 8.1
Underwater Noise Desktop Baseline Technical Paper

Papua LNG Project

Underwater Noise Technical Paper

Prepared for: ERIAS Group and Total E&P PNG Limited

Report No. TR 167/2, December 2017

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Executive Summary

Introduction

An underwater noise desktop baseline characterization study was undertaken to assess the existing underwater acoustic environments (soundscapes) of representative rivers, estuaries, nearshore and offshore areas of the Project Area of Influence. Seven underwater noise desktop assessment locations were selected for baseline characterization, which were:

- Assessment Location 1 (Caution Bay): Nearshore approach to Caution Bay.
- Assessment Location 2 (south of Kerema): Offshore marine environment.
- Assessment Location 3 (south of Ihu): Offshore marine environment.
- Assessment Location 4 (Orokolo Bay): Nearshore marine environment.
- Assessment Location 5 (Aievi Passage): Purari Delta estuary.
- Assessment Location 6 (Port Romilly): Pie River estuary.
- Assessment Location 7 (Purari River): Purari River downstream of Herd Base.

Assessment locations 1 through 4 were representative of existing underwater soundscapes along the Project's proposed offshore export pipeline corridor, assessment locations 5 and 6 were representative of shallow-water estuaries of the Project's river transport corridor, and assessment location 7 was representative of the riverine environments of the Project's upstream onshore area.

Study Approach

This report is based on a desktop study of the literature; however, the review did not reveal any underwater noise measurement data for the Gulf of Papua, Purari Delta estuaries or Purari River. Therefore, background ambient noise levels were estimated based on known or calculated noise levels from natural (i.e., physical and biological) sources and anthropogenic sources (e.g., ships).

In the case of anthropogenic noise source levels from shipping and fishing vessels, a list of the types and size of ships known to frequent in the Gulf of Papua, Caution Bay and the Purari River was complied. Based on the key shipping and fishing vessel routes in the Gulf of Papua, the distance from the nearest approach point of a shipping route to each assessment location was determined, and the distances used in sound transmission loss equations (e.g., spherical or cylindrical models) to calculate the received sound levels at the assessment locations. By this means, existing anthropogenic noise levels at the assessment locations could be calculated.

In addition, the literature was examined for background underwater noise measurements in similar tropical water environments and used as comparative analogues, with the aim of confirming average background ambient noise levels estimated for the seven assessment locations selected within the Project's area of influence.

Study Findings

Characterization of background ambient noise at the seven assessment locations was as follows:

Assessment Location 1 (Caution Bay)

Background ambient underwater noise at the nearshore Caution Bay assessment location is assessed as a typical range of between 90 to 110 dB re 1 µPa rms, with a maximum transient noise source level of 180 dB 1 µPa at 1 m for shipping (e.g., a LNG carrier) increasing the range of the upper value to 161 dB re 1 µPa rms, which represents a noise transmission loss of 19 dB between the noise source (propellers at 6 m depth) and the mid-water depth assessment point of 15 m.

Assessment Location 2 (South of Kerema)

Background ambient underwater noise at the offshore Gulf of Papua assessment location from natural physical and biological sources and anthropogenic sources (i.e., distant shipping) is expected to be in the range 75 to 95 dB re 1 µPa rms, with maximum transient noise from a trawler passing directly over the assessment location, increasing the range upper value to 123 dB re 1 µPa rms for a mid-water depth assessment point at 40 m.

Assessment Location 3 (South of Ihu)

Background ambient underwater noise from natural physical and biological sources and anthropogenic sources (i.e., distant shipping) is expected to be in the range 75 to 95 dB re 1 µPa rms, with transient noise from a trawler actively fishing increasing the range upper value to 127 dB re 1 µPa rms for a mid-water depth assessment point at 25 m.

Assessment Location 4 (Orokolo Bay)

Background ambient underwater noise from natural physical and biological sources and anthropogenic sources (i.e., distant shipping) at the Orokolo Bay assessment location is assessed as a typical range of between 85 to 95 dB re 1 µPa rms, with transient noise from a supplies barge (passing directly over the assessment location) or an outboard motor-driven banana boat (travelling along the coast, about 2 km distance from the assessment location) increasing the range upper value to 163 dB re 1 µPa rms or 130 dB re 1 µPa rms, respectively for a mid-water depth assessment point at 6 m.

Assessment Location 5 (Aievi Passage)

Background ambient noise at the estuarine Aievi Passage assessment location in the Purari River delta is assessed as a typical range of between 75 and 85 dB re 1 *µ*Pa rms, with transient noise from a supplies barge (i.e., 64-m-long MV GFS Marine 01) passing directly over the assessment location increasing the upper range value to 175 dB re 1 *µ*Pa rms for a mid-water depth assessment point at 3 m.

Assessment Location 6 (Port Romilly)

Background ambient underwater noise at the estuarine Port Romilly assessment location is assessed as a typical range of between 80 and 90 dB re 1 *µ*Pa rms, with transient noise from a logging barge/landing craft passing directly over the assessment location increasing the upper range value to 164 dB re 1 *µ*Pa rms for a mid-water depth assessment point at 4 m.

Assessment Location 7 (Purari River)

Background ambient underwater noise at the Purari River assessment location is assessed to be a typical range of between 75 to 85 dB re 1 µPa rms, with transient noise from a supplies barge passing directly over the assessment location increasing the range upper value to 170 dB re 1 µPa rms at a mid-water depth assessment point at 3 m.

CONTENTS

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FIGURES

1. Introduction

Total E&P PNG Limited (TEP PNG), a wholly owned subsidiary of TOTAL S.A. (TOTAL), is the largest partner in a joint venture to develop the Elk-Antelope gas field, located in Petroleum Retention License 15 (PRL-15) in Gulf Province, Papua New Guinea. This Project, known as the Papua LNG Project, will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to a liquefied natural gas (LNG) plant site at Caution Bay, Central Province, 20 km northwest of Port Moresby.

TEP PNG is preparing an environmental impact statement (EIS) and an environmental, social and health impact assessment (ESHIA) for the development of the Elk-Antelope gas field in Papua New Guinea. An environmental and social baseline study (ESBS) is being prepared for the Project's EIS/ESHIA. This technical paper provides an underwater noise baseline characterization, which is a component of the ESBS.

1.1 Study Scope

The study scope is to characterize the ambient background acoustic environment of the marine, estuarine and riverine environments within the Project's area of influence and neighboring areas. The following areas are covered for the underwater noise desktop baseline characterization:

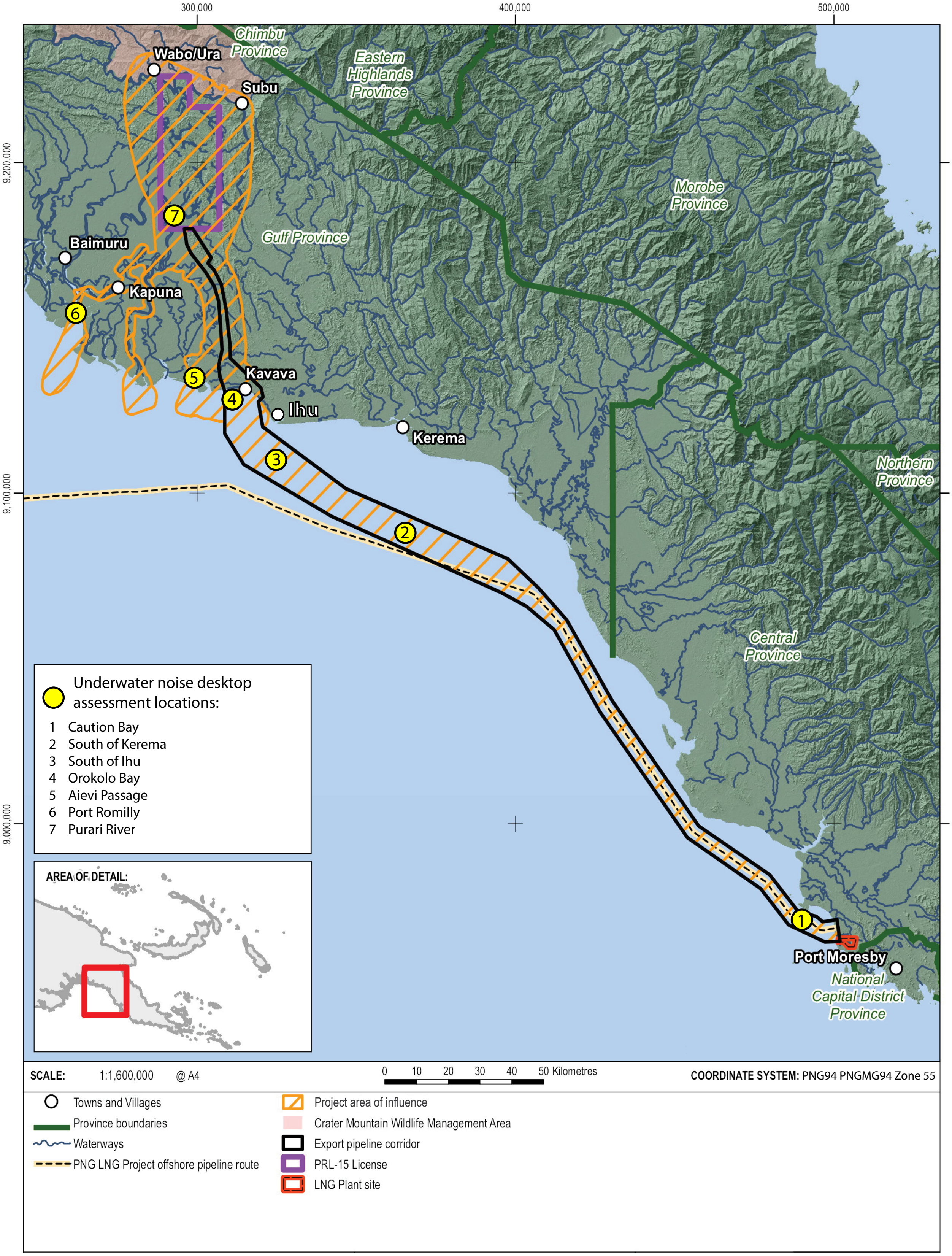
- Offshore marine environment of the Gulf of Papua (export pipeline corridor).
- Nearshore marine environment of Orokolo Bay (export pipeline corridor).
- Nearshore environment of Caution Bay (export pipeline corridor and the PNG LNG marine terminal).
- Estuaries of the Purari, Urika and Wame rivers (river transport corridors).
- Purari, Urika-Ivo and Wame-Varoi rivers (river transport corridor options for Project vessels).

Figure 1 shows the upstream Project Area of Influence (PAOI) and also shows the assessment locations where background underwater noise has been characterized.

1.2 Study Objectives

The key objectives of the underwater noise desktop characterization study are to:

- Characterize existing levels of underwater ambient noise from natural sources, including physical sources (e.g., wind, rain, surface waves, earthquakes, lightning) and biological sources (e.g., whales, dolphins, fish choruses and snapping shrimp).
- Characterize existing levels of underwater noise from anthropogenic sources:
  - Marine, estuarine and riverine commercial shipping traffic (e.g., ships, tugs, LNG carriers, barges and trawlers).
  - Coastal, estuarine and riverine village watercraft (e.g., outboard motor-driven dugout canoes, banana boats and dinghies).
- Characterize the combined baseline natural and anthropogenic ambient noise in the above-mentioned Project areas of influence (see Section 1.1).



Source: Base map from ERIAS Group and Mipela GeoSolutions (2017)

EnviroGulf Consulting	Job No: 167 File No: 167-1-F1	To: ERIAS Group Pty Limited Project: Papua LNG Project	Project Area of Influence and Baseline Underwater Noise Desktop Assessment Locations	Figure No: 1

2. Legislative Framework

Papua New Guinea legislation and regulations do not specify underwater noise level criteria or standards, and there is a corresponding lack of international standards related to underwater noise. During the EIS approvals process for oil and gas projects in Papua New Guinea, the Conservation and Environment Protection Authority (CEPA) typically includes conditions in an Environment Permit issued under Section 65 of the *Environment Act 2000*, which typically require a proponent to address baseline ambient terrestrial and underwater noise.

With respect to international legislation and guidance, the Internatioal Finance Corporation (IFC) environmental health and safety (EHS) guidelines for onshore oil and gas (IFC, 2007) do not mention underwater noise. Both the IFC EHS guidelines for offshore oil and gas (IFC, 2015) and for ports, harbors and terminals (IFC, 2017) refer to underwater noise and vibration levels which may be generated from several sources, including offshore infrastructure installations (e.g., pipelines) dredging, ship traffic, port operations and operational phases. The guidelines state that underwater noise from these activities may adversely impact aquatic habitats and the health and behaviors of aquatic life, including fish, marine mammals, and sea turtles. These guidelines state that assessments should be conducted to (i) identify where and/or when underwater noise has the potential to impact aquatic life significantly and (ii) to identify appropriate mitigation measures. The IFC EHS guidelines for offshore oil and gas also make several recommendations to mitigate or reduce underwater noise levels but primiarly for anthropogenic impact noise sources, rather than the type of continuous broadband noise from shipping operations of pipeline installation.

3. Underwater Sound Terminology and Units

Prior to characterizing baseline underwater noise, a brief overview of underwater acoustic terminology and units is given below.

3.1 Fundamentals of Underwater Noise and Vibration

There are several components that are used in describing underwater sound:

- ***Frequency:*** most underwater sounds are composed of many different frequencies, which are referred to as the frequency spectrum or bandwidth. The rate of oscillation or vibration measured in cycles per second or hertz (Hz).

- ***Wavelength:*** the length of the fundamental oscillation of the sound in the propagation medium, measured in meters (m).

- ***Acoustic wave velocity:*** in seawater, the velocity is close to 1,500 m/s (typically between 1,450 and 1,550 m/s), depending on pressure, salinity and temperature. For a sound velocity of 1,500 m/s, underwater acoustic wavelengths will be 150 m for 10 Hz, 1.5 m at 1 kHz and 0.0015 m at 1 MHz (Lurton, 2010).

- ***Seawater density:*** density is approximately 1,030 kg/m^3 on average, but depends on pressure, salinity and temperature.

- ***Decibel:*** the decibel is used to describe sound the 'base 10 logarithmic function of the ratio of the pressure fluctuation to a reference pressure'. The reference pressure for marine water or freshwater is 1 μPa compared to 20 μPa for air. The reference level must be known to allow proper interpretation of the dB value.

- ***Sound pressure level (SPL):*** the unit is the Pascal (Pa), which is equivalent to a Newton per meter squared (N/m^2), as defined by the International System of Units (S.I.). The SPL unit is expressed in terms of dB referenced to 1 microPascal at 1 meter (i.e., dB re 1 μPa at 1m), where 're' denotes 'with reference to'. A 10 dB increase represents a ten-fold increase in power, a 20 dB increase would be a 100-fold increase and 30 dB would be a 1,000-fold increase.

- ***Sound Exposure Level (SEL):*** total noise energy over a measurement period expressed in units of referenced to 1 microPascals-squared in one second (i.e., dB re 1 $\mu Pa^2 \cdot s$). The SEL is commonly used for impulsive noise sources because it allows a comparison of the energy contained in impulsive signals of different duration and peak levels.

- ***Power Spectral Density:*** the decibel unit is the mean square pressure per unit bandwidth in microPascal squared per hertz (i.e., dB re 1 $\mu Pa^2/Hz$). Note that the bandwidth of the power spectral density is explicitly part of the unit. In some cases, ambient background noise in the literatures is presented as spectral densities rather than as sound pressure levels.

- ***Peak Sound Pressure Level (SPL_p):*** The maximum noise level recorded during a measurement period expressed in dB re 1 μPa. The peak level is commonly used as a descriptor for impulsive noise sources, such as impact pile driving or marine seismic survey operating airguns.

- ***Peak-to-peak Sound Pressure Level (SPL_{p-p}):*** Difference between the maximum and minimum noise level recorded during a measurement period, expressed in units of dB re 1 μPa at 1 m. The peak-to-peak level is also commonly used as a descriptor for impulsive noise sources.

All underwater noise source levels referenced in this technical paper are expressed in terms of dB re 1 μPa at 1m. Note that dB values for sounds in air are calculated for a reference pressure of 20 μPa, as opposed to the 1 μPa in seawater or river water, but both were chosen to be near the limit of human hearing.

While sound source levels are measured as dB re 1 μPa at 1 m, received sound levels at distance from the source are expressed in units of dB re 1 μPa root mean square (rms). Root-mean-square pressure is what a marine animal perceives via its auditory system or what a hydrophone[1] measures.

In the following sections, where underwater noise source levels are outside the Project's area of influence, extrapolation of the source noise levels (dB re 1 μPa at 1 m) to received noise levels (dB re 1 μPa rms) at a given location from the noise source requires the use of sound transmission loss equations to estimate the received noise levels at the given location.

3.2 Underwater Sound Transmission Loss

There are several factors that affect underwater sound propagation and transmission loss. Sound propagation in water is a complex phenomenon, and is affected by location (e.g., position and orientation of the sound source in the water column), water depth, seabed type, and water column temperature/density. Received sound levels are a function of both source and receiver depth, where the receiver could be a measuring device (e.g., a hydrophone) or a marine animal (e.g., fish or whale).

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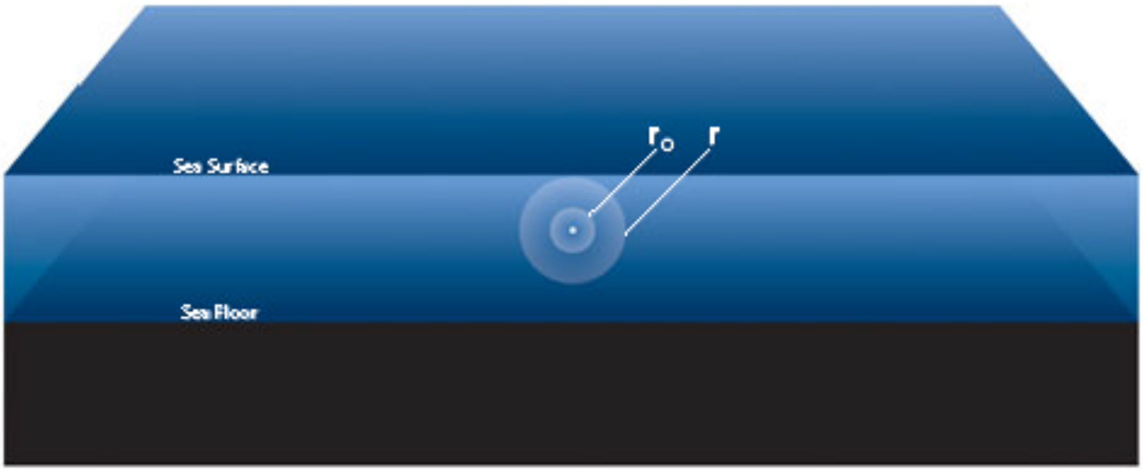
1 An underwater microphone that will listen to, or pick up, acoustic sugnals.

3.2.1 Underwater Sound Spreading Models

As a point source of underwater sound energy propagates through the sea it spreads over a larger volume and the intensity of the sound energy decreases. This is called the term transmission loss (TL), which describes the drop in sound energy level as it propagates from one point in the ocean to another (Collins, 2017). The transmission loss is defined as the ratio of the acoustic intensity at the particular point, to the level at some reference position.

A generalized spreading model (i.e., nlog10[R], where R means radial distance from the noise source in meters) can be used to estimate sound propagation or transmission loss (i.e., by attenuation) in the marine environment. For example, a spherical spreading (20log10[R]) TL formula is normally applied to noise sources in moderate to deep water, where the spreading is spherical to a radial distance (i.e. R) approximately equivalent to water depth. Figure 2 shows a diagram representative of a spherical spreading model.

Figure 2 – Diagram of a Spherical Spreading Model



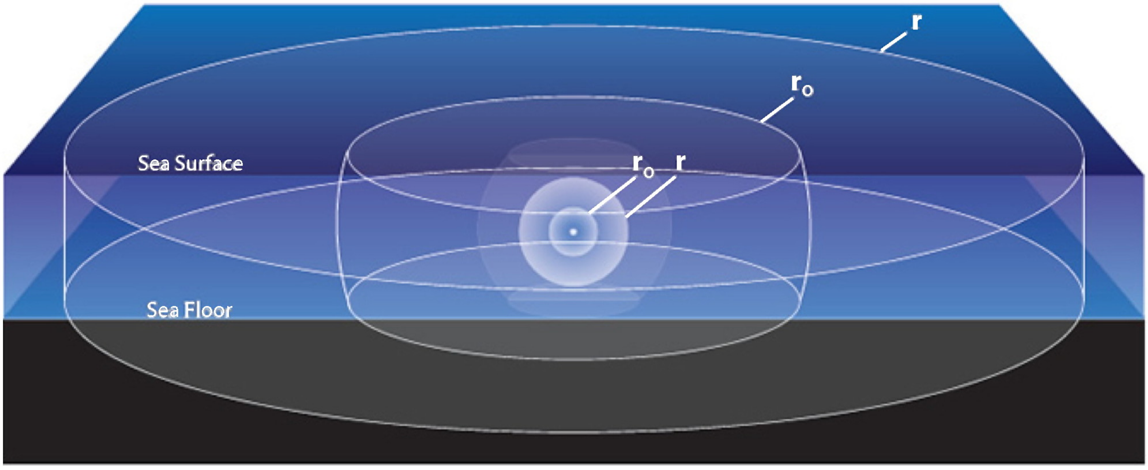
Source: DOSITS (2017).

In Figure 2 sound generated by a sound source (shown as a white dot) at mid-depth in the sea or ocean is radiated equally in all directions. Sound levels are therefore constant on spherical surfaces surrounding the sound source. Sound levels decrease rapidly as sound spreads out from a sphere with a radius of r_0 to a larger sphere with a radius (r).

Spherical spreading results in a general 6 dB decrease in the intensity[2] of noise per doubling of distance. The spherical TL formula can be applied at short range from a point or a line noise source. As R increases, boundary interactions begin to focus the sound (e.g., by reflection from the sea surface and seafloor) and a cylindrical spreading model (10log[R]) may provide a closer approximation to TL, such as in the case of shallow coastal waters (e.g., Orokolo Bay and Caution Bay) or the Purari River delta inlets (i.e., estuaries) of the Project study area. Figure 3 shows a diagram representative of a cylindrical spreading model. Cylindrical spreading results in a general 3 dB decrease in the intensity of noise per doubling of distance.

2 Intensity is the average amount of sound energy transmitted per unit time through a unit area in a specified direction.

Figure 3 – Diagram of a Cylindrical Spreading Model



Source: DOSITS (2017).

In Figure 3 sound generated by a source (shown as a white dot) in the sea cannot continue to spread uniformly in all directions once it reaches the sea surface or the sea floor. Once the sound is trapped between the top and bottom of the ocean it gradually begins to spread cylindrically, with sound radiating horizontally away from the source. Sound levels decrease more slowly as sound spreads from a cylinder with a radius of r_0 to a larger cylinder with radius r compared with the rate of decrease for spherical spreading.

The water depths along the Project's offshore section of the export pipeline corridor vary from 30 m near the coastline at both Orokolo Bay and Caution Bay and a general 100 m along the continental shelf route within the inner continental shelf of the Gulf of Papua. In this case, cylindrical spreading formula is more appropriate for these shallow waters; however, in the case of ships transiting the central part of the Gulf of Papua where the water depth varies between 1,600 m and 4,200 m deep, the spherical spreading formula is appropriate. In general, at a horizontal distance of about 1.5 times the water depth in the central Gulf of Papua, sound transmission loss by cylindrical spreading takes over from spherical spreading as sound at distance from anthropogenic noise point sources (e.g., ships) can be ducted by sea surface and seafloor reflections.

For the purposes of the present technical paper, both spherical spreading and cylindrical spreading transmission loss formulae are used when appropriate.

3.3 Factors Affecting Underwater Sound Propagation

Sound propagation in water is a complex phenomenon, and is affected by location (e.g., position and orientation of the sound source in the water column), water depth, seabed or river bed type, and water column temperature/density.

There are several factors that affect underwater sound propagation and transmission loss, which are briefly described below.

Absorption

As sound waves propagate, they interact at a molecular level with the constituents of seawater through a range of mechanisms, resulting in absorption of sound energy (Francois and Garrison 1982a, 1982b; Medwin 2005). This occurs even in completely suspended particulate-free waters, and is in addition to scattering that may occur from objects such as phytoplankton, zooplankton or suspended sediments.

The absorption of sound energy by water contributes to sound transmission loss linearly with distance (range) and is given by an attenuation (absorption) coefficient in units of decibels per kilometer (dB/km). Absorption coefficients can be computed from empirical equations and increases with the square of frequency. For example, for typical temperate open-ocean values of temperature of 10°C, pH 8.0 and a salinity of 35 practical salinity units (PSU), the equations presented by Francois and Garrison (1982a,b) yield the following values for sound attenuation near the sea surface:

- 0.001 dB/km at 100 Hz.
- 0.06 dB/km at 1 kHz.
- 0.96 dB/km at 10 kHz.
- 33.6 dB/km at 100 kHz.

The above absorption coefficients clearly indicate that low frequencies (e.g., 100 Hz) can propagate over long distances (ranges) with low sound attenuation whereas high frequencies (e.g., 100 kHz) propagate over short distances, since transmission loss rates are higher. This property of low frequency sound is used by large whales to communicate over hundreds of kilometers in the ocean. In general, as most ships transiting the Gulf of Papua generate low-frequency (20 Hz to <1 kHz) continuous noise, absorption losses will be small to negligible.

Refraction

Reflections from the water surface cause interference with direct sound waves from a noise source, a phenomenon often referred to as the Lloyd’s Mirror effect (Robinson et al. (2011). Refraction refers to a change of direction in a propagating wave due to spatial variations in sound speed within the medium. As a wave travels across a sound speed interface or gradient, portions of the wave front travel at different speeds, resulting in bending of the ray path (Medwin, 2005). By affecting travel paths within the medium, refraction controls the angle of arrival of the sound at a receiver (e.g., marine fauna or hydrophone) as well as the angle of incidence upon boundaries (e.g., the seafloor).

Bathymetry

Water depth has a very large influence on underwater sound propagation, especially at low to mid frequencies (less than a few kilohertz) where scattering losses are low. In shallow water (<100 m depth), which will be the case along Project’s export pipeline corridor, propagation loss is dominated by reflection and scattering of sound from the seabed. In deep water (>1,000 m depth) sound propagation is dominated by refraction in the water column, which will be the case for ships plying the central Gulf of Papua where the water depth range is between 1,600 m and 4,200 m. At intermediate depths, propagation loss is influenced by a combination of these two factors.

4. Sources of Ambient Underwater Noise in the Gulf of Papua

A review of the literature did not reveal any underwater noise measurements for the Gulf of Papua. Therefore, background noise levels measured in similar offshore environments have been researched and used as comparative analogues, with the aim of deriving average background ambient noise levels along the offshore section of Project’s export pipeline corridor in the Gulf of Papua.

The underwater acoustic environment of the Gulf of Papua consists mainly of ambient noise, which is defined as environmental background noise lacking a single source or point (MMS, 2001). In general, natural and anthropogenic sources of ambient noise may be continuous or intermittent and may be concentrated at low or high frequencies. Ambient noise levels at a given frequency and location typically can vary as much as 20 dB or more from one day to the next. In general, the ambient background noise in the Gulf of Papua is expected to be highly variable at a given time and place, and a broad range of sources may be combined.

Baseline ambient noise sources include natural physical and biological sources, as well as anthropogenic sources such as ships, trawlers and marine seismic geophysical surveys. Typical natural physical noise sources in the Gulf of Papua are summarized below.

4.1 Natural Physical Sources

There are several natural physical sources of underwater sound that may be expected to be present in the Project's area of influence and the broader area of the Gulf of Papua, these are:

- Sea surface sound sources:
  - Surface wind is a major contributor.
  - Breaking waves, bubbles and sea spray.
  - Rainfall noise at the sea surface.
- Lightning and thunder sound sources.
- Earthquake and tremor sound sources.

Table 1 gives a summary of natural physical sources and typical sound levels, which may be expected to occur in the Gulf of Papua.

4.1.1 Sea Surface Sound Sources

The dominant source of naturally occurring noise across the frequencies from 1 Hz to 100 kHz is associated with waves generated by the wind acting on the sea surface (NRC, 2003).

The dominant sources of ambient noise and their frequencies at the sea surface may be summarized as:

- Surface wind is a major contributor (100 Hz to 30 KHz) (Simmonds et al., 2003).
- Breaking waves, bubbles and spray (100 Hz to 20 kHz) (Richardson et al., 1995).
- Rainfall (100 Hz to 30 kHz) (Richardson et al., 1995).

In Table 1 it is evident that wind will be a major contributor to background ambient noise in the Gulf of Papua. In the absence of anthropogenic and biological sound, ambient physical noise in the gulf will be wind dependent and over an extremely broad frequency band from below 1 Hz to at least 100 kHz. At frequencies below 10 Hz, interactions of surface waves are likely to be the dominant mechanisms for sound generation. Across the remainder of the band from 10 Hz to 100 kHz, oscillating bubbles in the water column are the primary noise source, both as individual bubbles and as bubble clouds (Hildebrand, 2005).

In Table 1 Richardson et al. (1995) note that winds of <1 knot, 11 to 16 knots and 22 to 27 knots have source levels at the sea surface of 60, 97 and 102 dB re 1 µPa at 1 m, respectively. Mean wind speeds in the Gulf of Papua average 14 knots with a maximum of 30 knots during the winter southeast trade wind season (May to October), which could generate surface sea noise levels of around 100 dB re 1 µPa at 1 m along the export pipeline corridor.

Table 1 – Natural Physical Noise Sources, Frequencies and Levels

Source	Aspect	Sound Source Level	Reference
Wind	<1 knot 100 Hz to 30 kHz	60 dB re 1 μPa at 1 m	Richardson et al. (1995)
	11 to 16 knots 100 Hz to 30 kHz	97 dB re 1 μPa at 1 m	Richardson et al. (1995)
	22 to 27 knots 100 Hz to 30 kHz	102 dB re 1 μPa at 1 m	Richardson et al. (1995)
Rainfall	<2 mm/hr (wind 6 m/s) at (0.5 kHz)	63 dB re 1 μPa at 1 m peak	Pensieri et al (2015)
	2 to 10 mm/hr (wind >10 m/s) at (0.5 kHz)	65 dB re 1 μPa at 1 m peak	Pensieri et al (2015)
	10 to 20 mm/hr (wind <10m/s) at (0.5 kHz)	67 dB re 1 μPa at 1 m peak	Pensieri et al (2015)
	>20 mm/hr (wind >10 m/s) at (0.5 kHz)	66 dB re 1 μPa at 1 m peak	Pensieri et al (2015)
Lightning and thunder	5 to 10 km Sudden short pulse	Peak energy between 50 and 250 Hz producing up to 15 dB above background	Hildebrand (2005)
	<100 km Sudden short pulse	Peak energy between 5 and 20 Hz producing 30 to 40 dB above background	Schreiner et al (1995)
	Lightning strike on sea surface; 20 to 1,000 Hz	250 dB re 1 μPa at 1 m	Heathershaw et al. (2001)
Earthquakes	Sudden irregular transient of low frequency 10 to 100 Hz	220 to 250 dB re 1 μPa at 1 m	Baggeroer et al. (2005)
	Undersea earthquake of magnitude 4.0 on Richter scale (energy integrated over 50 Hz bandwidth); 20 to 1,000 Hz	272 dB re 1 μPa at 1 m	Heathershaw et al. (2001)

During the northwest monsoon season (December to March), winds are from the northwest and generally relatively weak with an average <10 knots (Slingerland et al., 2008), which would generate noise source levels of between 60 and 95 dB re 1 µPa at 1 m. Short-lived squalls, known locally as *Gubas*, are common during the northwest monsoon in the Gulf of Papua but their duration is generally short (< 1 hour) with wind speeds of between 30 and 35 knots (ERIAS Group, 2016a), which can generate noise source levels of >110 dB re 1 µPa at 1 m. Winds during the changeover periods (months) following the end of southeast trade wind season (April) and the beginning of the northwest monsoon season (November) represent periods when wind strengths and direction are variable but of short duration (i.e., <1 month).

Wind and sea state affect underwater noise levels and Table 2 gives the 12-level Beaufort Scale for winds and associated sea states.

Figure 4 shows the ambient noise spectra[3] levels that are generated by natural and anthropogenic (shipping traffic) noise sources. For example, noise sources levels at a frequency of 600 Hz for Beaufort scales 1, 2, 3, 5 and 8 in Figure 4 are 46.5, 55.0, 66.0, 73.0 and 81.0 dB re 1 µPa at 1 m, respectively.

3 In Figure 4 the noise level spectra level unit of dB re 1 µPa2 is the same as dB re 1 µPa at 1m.

Table 2 – Beaufort Wind Scale and Sea State

Wind Speed (knots)	Beaufort Scale	Sea State	Wave Height (m)	*WMO terms	Description
<1	0	0	0	Calm	Flat glassy
1–2	1	0.5	0.1	Light air	Ripples without crests
3 to 6	2	1	0.2	Light breeze	Small wavelets, glassy crests
7 to 10	3	2	0.6	Gentle breeze	Large wavelets, crests begin to break
11 to 15	4	3	1	Moderate breeze	Small waves, whitecaps
16 to 20	5	4	2	Fresh breeze	Moderate waves, some foam + spray Large waves with foam crests
21 to 26	6	5	3	Strong breeze	Large waves with foam crests
27 to 33	7	6	4	Near gale	Sea heaps up, foam begins to be blown
34 to 40	8	6	5.5	Gale	High waves, breaking crests form spindrift, streaks of foam
41 to 47	9	6	7	Strong gale	High waves with dense foam, crests roll over
48 to 55	10	7	9	Storm	Storm Considerable tumbling of waves with heavy impact, large amounts of airborne spray reduce visibility
56 to 63	11	8	11.5	Violent storm	Very large patches of foam driven before the wind cover much of the sea surface
>64	12	9	>14	Hurricane[#]	Sea completely white with foam, air filled with spray

Source: Erbe (2011). * World Meteorological Organization. [#] Hurricanes are known as cyclones in Southern Hemisphere.

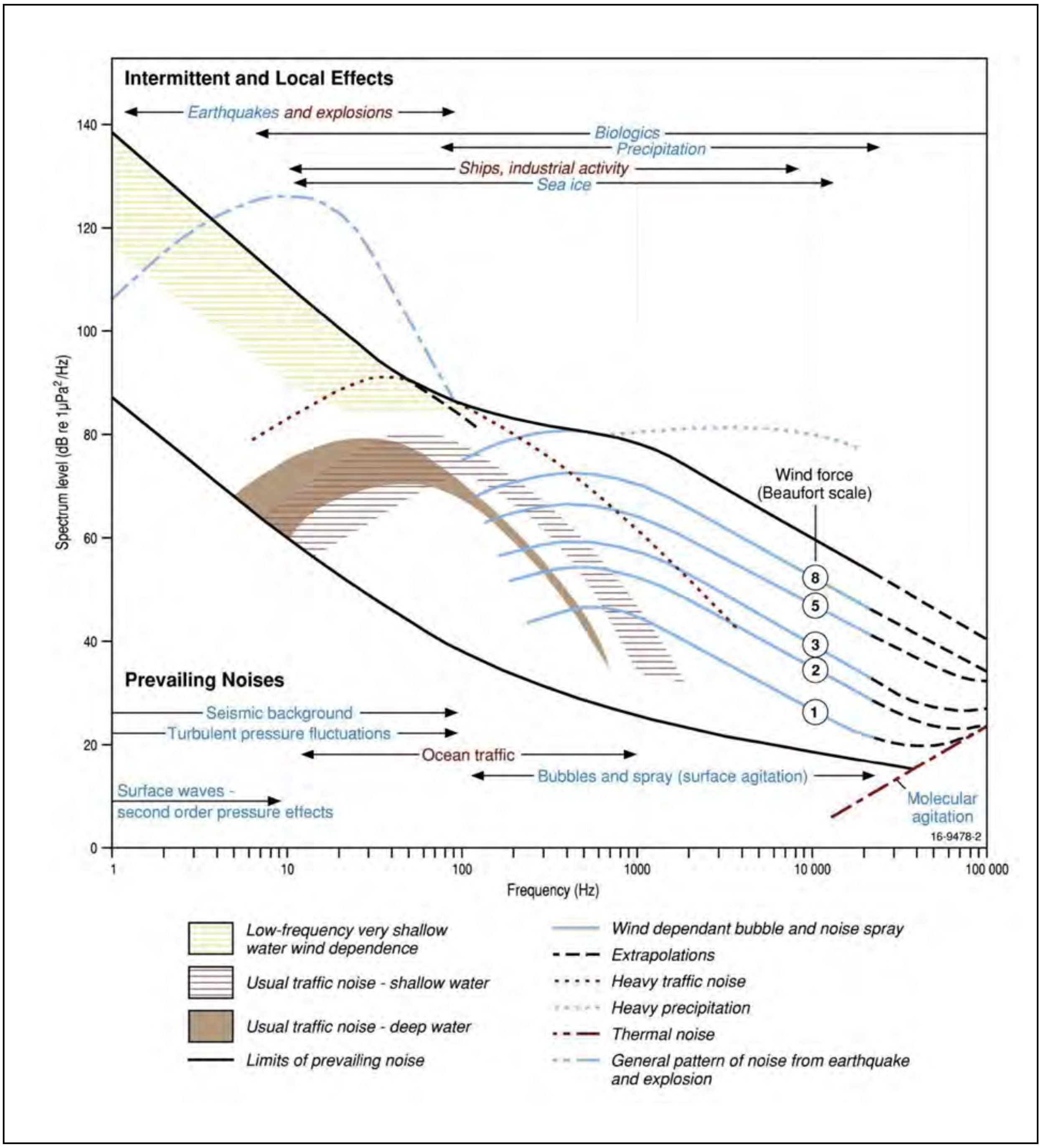
4.1.2 Lightning and Thunder

Lightning and thunder are transient natural sound sources. A lightning strike at the sea surface can produce a noise source level of 250 dB re 1 µPa at 1 m with frequencies in the range 20 to 1,000 Hz. Actual underwater recordings of lightning/thunder from storms 5 to 10 km distant from a measuring point show peak energy between 50 and 250 Hz, and up to 15 dB above background levels (Hildebrand, 2005; Dubrovsky and Kosterin, 1993). Storms and lightning strikes would be expected to be a common occurrence in the wet tropical environment of the Gulf of Papua and along its coastline.

4.1.3 Earthquakes

The Project's export pipeline corridor is in the northern and eastern sections of the Gulf of Papua and lies within seismic Zone 3 near the coast of Gulf Province and Zone 4 offshore (PNGNSC, 1982).

Volcanic and tectonic noise generated by earthquakes on land or in water propagates as low frequency and locally generated T-phase (i.e., tertiary) waves in addition to the usual P-phase (primary) and S-phase (secondary) seismic waves that are observed on land. At ranges of less than 100 km, T-phase energy can have frequencies greater than 100 Hz with peak energy at 5 to 20 Hz. It can be as much as 30 to 40 dB above background noise, with a sharp onset, and can last from a few seconds to several minutes (Schreiner et al. 1995). An undersea earthquake of magnitude 4.0 on the Richter scale (energy integrated over 50 Hz bandwidth) was observed to produce a noise source level of 272 dB re 1 µPa at 1 m (Heathershaw et al., 2001).



Source: Based on Carroll et al. (2016) and Wenz (1962)

EnviroGulf Consulting	Job No: 167 File No: 167-1-F4	To: ERIAS Group Pty Limited Project: Papua LNG Project	**Wenz Curves** **Ambient Noise Spectra Levels**	Figure No: 4

4.2 Natural Marine Biological Sources

There are several natural biological sources of underwater sound that may be expected to be present in the Project's offshore export pipeline corridor in the Gulf of Papua, which are principally from marine mammals (whales and dolphins), some fish species with air bladders and decapod crustaceans (e.g., snapping shrimps).

Table 3 presents underwater source levels of sounds emitted by various marine mammals for communication or echolocation[4] purposes, which cover a broad frequency spectrum. Richardson et al. (1995) described the dominant sources of ambient noise due to biological sources as having frequencies in the range 10 Hz to 100 kHz.

Table 3 – Marine Mammal Communication and/or Echolocation Frequencies

Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)	Estimated Source Level (dB re 1 μPa at 1 m)	Reference
Odontocetes (Toothed Whales)				
Common dolphin*	0.2 to 150	23 to 67	–	a, b
Irrawaddy dolphin	1.1 to 6.0	–	–	a
Bottlenose dolphin*	0.05 to 150	110 to 130	218-228	a, b
Risso's dolphin*	0.1 to 23.7	65	-	a, b
Killer whale	0.1 to 35	12 to 25	180	a, b
Sperm whales	0.1 to 4	0.1 to 20	236	e
Delphinid whistles/squeaks	_	>10 kHz	10 to 195	d
Toothed whale sonar	–	>10 kHz	190 to 232	d
Mysticetes (Baleen Whales)				
Southern right	0.03 to 2.2	–	172-192	a, b
Pygmy right	0.06 to 0.135	–	165-179	a, b
Humpback*	0.02 to 10	–	144-192	a, b
Fin	0.02 and 1.5 to 2.5	–	155-186	a, b
Blue	0.012 to 0.4	–	130-188	a, b
Bryde's*	0.124 to 0.900	–	152-174	a, b
Dwarf minke*	0.06 to 6	–	151-175	a, b

Sources: a = Richardson et al. (1995); b = NRC (2003); c = SCAR (2002); d = URS (2009); e = Richardson et al (1995).
* denotes species expected to be present in the Gulf of Papua (ERIAS Group, 2016a).

Marine mammals use sound for social interaction and communication between individuals and pods as well as for echolocation and navigation purposes, reproduction, predator avoidance, feeding and in perception of their environment (McCauley, 1994; Richardson et al., 1995; SCAR, 2002).

Other marine fauna also generate biological noise at different frequencies, such as dugongs (2 to 5 kHz), rock lobster (2 to 10 kHz), and fish (0.1 to 5 kHz) (Richardson et al., 1995). Table 4 lists non-cetacean biological sound sources and/or frequencies that may be present in the Gulf of Papua.

4 the ability by which animals can produce mid- or high-frequency sounds and detect echoes of these sounds that bounce back off distant objects to determine physical features of their surroundings.

Table 4 – Other Marine Biological Sound Sources

Source	Frequencies	Sound Source Level	Reference
Fish			
General fish sounds and choruses	0.1 to 5 kHz	Mean of 120 dB re 1μPa at 1 m Maximum of 160 dB re 1μPa at 1 m	Mann (2012), Richardson et al. (1995)
Air bladder sounds	75 to 150 Hz	Not stated	URI (2017)
	4 to 60 Hz	Not stated	Tsai (2009)
Stridulatory* sounds	150 to 8000 Hz	Not stated	URI (2017)
Macroinvertebrates			
Snapping shrimp	Peak 1 kHz (range 1 to 50 kHz)	86 dB re 1 μPa at 1 m	APPEA (2005)
	5 kHz to 300 kHz	Not stated	McCauley (1994)
Rock lobster	2 to 10 kHz	Not stated	McCauley (1994)

* The act of producing sound by rubbing together certain body parts.

In general, sounds produced by soniferous (sound-producing) fish for communication are generally associated with either reproductive activities (e.g., courtship or spawning) or stressful conditions (e.g., aggression or territorial defense).

Bony fish (Osteichthyes) produce sounds by means such as striking bony structures against one another, or by muscle movement amplified by the gas-filled swim bladder (or air bladder) (NRC, 2003). Sciaenid fish, such as croakers and jewfish that are present in the Gulf of Papua, also emit underwater noise by drumming their swim bladders with their sonic muscles and producing short pulses of between 45 and 60 Hz but generally less than 500 Hz (Tsai, 2009). Some marine catfish also emit low frequency sound (<1,000 Hz), while other catfish species emit sounds up to 8 kHz (Tsai, 2009).

Other marine fauna also generate biological noise at different frequencies, such as rock lobster (2 to 10 kHz) and fish (0.1 to 5 kHz) (Richardson et al., 1995). Snapping shrimps, stomatopods and some sea urchins have been reported to produce high frequency sounds (McCauley, 1994). Snapping shrimps have been reported to produce high frequency sounds at around 2,500 Hz (McCauley et al., 2000). Overall, the frequencies used by marine fauna cover a broad frequency spectrum (NRC, 2003; McCauley, 1994).

In general, marine biological sources of underwater noise in the Gulf of Papua will generally be intermittent and of short duration, whereas some biological generated noise may be more or less continuous broadband noise, such as that produced by snapping shrimp (e.g., 60 to 90 dB re 1 μPa at 1 m in the frequency range 1 to 10 kHz).

4.3 Anthropogenic Noise Levels

There is a wide range of human-generated (anthropogenic) sounds in the marine environment, including sources such as distant ships, oil and gas exploration (seismic surveys and explorations drilling) and operations (machinery, helicopters and service vessels) and commercial fishing trawlers (e.g., the GOPPF). These include anthropogenic underwater noise sources, such as:

- Distant ships in the Gulf of Papua and Coral Sea shipping traffic lanes.
- Oil and gas explorations activities in the Gulf of Papua:
  - Marine seismic surveys.

– Sonar systems.

– Oil terminal platforms (e.g., Kumul Marine Terminal).

Given the scarcity of underwater noise measurements in the Gulf of Papua and a lack of underwater noise source level data for ships and vessels currently plying the Gulf, a literature review was carried out to characterize underwater noise source levels for a range of vessel types, equipment and activities (e.g., drilling, dredging and marine seismic surveys). Table 5 presents a summary of the literature review and gives examples of recorded noise source levels and frequencies, which have been used as comparative analogues to determine typical anthropogenic noise source levels that may be applicable to the Gulf of Papua (EGC, 2017).

Table 5 – Typical Underwater Source Levels of Anthropogenic Noise

Aspect	Speed/Frequency	Sound Source Level	Reference
Large Ships			
Super tanker (337 m long)	Fast moving (20 knots)	195 dB re1 µPa at 1 m	Hildebrand (2005)
Super tanker (337 m long)	Fast moving (18 knots) Peak 23 Hz	185 dB re 1 µPa at 1 m	Hildebrand (2005)
Three crude oil tanker (229 to 243 m long)	Slow speed (6.5 to 7.5 knots)	179 to 182 dB re 1 µPa at 1 m	McKenna et al. (2012)
Two product tankers (180 to 182 m long)	Slow speed (7.1 to 8.0 knots)	109 to 111 dB re 1 µPa at 1 m	McKenna et al. (2012)
Six container ships (214 to 298 m long)	Moderate speed (10.4 to 11.2 knots)	114 to 119 dB re 1 µPa at 1 m	McKenna et al. (2012)
Medium size container ship (173 m long)	High speed (16 knots); 40 to 100Hz	192 dB re 1 µPa at 1 m	Hildebrand (2009)
Fishing Vessels			
Small fishing vessels	Transiting	140 dB re 1 µPa at 1 m	Hildebrand (2005)
Operating fishing trawler	Slow moving (6 to 8 knots)	150-160 dB re 1 µPa at 1 m	Statoil (2000)
Fishing vessel (12 m long)	Moderate speed (7 knots); Peak 300 Hz	151 dB re 1 µPa at 1 m.	Hildebrand (2005)
Tugs and Barges			
Tugs (maneuvering a barge) shallow water	4 knots	144 dB re 1 µPa at 60 m peak to peak 170 dB re 1 µPa at 1 m	Seiche (2008)
Tug towing a barge (19.5 m long, 8.2 m beam and 1 m draft)	Unloaded underway at 7.4 knots; 0.01 to 20 kHz	173 dB re 1 µPa at 1 m	Zykov and Hannay (2006)
Tug towing a barge (19.5 m long, 8.2 m beam and 1 m draft)	Unloaded underway at 8.7 knots; 0.01 to 20 kHz	182 dB re 1 µPa at 1 m	Zykov and Hannay (2006)
Tug towing a barge (19.5 m long, 8.2 m beam and 1 m draft)	Partially loaded and underway at 6.4 knots; 0.01 to 20 kHz	177 dB re 1 µPa at 1 m	Zykov and Hannay (2006)
Self-propelled barge (43 m long by 12 m beam)	Unloaded underway at 5.5 knots; 0.01 to 1 kHz (cavitation tones up to 20 kHz)	163 dB re 1 µPa at 1 m	Zykov and Hannay (2006)

Table 5 – Typical Underwater Source Levels of Anthropogenic Noise (cont'd)

Aspect	Speed/Frequency	Sound Source Level	Reference
Tugs and Barges (cont'd)			
Self-propelled barge (43 m long by 12 m beam)	Fully loaded underway at 4.9 knots; 0.01 to 1 kHz (cavitation tones up to 20 kHz)	168 dB re 1 μPa at 1 m	Zykov and Hannay (2006)
Self-propelled barge (43 m long by 12 m beam)	Fully loaded underway at 5.8 knots; 0.01 to 20 kHz	174 dB re 1 μPa at 1 m	Zykov and Hannay (2006)
Offshore Support Vessels			
Offshore Support Vessel (67 m long)	Dynamic positioning with four main engines, two 600 HP thrusters and one 800 HP thruster; 0.001 to 20 kHz	187.7 dB re 1 μPa at 1 m	Austin et al. (2005)
Offshore Support Vessel and anchor handling tug (67.6 m long)	Full speed underway; 10,560 BHP main engine; 0.01 to 8 kHz	190.3 dB re 1 μPa at 1 m	Chorney et al. (2010)
Offshore Support Vessel and anchor handling tug (45 m long)	Full speed underway; 6,600 BHP main engine; 0.01 to 8 kHz	202.7 dB re 1 μPa at 1 m	Chorney et al. (2010)
Seismic Survey Vessel (84.9 m long	Underway profiling; Five diesel electric engines; 0.01 to 20 kHz	125 to 132 dB re 1 μPa at 1 m	Ireland et al. (2009)
Dive support vessel (107 m long by 35 m beam)	Stationary and dynamically positioned using thrusters operating between 20% and 30% of maximum thrust (a typical level)	178 dB re 1 μPa at 1 m Thrusters operating between 20 and 30% of maximum thrust (a typical level)	Seiche (2008)
Small and Recreational Boats			
Crew boat (8.5 m long); inboard diesels	0.01 to 20 kHz	166 dB re 1 μPa at 1 m	Zykov and Hannay (2006)
Flat-bottom workboat (7 m long)	Idling 90 HP outboard motor; 0.01 to 10 kHz	141 dB re 1 μPa at 1 m	Galli et al. (2003)
Flat-bottom workboat (7 m long)	Full speed 90 HP outboard motor; 0.01 to 10 kHz	163 dB re 1 μPa at 1 m	Galli et al. (2003)
Skiffs (2.4 to 5.5 m long)	Low speed <10 knots; 25 to 40 HP outboard motors; 0.01 to 40 kHz	157 dB re 1 μPa at 1 m	Zykov and Hannay (2006)
Skiffs (2.4 to 5.5 m long)	High speed 20 knots; 20 to 40 HP; 0.01 to 40 kHz	163 dB re 1 μPa at 1 m	Zykov and Hannay (2006)
Oil and Gas Exploration Activities			
Exploration drill rig (drilling)	110 m water depth 0.01 to 10 kHz	115 dB re 1 μPa at 405 m	Todd et al. (2007)
Drilling ship	17m depth 0.02 to 1.0 kHz	122 dB re 1 μPa at 1 m	Green (1987).
Jack-up drill rig	0.02 to 1.4kHz	120 dB re 1 μPa at 1 m	Todd et al. (2007)

Table 5 – Typical Underwater Source Levels of Anthropogenic Noise (cont'd)

Aspect	Speed/Frequency	Sound Source Level	Reference
Marine Geophysical Surveys			
Seismic exploration (marine seismic surveys)	Array peak pressure levels frequency range 5 to 300 Hz	259 dB re 1 µPa at 1 m	Greene and Moore (1995)
24-airgun array	Airgun volume 3,147 cubic inch; 2,000 psi*; 0.005 to 20 kHz	256 to 272 dB re 1 µPa at 1 m	Patterson (2007)
12-airgun array	Airgun volume 2,869 cubic inch; 2,000 psi; 0.02 to 20 kHz	222 dB re 1 µPa at 1 m	Greene (1988)
Multibeam echo sounder (hull mounted)	Peak frequency 12 kHz	235 dB re 1 µPa at 1 m	Hildebrand (2005)
Sidescan sonar	50 to 500 kHz	220 to 230 dB re 1 µPa at 1 m	Heathershaw et al. (2001)
Depth sounders	12 to 36 kHz	180 to 220 dB re 1 µPa at 1 m	Heathershaw et al. (2001)
Bottom profiler	0.4 to 30 kHz	200 to 230 dB re 1 µPa at 1 m	Heathershaw et al. (2001)

Notes: Skiff is a shallow, flat-bottomed open boat with a sharp bow and square stern. * psi = pounds per square inch.

The highest noise source levels presented in Table 5 were associated with marine seismic surveying with a maximum level of 259 dB re 1 µPa at 1 m reported (Greene and Moore, 1995).

Shipping

Underwater noise generated by ships is primarily from (a) propeller action, (b) propulsion machinery, and (c) hydraulic flow over the hull (Hildebrand, 2005). In general, underwater noise levels are related to ship size, speed and mode of operation. Reference to Table 5 reveals that for shipping, super tankers transiting at high speeds 18 and 20 knots had the highest underwater noise source levels of 185 and 195 dB re 1 µPa at 1 m, respectively.

In general, the noise source levels presented in Table 5 indicate that fully laden barges produce more noise than unladen barges, and that noise increases with a ship's speed. Small ships (e.g., offshore supply vessels and barge landing craft) tend to have noise spectra around the 300 Hz level due to their higher-speed engines and propellers, compared to the lower-speed engines of large coastal and international ships whose noise spectra are around the 50 to 100 Hz level. Shipping noise also tends to dominate other ambient noise at frequencies between 20 and 300 Hz.

At distant ranges in the open ocean, multiple ships contribute to the background noise, and the sum of many distant sources creates broad spectral peaks of noise in the 5 to 500 Hz band (Hildebrand, 2005). In the Gulf of Papua the main shipping lanes from Port Moresby, as well as those from the eastern seaboard of Australia, converge to the south of the gulf prior to passing through Great North East Channel, which is the eastern gateway to and from the Torres Strait.

Propeller noise is associated with cavitation (Ross 1987), the creation of voids from zones of pressure below the ambient water pressure. The reduction in pressure causes the bubbling in cavitation, which form and collapse creating loud noise (AMC, 2015). Cavitation creates both broadband and tonal sounds, which accounts for between 80 and 85% of ship-radiated noise power (Ross, 1987).

Based on the general source noise levels of ships and vessels given in Table 5, Table 6 presents the adopted source noise levels for vessels known to transit the Gulf of Papua as described in EGC (2017). This information is required as part of the baseline characterization of shipping noise levels received at the assessment locations (1 through 3) indicated in Figure 1.

Table 6 – Details of Commercial Vessels Known to the Gulf of Papua

Vessel	Length (LOA*) (m)	Beam (m)	Gross Tonnage (GRT) (t)	Estimated Underwater Noise Source Level (dB re 1 μPa at 1 m)	
				Range	Average
Kumul Marine Terminal Crude Tankers					
Crude Oil Tankers	229 to 243	35	–	179 to 182	180
MV Venture (tug)*	50	16	1,524	144 to 182	165
MV Vision (tug)*	50	16	1,524	144 to 182	165
Ok Tedi Mining Copper Concentrate Barges					
MV *Fly Prosperity*	90.4	23.0	3,500	135 to 145	140
MV *Fly Alliance*	91.8	19.4	3,577	135 to 145	140
LNG Carriers to PNG LNG Marine Terminal (Caution Bay)					
MV *Spirit of Hela*	298	46	114,277	185 to 195	190
MV *Gigera Laitebo*	298	46	114,277	185 to 195	190
MV *Papua*	290	47	114,166	185 to 195	190
MV *Kumul*	290	47	114,166	185 to 195	190
MV *LNG Flora*	272	47	106,151	180 to 190	185
SL *Logohu**	32	13	495	145 to 185	165
SL *Siage**	32	13	495	145 to 185	165
SL *Korowi**	32	13	495	145 to 185	165
SL *Jamba**	32	13	495	145 to 185	165
Gulf of Papua Prawn Fishery Fishing Trawlers					
FV *Charisma*	21.4	–	138	145 to 155	150
FV *Ma Mori*	22.8	–	134	145 to 155	155
FV *Siwi*	29.3	–	113	145 to 160	155
FV *Diana*	25.6	–	134	145 to 155	150
TOTAL Exploration Phase Barge Landing Craft					
MV *Balimo Chief*	45.5	11.0	498	165 to 175	170
MV *GFS Marine 01*	64.0	14.0	878	170 to 180	175
Rimbunan Hijau Log Barge Landing Craft					
MV *Swift No. 5*	44.9	11.6	442	165 to 175	170

Source: EGC (2017); Notes: TOTAL Papua LNG Project exploration phase barge landing craft (information provided by TEP PNG.); Log ship (Rimbunan Hijau, 2017). * denotes tugs maintaining dynamic positioning or actively towing a barge or ship.

5. Baseline Underwater Noise Desktop Characterization

This section preesents the finding of the desktop assessment of ambinet underwater natural and anthorpogenic noise levels in the Project's area of influence. Seven underwater noise desktop assessment locations were selected for baseline characterization, which were:

- Assessment Location 1 (Caution Bay): Nearshore approach to Caution Bay.
- Assessment Location 2 (south of Kerema): Offshore marine environment.

- Assessment Location 3 (south of Ihu): Offshore marine environment.
- Assessment Location 4 (Orokolo Bay): Nearshore marine environment.
- Assessment Location 5 (Aievi Passage): Purari Delta estuary.
- Assessment Location 6 (Port Romilly): Pie River estuary.
- Assessment Location 7 (Purari River): Purari River downstream of Herd Base.

The following subsections present the findings and estimated ambient baclkground noise levels at each desktop assessment location.

5.1 Purari River

Underwater noise in rivers is affected by abiotic sources, such as water flow, velocity and turbulence, wind, waves and rainfall, as well as biological sources (Amoser and Ladich 2011; Wysocki et al., 2007) such as soniferous fish (e.g., certain fork-tailed catfish species). In addition, short-duration anthropogenic ambient noise sources include transiting barges and outboard motor-driven canoes, banana boats and dinghies. Paddle-driven canoes generate low noise source levels of anthropogenic noise.

In rivers, fast-flowing reaches generate higher noise sources levels than slow-flowing reaches or backwater areas. For example, Amoser and Ladich 2011) found a typical mean underwater noise level of 112 dB re 1 µPa at 1 m in a boulder- and cobble-bed tributary of the Danube River (Triesting stream), which they attributed to changes in water volume and high flows and turbulence. In comparison, the main channel of the Danube River had a cobble substratum and a mean source noise level of 133 dB re 1 µPa at 1; however, comparison of the Danube River with the Purari River is not tenable given the former's high river traffic density and presence of a cobble substratum and the latter's very low river traffic density and very fine sand and silt substratum (see below).

5.1.1 Assessment Location 7 (Purari River)

Assessment Location 7 (7° 22' 25.36" S, 145° 7' 2.61" E) named 'Purari River' is located in the main channel of the Purari River about 1 km downstream of Mapaio Fish Camp and 8.5 km downstream of Herd Base. This site is considered to be representative of the underwater acoustic environment related to the river pipeline crossings.

The Purari River at the assessment location is about 580 m wide at bank full and estimated to be 6 m deep. The river bed is comprised mainly of very fine sands and silts, so is unlikely to be a major source of noise as water flows over the river bed. The principal natural physical noise sources are expected to be wind and waves, rainfall and noise generated at the river banks where the flow passes through vegetation. The main natural biological sound sources are expected to be soniferous fish, such as catfish and other fish species that make grunting sounds for communication and courtship display purposes. Fish grunts tend to be low frequency sound <100 Hz.

Anthropogenic noise in the Purari River may be generated by a transiting TEP PNG contracted barge (e.g., MV *GFS Marine 01*) typically with a noise source level of 175 dB re 1 μPa at 1 m and at low frequencies 10 to 1,000 Hz. In addition, outboard motor-driven dugout canoes, banana boats or dinghies used by river communities generate typical noise source levels of about 163 dB re 1 μPa at 1 m when transiting at high speed (20 knots) and using the typical size of outboard motors (i.e., between 20 and 40 horsepower (HP). At slower transit speeds (<10 knots), the noise source levels are around 157 dB re 1 µPa at 1 m, while the noise source level at idling is typically less than 110 to 120 dB re 1 µPa at 1 m.

Overall, a baseline characterization of underwater ambient noise at the Purari River assessment location is assessed to be a typical range of between 75 to 85 dB re 1 µPa rms, with transient barges passing directly over the assesment location increasing the upper range value to 170 dB re 1 µPa rms at mid-water depth (3 m) in the river.

5.2 Purari River Delta Estuary

The literature was reviewed for examples of underwater noise measurements in tropical estuaries, similar to those of the Purari River delta. There were few measurement data available and most knowledge about ambient noise mainly pertains to the marine environment and, by contrast, baseline data from tropical estuaries are limited.

Bittencourt et al. (2014) measured underwater noise in a quiet embayment (Guapimirim Environmental Protection Area) of the Guanabara Bay in Brazil and recorded received noise levels of 93.2 dB re 1 µPa rms at < 1kHz and levels averaging about 60 dB re 1 µPa rms for the frequency range to 24 kHz. These recorded values represent generally low ambient noise source levels for a tropical estuary when powered boats or other vessels are absent.

5.2.1 Assessment Location 5 (Aievi Passage)

Assessment Location 5 (7° 50' 3.81” S, 145° 10' 45.10" E) named ‘Aievi Passage’ is located at the mouth of the Purari River, west of Aievi Island. This assessment location was selected as it is one of the Project’s preferred river traffic corridors in the Purari River delta, the other delta corridors are the Wame-Varoi and Urika-Ivo distributaries. Aievi Passage is representative of the type of estuarine environment typical of the Purari River delta. The water depth at this location is about 6 m.

Ambient noise in the Aievi Passage includes natural physical sources, such water and tidal flow, water velocity, wind, rainfall, waves and surf (along the nipa- and mangrove-lined estuary banks); however, river flow and flows are low given the very low gradient of the lower Purari River in the Aievi Passage and are therefore unlikely to be significant source of ambient physical noise. The soft bottom sediment of the estuary also reduces the level of noise due to turbulence that would be associated more with coarse sediment types, such as boulders and stones. Given the high rainfall (about 3,000 mm/yr) of the Purari River delta, rain when it occurs can be a significant source of ambient physical noise in the shallow waters of Aievi Passage. For example, heavy rain is about 30 dB higher than sea state noise and has a frequency range of 1 to 100 kHz.

Natural biological sources will include soniferous fish (e.g., catfish) and marine mammals’ echolocation and communication clicks and squeals at high frequencies. The Omati-Kikori-Purari delta complex harbors a number of inshore species of dolphin. Examples include the snubfin dolphin (*Orcaella heinsohni*) sighted in the Era River (ERIAS Group, 2016b), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) found in the Kikori delta (Bonaccorso et al., 2000), Indo-Pacific humpback dolphin (*Sousa chinensis*) found in the Kikori Delta (Leary, 2000) and the Australian humpback dolphin (*Sousa sahulensis*) has been found recently in the Kikori delta by Beasley et al. (2015). For example, bottlenose dolphins have high communication frequencies in the range 0.05 to 150 kHz and very high echolocation frequencies in the range 110 to 130 kHz, which produce noise source levels of between 218 and 228 dB re 1 µPa at 1 m; however, these biological noise sources are transient.

Anthropogenic noise in Aievi Passage will be generated by transiting TEP PNG contracted barges typically with a noise source level of between 170 and 175 dB re 1 μPa at 1 m at low frequencies 10 to 1,000 Hz. In addition, outboard motor-driven dugout canoes, banana boats or dinghies used by estuarine and coastal communities generate typical noise source levels of about 163 dB re 1 μPa at 1 m when transiting at high speed (20 knots) and using the typical size of outboard motors (i.e., between 20 and 40 horsepower (HP). At slower transit speeds (<10 knots), the noise source levels are around 157 dB re 1 μPa at 1 m, while the noise source level at idling is typically less than 110 to 120 dB re 1 μPa at 1 m.

Based on the relatively sheltered location within Aievi Passage and data from Bittencourt et al. (2014), a baseline characterization of underwater noise at the Aievi Passage assessment location is assessed as a typical range of between 75 and 85 dB re 1 μPa rms, with TEP PNG contracted barges (i.e., 64-m-long MV *GFS Marine 01*) passing directly over the assessment location increasing the upper range value to 175 dB re 1 μPa rms at a mid-water depth (3 m)

5.2.2 Assessment Location 6 (Port Romilly)

Assessment Location 5 (7° 38' 48.01” S, 144° 50' 29.69" E) named ‘Port Romilly’ is located in the middle of the wide estuary of the Pie River into which the Wame-Varoi distributary flows. This assessment location was selected as there are few commercial ships transiting this estuary and there are virtually no villages along its low-lying nipa- and mangrove-lined banks.

The lower estuary of Port Romilly is about 1.8 km wide and is expected to be shallow (estimate of 8 m) at the assessment location. Therefore, most natural physical and biological noise sources will be the same as for the Aievi Passage assessment above. Port Romilly is a much larger and open and exposed estuary than Aievi Passage, therefore, wind and wave action may be expected to generate more noise than within the latter; however, anthropogenic noise sources are anticipated to be lower, given the lack of villages along the estuary banks and, therefore, fewer outboard motor-driven small watercraft transiting the estuary.

ERIAS Group (2016b) conducted community level surveys of villages along the Wame River and confirmed that local villagers stated that barges passed their villages, which means that barge traffic occasionally transit Port Romilly to enter the Wame River. It is suspected that the barges are indeed log ships or log barge-landing craft. In that case, the noise source level for a typical logging barge is 170 dB re 1 μPa at 1 m.

Overall, based on the relatively more exposed location within Port Romilly and data from Bittencourt et al. (2014), a baseline characterization of underwater noise at the Port Romilly assessment location is assessed as a typical range of between 80 and 90 dB re 1 μPa rms, with a logging barge/landing craft (e.g., the 45-m-long MV *Swift No. 5*) passing directly over the assessment location having a noise source level of 170 dB re 1 μPa at 1 m increasing the upper received noise range value to 164 dB re 1 μPa rms at a mid-water depth (4 m), which represents a transmission loss of 6 dB.

5.3 Nearshore Gulf of Papua

A baseline characterization of the nearshore marine environment of the Gulf of Papua within the Project’s export pipeline corridor was determined for two assessment locations:

- Assessment Location 1 (Caution Bay).
- Assessment Location 4 (Orokolo Bay).

The southeastern limit of the Gulf of Papua has been not clearly delineated based on a literature review. Therefore, the Caution Bay nearshore assessment location may actually be part of the northern Coral Sea. For the purposes of this technical paper, the Caution Bay assessment location has been included as part of the nearshore Gulf of Papua.

5.3.1 Assessment Location 1 (Caution Bay)

Assessment Location 1 (9° 18' 28.38” S, 146° 54' 9.03" E) named ‘Caution Bay’ is located at the northwestern approach taken by LNG carriers to the navigation channel leading to the PNG LNG marine terminal in Caution Bay. This assessment location was selected as it lies on a major shipping lane crossed by both LNG carriers as well as an array of coastal shipping (e.g., barges, container ships, fishing vessels). Altogether, shipping noise is relatively high at this location and regularly generates transient underwater noise that augments natural background noise.

In the absence of actively crossing or passing shipping, underwater ambient noise levels from natural sources will be dominated by sea surface noise (wind and wave action) in the 0.020 to 100 kHz frequency range due to the shallow water depth of 30 m at this location. In addition, transient natural biological sources will also be present, such as nearby snapping shrimp (60 to 90 dB re 1 µPa at 1 m in the 1 to 10 kHz frequency range). A typical range might be 65 to 85 dB re 1 µPa rms in the absence of shipping. Due to the presence of the major coastal shipping lane near the entrance to Caution Bay and regular LNG carrier and tug activity at the PNG LNG marine terminal in Caution Bay, a maximum transient noise of around 180 dB re 1 µPa rms at mid-water depth (15 m) could be expected from an LNG carrier passing directly over the assessment location.

Overall, a baseline characterization of underwater ambient noise at the Caution Bay assessment location is assessed as a typical range of between 90 to 110 dB re 1 µPa rms, with transient noise from a LNG carrier (passing directly over the assessment location) with a noise source level of 180 dB r re 1 µPa at 1 m (near the propellers at an assumed depth of 6 m) increasing the range upper value to 161 dB re 1 µPa rms at the mid-water depth of 15 m, which represents transmission loss of 19 dB. The adopted ambient background range includes higher frequency (1 to 10 kHz) biological noise sources, as well as low-frequency (10 to 500 Hz) from distant shipping (e.g., Great North East Shipping Channel to Torres Strait). The ambient noise range at the Caution Bay assessment location is higher than at all other assessment locations as may be expected given the increased frequency of shipping traffic in this shallow coastal area, as well as breaking surf, wind-induced breaking wave, and biological noise sources due to the presence of nearby coral reefs (e.g., snapping shrimps and other noise-emitting crustaceans, and soniferous fish).

5.3.2 Assessment Location 4 (Orokolo)

Assessment Location 2 (7° 52' 46.81” S, 145° 16'1 9.41" E) named ‘Orokolo Bay’ is located within the export pipeline corridor about 2.76 km from the shore, which is the mid-point of the three nautical mile zone. This site was selected to characterize the ambient noise levels typical of the nearshore environment close to coastal villages. The depth of the water at this location is about 12 m.

The nearshore environment at Orokolo Bay is shallow and natural physical noise sources will predominate, such as wind, sea state (waves), turbulence rainfall and surf. Natural biological noise sources, will include transient echolocation and communication sounds from marine mammals (e.g., inshore dolphins), fish choruses, stridulatory fish (e.g., some species of jewfish common in the area), fish choruses and distant snapping shrimp.

The main anthropogenic noise sources are expected to be alongshore transit of outboard motor-driven banana boats and dinghies. Outboard-driven dugout canoes may be expected to be less common than in the estuaries and rivers, given their small freeboard and instability under sea conditions. Transiting coastal village outboard motors are typically 20 and 40 horse power four-stroke engines, which generate a noise level of 155 dB re 1 µPa at 1 m at moderate speed (10 knots) and 165 dB re 1 µPa at 1 m at high speed (20 knots). In addition, TEP PNG contracted barges transit through this Orokolo Bay assessment location and generate a noise source level of between 170 and 175 dB re 1 μPa at 1 m at low frequencies 10 to 1,000 Hz.

In the case of the larger TEP PNG contracted barge (i.e., the 64-m-long MV *GFS Marine 01*) passing directly over the assessment location in Orokolo Bay, the noise source level of 175 dB re 1 μPa at 1 m (10 to 1,000 Hz) near the stern (propellers located at 2 m depth) produces a received noise level of 163 dB re 1 μPa rms at the mid-water depth level of 6 m at the assessment location, which represents a transmission loss of 12 dB.

In the case of a 40-HP outboard motor-driven banana boat driven parallel to the coast and at a distance of 2 km from the assessment location in Orokolo Bay, the noise source level of 163 dB re 1 μPa at 1 m (0.01 to 40 kHz) near the stern (propellers located at 1.2 m depth) produces a received noise level of 130 dB re 1 μPa rms at the mid-water depth level of 6 m at the assessment location, which represents a transmission loss of 33 dB over the intervening 2 km of shallow coastal water.

Overall, a baseline characterization of underwater ambient noise at the Orokolo Bay assessment location is assessed as a typical range of between 85 to 95 dB re 1 µPa rms, with noise from a transient barge passing directly over the assessment location or an outboard motor-driven banana boat 2 km away increasing the upper range value to 163 dB re 1 µPa rms or 130 dB re 1 µPa rms at mid-water depth (6 m).

5.4 Offshore Gulf of Papua

Ambient underwater noise in the offshore marine environment of the Gulf of Papua within the Project’s export pipeline corridor was determined for two assessment locations:

- Assessment Location 2 (South of Kerema).
- Assessment Location 3 (South of Ihu).

5.4.1 Assessment Location 2 (South of Kerema)

Assessment Location 2 (8° 15' 49.19” S, 145° 49' 52.70" E) named ‘South of Kerema’ is located within the export pipeline corridor about 35 km south of Kerema and on the inner continental shelf of the Gulf of Papua. This assessment location was selected as it lies outside the GOPPF trawling grounds and the main shipping routes of the Gulf of Papua, except for occasional trawler transits. The depth of water at this location is about 80 m.

This location lies outside the GOPPF reporting area known as Kerema Bay, which lies about 5 km to the north; however, a number of GOPPF trawlers occasionally transit the area of this assessment point. Trawlers underway at about 7 to 8 knots have a noise source level of around 155 dB re 1 µPa at 1 m at a peak frequency of 300 Hz. Below the stern of the trawler, the sound transmission loss using the spherical spreading formula described in Section 3.2.1 is about 32 dB giving a received sound level of 123 dB re 1 µPa rms at a mid-water depth of 40 m at this location.

Overall, the background ambient noise from natural physical and biological sources is expected to be in the range 75 to 95 dB re 1 µPa rms and, with the addition of low-frequency noise (10 to 500 Hz) from distant shipping, baseline characterization of ambient noise is assessed to be in the range of 85 to 95 dB re 1 µPa rms, with a trawler's passing directly over the assessment location increasing the upper range value to 123 dB re 1 µPa rms.

5.4.2 Assessment Location 3 (South of Ihu)

Assessment Location 3 (8° 5' 4.29" S, 145° 26' 26.81" E) named 'South of Ihu' is located within the export pipeline corridor about 15 km south of Kerema and on the inner continental of the Gulf of Papua. This assessment location was selected as it lies within the main trawling ground of the GOPPF reporting area known as Kerema Bay and it is also located on the transit route of TEP PNG exploration barges to and from Port Moresby to Herd Base on the Purari River in PRL-15, as well as log ships to and from the Evara logging camp on the Purari River and Port Moresby. The water depth at this location is about 50 m.

In the absence of actively crossing ships or active trawling, underwater ambient noise levels from natural sources will be dominated by sea surface noise (wind and wave action) in the 0.020 to 100 kHz frequency range due to the shallow water depth of 50 m at this location. In addition, residual noise from natural biological sources will also be present, such as nearby snapping shrimp (60 to 90 dB re 1 µPa at 1 m in the 1 to 10 kHz frequency range). A typical ambient noise range might be 65 to 85 dB re 1 µPa rms in the absence of shipping or active trawling.

In the presence of trawlers actively fishing at about 3 knots, the average noise source level is around 155 dB re 1 µPa at 1 m at a peak frequency of 300 Hz. Below the stern of the trawler, the sound transmission loss using the spherical spreading formula described in Section 3.2.1 is about 28 dB giving a received sound level of 127 dB re 1 µPa rms at a mid-water depth of 25 m at this assessment location.

Overall, the background ambient noise from natural physical and biological sources is expected to be in the range 75 to 95 dB re 1 µPa rms and, with the addition of low-frequency noise (10 to 500 Hz) from distant shipping, baseline characterization of ambient noise is assessed to be in the range of 85 to 95 dB re 1 µPa rms, with transient actively fishing trawler noise increasing the range upper value to 127 dB re 1 µPa rms.

6. Conclusions

This underwater noise desktop baseline characterization study was undertaken to assess the existing underwater acoustic environments (soundscapes) of representative rivers, estuaries, nearshore and offshore areas of the upstream Project area. The assessment has characterized the soundscapes for seven assessment locations and examined the contribution of both natural biological and physical noise sources and anthropogenic noise sources. The study assessed that the existing underwater noise levels along the offshore export pipeline corridor south of Kerema and Ihu (assessment locations 2 and 3) to be notably lower than other locations, ranging from 75 to 127 dB re 1 µPa rms at mid water depth. At these two locations, the ambient noise from natural physical and biological noise sources would include the wind, waves and snapping shrimp with distant shipping and trawlers being the main anthropogenic noise sources.

The proximity of the assessment locations to vessel traffic results in the upper noise levels (up to 175 dB re 1 µPa rms) being higher than the upper ambient noise levels reported in the literature for marine locations elsewhere in the world of up to 110 dB re 1 µPa rms

This underwater noise desktop baseline characterization study undertaken describes the underwater noise environments in the river, nearshore and offshore marine environments of the upstream Project to support the impact assessment of potential underwater noise impacts from Project development activities in the EIS/ESHIA.

7. Data Limitations

The baseline characterization of underwater noise in this technical paper provides a reasonable but basic picture of the baseline underwater sound environments of the Gulf of Papua, Purari Delta and Caution Bay, which is based mainly on a literature search. Both natural and anthropogenic noise vary widely in space and time, depending on wind and surface water states, as well as whether vessels are transiting an assessment location directly or nearby; however, based on the literature review and published measured ambient noise levels in the marine and coastal water environments, the present desktop characterization of ambient underwater noise in the PAOI is sufficient for the purposes of undertaking an impact assessment in the EIS/ESHIA.

8. Abbreviations and Glossary

8.1 Abbreviations

The following abbreviations are used in this technical report:

µPa: microPascal

%: per cent

AIS: Automatic Identification System

CEPA: Conservation and Environmental Protection Authority

dB: decibel

dB re 1 µPa at 1 m: decibels with reference to 1 microPascal at 1 m (sound source level unit)

dB peak: decibels measured in terms of peak sound pressure

dB rms: decibels measured in terms of root-mean-square pressure

DP: dynamic positioning

DEC: Department of Environment and Conservation (forerunner to CEPA)

DWT: Dead Weight Tons

EHS: environmental, health and safety

EIR: Environmental Inception Report

EIS: Environmental Impact Statement

EP: Environmental Plan (forerunner to the EIS in Papua New Guinea)

ESHIA: Environmental, Social and Health Impact Assessment

ft^3: cubic feet

GIS: Geographic Information Systems

GOPPF: Gulf of Papua Prawn Fishery

HSC: High Speed Craft

IFC: International Finance Corporation

IMO: International Maritime Organization

km: kilometer

kg: kilogram

kHz: kilohertz

km: kilometer

km/h: kilometers per hour

KML: Kumul Marine Terminal

L: liter

L/s: liters per second

LNG: liquefied natural gas

LPG: liquefied petroleum gas

m: meter

MV: Motor Vessel (vessel class prefix)

NFA: National Fisheries Authority

NMSA: National Maritime Safety Authority

Pa: Pascal

OCIMF: Oil Companies International Marine Forum

OVMSA: Offshore Vessel Management and Self Assessment

PNGPCL: Papua New Guinea Ports Corporation Limited

RV: Research Vessel (vessel class prefix)

SL: Smit Lamnalco (vessel class prefix)

SOLAS: Safety of Life at Sea

TEU: Twenty-foot Equivalent Unit

8.2 Glossary

abiotic; physical rather than biological; not derived from living organisms.

ducted: channeling of sound waves between the sea surface and seabed in shallow water.

hydrophone: an underwater microphone that will listen to, or pick up, acoustic signals.

peak sound pressure (or zero-to-peak (0–P) sound pressure): the maximum sound pressure during a stated time interval. A peak sound pressure may arise from a positive or negative sound pressure, and the unit is the Pascal (Pa). This quantity is typically useful as a metric for a pulsed waveform, though it may also be used to describe a periodic waveform.

peak to peak (P–P) sound pressure: the sum of the peak compressional pressure and the peak rarefactional pressure during a stated time interval. This quantity is typically most useful as a metric for a pulsed waveform, though it may also be used to describe a periodic waveform. Peak-to-peak sound pressure is expressed in pascals (Pa).

received level (RL): a somewhat imprecise term meaning the level of an acoustic quantity at a specific spatial position within an acoustic field, usually the position of a marine receptor (which could be a hydrophone or an animal).

root mean square (rms) sound pressure: the square root of the mean square pressure, where the mean square pressure is the time integral of squared sound pressure over a specified time interval divided by the duration of the time interval.

soniferous: capable of producing sound, such as in some fish species with air bladders.

sound energy: the energy contained in a sound wave in a specified time duration. For an acoustic pulse, it is the total energy contained in the pulse when radiated by the source, and is equal to the spatial integral of the sound energy flux density over all directions. The unit is the joule (J).

sound exposure level (SEL): total noise energy over a measurement period expressed in units of referenced to 1 microPascals-squared in one second (i.e., dB re 1 $\mu Pa^2 \cdot s$). The SEL is commonly used for impulsive noise sources because it allows a comparison of the energy contained in impulsive signals of different duration and peak levels.

sound intensity: the average amount of sound energy transmitted per unit time through a unit area in a specified direction.

sound pressure level (SPL): the unit is the Pascal (Pa), which is equivalent to a Newton per meter squared (N/m^2), as defined by the International System of Units (S.I.). The SPL unit is expressed in terms of dB referenced to 1 microPascal at 1 meter (i.e., dB re 1 μPa at 1m), where ‘re’ denotes ‘with reference to’. A 10 dB increase represents a ten-fold increase in power, a 20 dB increase would be a 100-fold increase and 30 dB would be a 1,000-fold increase.

source level (SL): source level decibels referenced to 1 m from sound source.

spectral density: any quantity expressed as a contribution per unit of bandwidth. An example is sound exposure spectral density, expressed in units of Pa2·s/Hz.

stridulatory: the act of producing sound by rubbing together certain body parts.

9. References

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 9: Existing Environment – Social, Economic and Cultural

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TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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9. Existing Environment – Social, Economic and Cultural

9.1 Study Overview

The information in this chapter has been prepared from the following baseline reports, where further, more detailed information can be found:

- Upstream Community and Demographics Baseline Report (Part 14 of Volume 2).
- Upstream Governance and Economics Baseline Report (Part 15 of Volume 2).
- Upstream Community Health Baseline Report (Part 16 of Volume 2).
- Upstream Cultural Heritage and Archaeology Baseline Report (Part 17 of Volume 2).
- Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2).
- Marine and River Traffic and Transport Baseline Report (Part 22 of Volume 2).

The baseline characterization presented in each of these reports is based on a literature review and primary data collected through a community-level survey from 15 May to 3 June 2016, household survey from 14 August to 12 September 2016 and consultation with key stakeholders, as outlined in Chapter 6 and detailed in each of the social baseline reports. Traffic surveys relevant to the marine and river traffic and transport report were conducted during the freshwater and estuarine surveys in February 2017. Information has also been drawn from a human rights impact assessment (DIHR, 2017) focusing on the key topics of gender, security and conflict.

All the communities in the Project area of influence (PAOI) were surveyed as part of the community-level surveys. Those surveys revealed that several communities had the same history, the same cultural beliefs and traditional practices, as defined by language group, and the same patterns of natural resource use depending on their environmental setting or ecological zone (further described in Section 9.2.1). Combined, the surveys found that, in the PAOI, groups of communities had similar daily activities, lifestyles and values with little variability between those that shared language or ecological zone. The household survey was therefore conducted across a sample of communities from each language group and ecological zone.

The upstream study area for the social baseline studies comprises a local study area and a regional study area. The local study area corresponds with the PAOI, as described in Chapter 1. The regional study area includes the relevant provincial, district and local level government (LLG) areas. For the upstream study area, this includes Gulf Province, Kikori District, Baimuru Rural LLG and Ihu Rural LLG (Figure 9.1).

Throughout this section, where data is presented from the community-level surveys, the villages of Akoma and Kairu’u are presented as one community and shown with the hyphenated name Akoma-Kairu’u. This is because the villages are close to each other. While they retain their individual identities, they function as one community and were therefore presented together in the community-level surveys. The same applies to Ere and Kilavi which are shown in data tables herein as Ere-Kilavi and Oru, Lariau and Herekela, which are shown in data tables herein as Oru-Lariau-Herekela.

PROVINCIAL, DISTRICT AND LOCAL LEVEL GOVERNMENT AREAS

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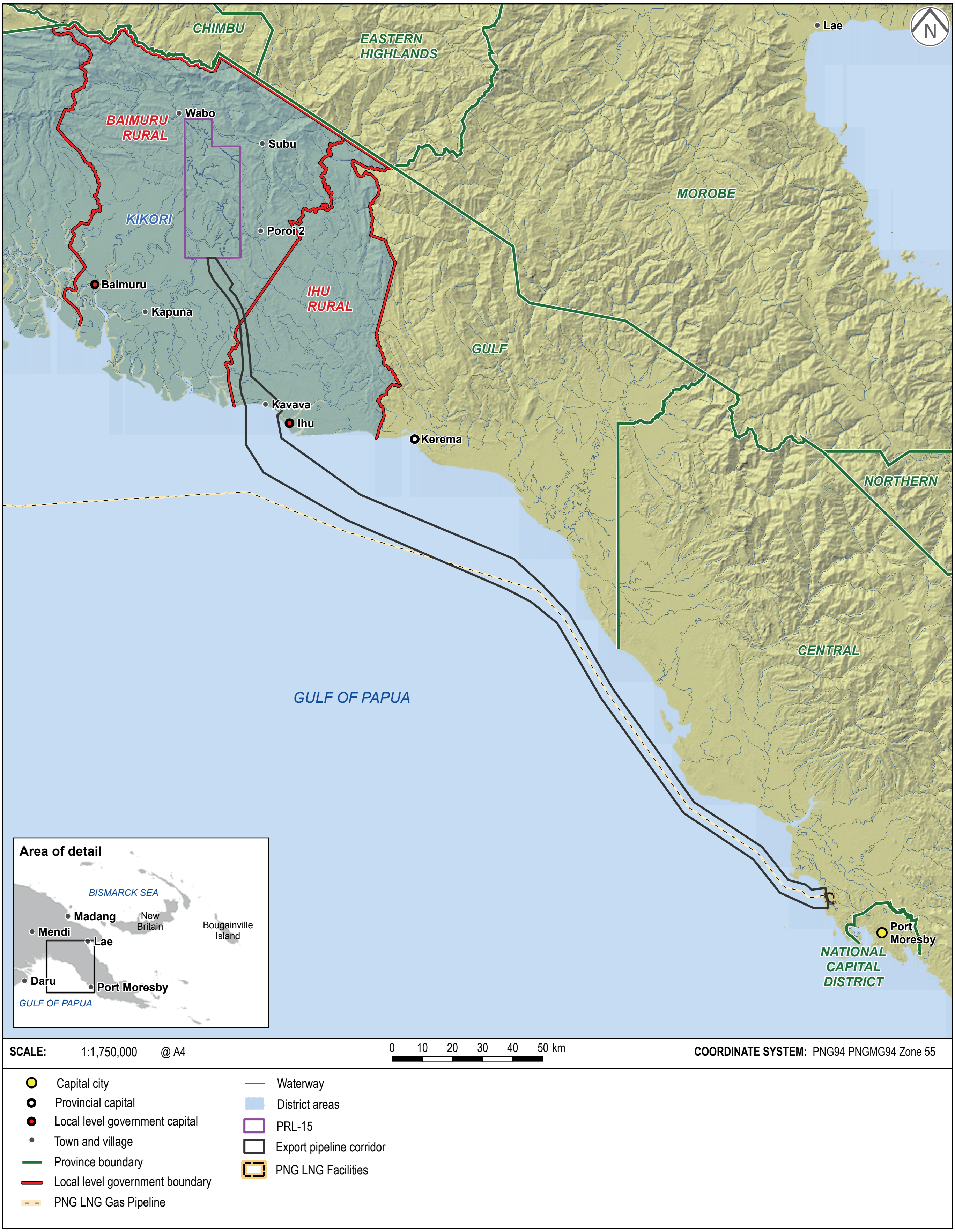
FIGURE 9.1



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9.2 General Setting

9.2.1 Communities and Language Groups

The Project is in Gulf Province, Papua New Guinea, in the Kikori District and extends across the Baimuru Rural LLG and Ihu Rural LLG areas (see Figure 9.1). Thirty-nine villages and one government station occur in the PAOI (see Figure 3.2 and Section 9.5).

Seven distinct community groups exist in the PAOI, defined by the language they speak, i.e., Pawaia, Koriki, Iare, Ahia, Kaimare, Maipua and Orokolo; and villages in each language group have similar history, cultural beliefs and traditional practices. Traditional language, known locally as *tok ples*, is typically the first language of all villagers, although villagers usually have degrees of fluency in other Papuan languages, such as Tok Pisin and Hiri Motu, and in English. The traditional language is seen as fundamental in maintaining cultural values and thus the cultural identity of each village.

The language group is one of two features that contribute strongly to the homogeneity of the seven community groups in the PAOI; the second is the ecological zone, i.e., the environmental setting in which communities are located (Figure 9.2). Ecological zones are described in Section 7.7.3. The language that people speak defines where they came from, their ancestors and their ancestral migration history, i.e., from the land on which they originated to the land they occupy in the present. As a result, it defines their cultural values, with whom they communicate, trade and marry and, in many cases, the behavioral and social norms they are expected to observe. Language and membership of a language group influences different individuals, clans and villages to behave similarly on cultural and social matters whether they live in nearby or not.

People in the PAOI depend significantly on their natural resources for survival and wellbeing; therefore, their environmental setting significantly influences their day-to-day activities. Communities that have access to the same natural resources have similar resource use patterns and undertake similar daily activities. The natural resource use pattern and the language group illustrate the homogeneity of communities that share a language and an ecological zone. This is unremarkable, as the ecological zones themselves are based on natural characteristics upon which communities have developed particular subsistence dependencies; therefore, while language affiliation defines residency, marriage patterns, trade relationships and cultural values, among other things, the environmental context in which people live (environmental setting) determines subsistence practices, hunting and gathering activities, water availability, food intake, travel patterns and access constraints, among others. Thus, in the context of the PAOI, a community's language group and the ecological zone in which they live are seen to significantly define how those people live from day-to-day. Table 9.1 shows the villages in the PAOI by language group and ecological zone.

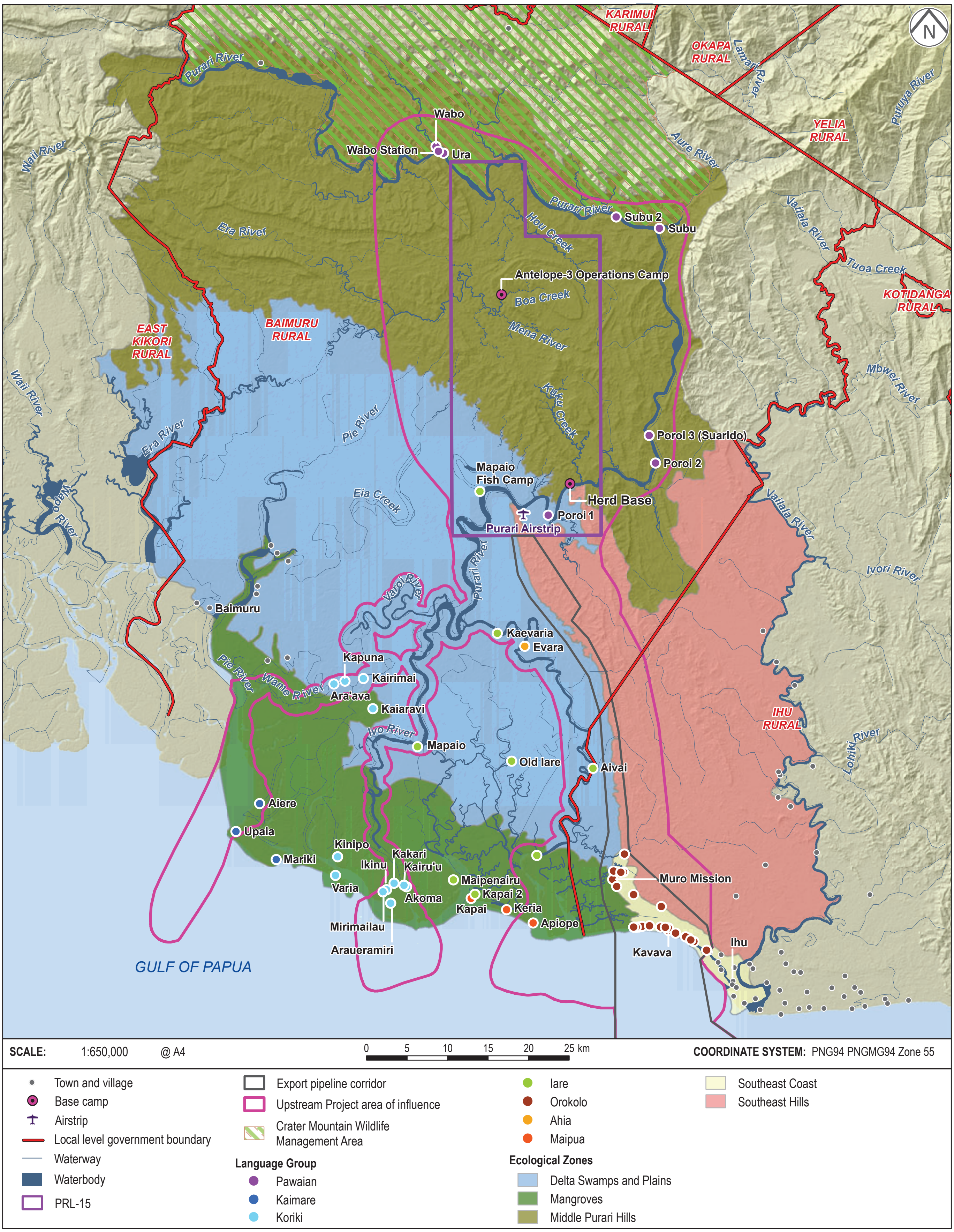
PRL-15 is largely unpopulated, with the Pawaia[1] people being the principal users of the PRL-15 area. Pawaian speakers reside in 14 villages in Gulf, Simbu and Eastern Highlands provinces. Approximately 4,000 people across these villages speak the Pawaian language (Lewis et al., 2016). Only two small villages[2] are in PRL-15[3]; Poroi 1 and Mapaio Fish Camp; the first is a Pawaia village, and the second is a settlement of Iare people. They are located on the Purari

1 Pawaia is a linguistic reference to a group of people who speak the same language and reside in a defined geographical territory rather than to a tribe (Kinkin & Kewibu, 2008).
2 Also known as hamlets, small settlements that associate as part of larger villages.
3 In this chapter, further references to villages and cultural heritage in PRL-15 consider the wider communities in and around PRL-15 in the PAOI.

UPSTREAM LANGUAGE GROUPS AND ECOLOGICAL ZONES

Papua LNG Project | Environmental Impact Statement

FIGURE 9.2



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context. Language group does not represent land ownership.

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River in the southern part of the license area. A government station (Wabo Station) and six Pawaia villages are located outside but near PRL-15 on the Purari River.[4]

Table 9.1 – Language Groups and Ecological Zones in the PAOI

Project Area	Language Group	Ecological Zone	Village/Station
PRL-15[1]	Pawaia	Middle Purari Hills and Delta Swamps and Plains	Poroi 1, Poroi 2, Poroi 3 (Suarido), Subu, Subu 2, Ura, Wabo, Wabo Station
River Transport Corridor[2]	Ahia	Delta Swamps and Plains	Evara
	Koriki	Delta Swamps and Plains and Mangroves	Akoma-Kairu'u, Ara'ava, Ikinu (including the hamlets of Mirimailau and Araueramiri), Kairimai
	Iare	Delta Swamps and Plains and Mangroves	Aivai, Aumu, Kaevaria, Mapaio, Mapaio Fish Camp (Nea Creek)
	Kaimare	Mangroves	Aiere, Upaia
	Maipua	Mangroves	Apiope*
Export Pipeline Corridor	Orokolo	Southeast Coast	Arehava 2, Avavu, Ere, Harevavo, Hepere, Herakela (including the hamlet of Hiloi), Hohoro, Huruta, Iuku, Kaivukavu, Kavava (including the hamlets of Hururu, Mirimurua and Miha-Kavava), Kilavi, Larihairu, Lariau, Marea, Mareke, Oru, Paevera

* Only one Maipua village is located in the PAOI, but three Maipua villages were surveyed for sample robustness. This table shows villages in the PAOI.
[1] The Mapaio Fish Camp is in PRL-15 but is an Iare settlement, listed under River Transport Corridor.
[2] Except for the Mapaio Fish Camp, which is in PRL-15.

In the northern part of the river transport corridor in the village of Evara are the Ahia speakers that originate from the Vailala River catchment to the east. Ahia has been classified as a dialect of the Keoru-Ahia language. While some 6,000 people speak Keoru-Ahia, only 700 people speak the Ahia dialect (Lewis et al., 2016).

Toward the coast, the onshore export pipeline corridor presents a relatively diverse social situation with a generally low inland population scattered or concentrated in small villages along riverbanks between Muro Mission (the Muro area) and Orokolo Bay. Much denser population resides in larger villages and hamlets along the gulf coastal strip of Orokolo Bay. Orokolo-speaking people inhabit this area. Approximately 10,000 people speak the Orokolo language, some of whom reside outside the PAOI).

The Koriki, Iare, Kaimare and Maipua languages are spoken by people living along the three Purari River delta distributaries, that may be used for Project transport and related activities, namely, the Purari, Urika-Ivo and Wame-Varoi rivers, called herein the river transport corridor. People from these language groups indicated that there is some commonality in their languages and in their ability, therefore, to have some understanding of each other's language; however, they differentiated between the languages. The number of people living in the villages in which these languages are spoken is relatively small (ERIAS Group, 2016a; NSO, 2013), as follows:

- Koriki – approximately 2,500.
- Iare – approximately 2,200.
- Kaimare – approximately 1,200.

4 Two other stations are in the PAOI (but not in the PRL-15 area) – the Kapuna Health Center is on one and the Muro Mission is on the other. Neither of these station areas accommodates 'communities' as such, but rather only the staff, patients or students attending the facilities. Thus, they are not considered 'communities' in this report.

- Maipua – approximately 400.

An estimated 36 migrant families live in villages in the PAOI, excluding those living on Wabo Station.[5] Conversely, 70% of villages in the PAOI indicate that 'more than 100 people' from their village have moved away to live in other parts of Papua New Guinea. In the past, out-migration has greatly exceeded in-migration, although in-migration has occurred at Ura and Wabo Station over the past decade.

9.2.2 Historical Context

The Pawaia people traditionally are semi-nomadic, living in small settlements. Until the 1920s, the Pawaias lived north of the Purari River in a remote, mountainous area encompassing parts of Gulf, Simbu and Eastern Highlands provinces. Today, villages are larger and more permanent than they were during pre-European contact times; however, family groups still spend long periods in temporary camps for subsistence purposes. Pawaia people have had limited interactions with outsiders and communities to the south, although prior to the 1940s, they obtained *Hiri*[6] shell valuables from coastal villagers, which they exchanged for bird of paradise feathers. In the 1960s, the then colonial government[7] and Christian denominations encouraged Pawaia people to establish permanent settlements for the provision of services and religious instruction. The settlements of Ura, Wabo and Poroi 2 were reportedly established in 1974 as a result of the proposed Purari River Dam Project;[8] although, it is likely the Pawaias had temporary fishing camps in the vicinity much earlier. Poroi 1 was established in the 1950s, abandoned and then re-established in 2007. Subu was established in 1996. The villages of Poroi 3 (Suarido) and Subu 2 were more recently established, in the case of the latter, because of significant flooding of Subu in 2014 when approximately half of its residents relocated.

The combination of small-sized settlements, frequent relocations, a limited inventory of material cultural items, and environmental conditions that are not conducive to preserving archaeological materials has created a situation whereby Pawaia cultural activities have left rare and faint archaeological signatures (Part 17 of Volume 2).

The people living along the riverways on the Purari River delta (i.e., from the Iare, Kaimare, Koriki and Maipua language groups) share common cultural practices. In the past, villages in this area were much larger than today and sometimes home to more than 2,000 people. These large villages were structured around men's houses called *ravi*. Each *ravi* was the focus of social and cultural life for the section of the village with which it was associated. The Koriki, Iare, Maipua and Kaimare language groups indicated that they all originated from further up the Purari River and relocated southward over time. It appears that villages were initially established in the Purari River delta between World War I and World War II, possibly to be closer to government services, with coastal villages being established after World War II, often in an attempt to grow coconuts and access coastal shipping services to sell copra.[9]

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5 A community-level survey was not undertaken at Wabo Station; however, the household survey indicated that five of the seven families living at Wabo Station were born elsewhere.

6 *Hiri* is the name for the traditional trade voyages that carried the much-prized Motu cooking pots to the people of the Gulf of Papua and brought back plentiful supplies of sago for the Motu.

7 Between 1951 and 1964, Papua New Guinea was governed by a 28-member legislative council set up by Australia, and by a judiciary and a public service. An elected House of Assembly replaced the council in 1964.

8 The proposed Purari River Dam Project involved a feasibility study for a dam on the Purari River near Wabo. The Australian Snowy Mountain Engineering Corporation, the Japanese Nippon Koei, and the Government of Papua New Guinea jointly commissioned the study.

9 Copra is the dried meat or kernel of the coconut.

The Orokolo speakers also believe they originate from the middle or upper reaches of the Purari River. They moved to a location known as Popo, from where they dispersed to their current locations along Orokolo Bay and inland in the area surrounding Muro Mission (Muro area), approximately 10 km inland from Orokolo Bay. The ancestral Popo village site (Plate 9.1) is of archaeological note. Archaeologist Jim Rhoads investigated the site in 1976, and his excavations indicated the site was used around 400 years ago with evidence of Motu *Hiri* trade.

Plate 9.1 – Cultural Heritage at Popo

Photo: Robert Skelly.

Also in the Orokolo Bay area are the archaeological investigations east of the PAOI and east of the Vailala River that have revealed pottery with decorations stylistically akin to those found on Lapita pottery. Lapita peoples were the bearers of the earliest known ceramic tradition in the Oceanic region. Lapita ceramics first appeared in the Bismarck Archipelago, east of mainland Papua New Guinea, from 3,470 to 3,250 cal BP[10] (Denham et al., 2012). At the time, Lapita peoples were expanding westward along the south coast of Papua New Guinea. Lapita people are likely to have established a presence on the ancient beaches of Orokolo Bay; therefore, it is possible that Lapita and post-Lapita sites of national and international significance may occur on the deflated dunes and beach plains 2 to 7 km inland from the present-day coastline in Orokolo Bay.

Research shows that, some 1,200 to 1,500 years ago, pottery sherd deposition increased ten-fold, suggesting that populations were flourishing during a period of increased communication and interactions between beach-fronting villages on the south coast of Papua New Guinea (Skelly, 2014). Then a 500-year-long cultural hiatus appeared that corresponds with the Ceramic Hiccup, a period of social disruption that affected villages from the Kikori River delta in the west and eastward as far as Caution Bay near Port Moresby.

People returned to the south coast some 700 years ago, and cultural activity in coastal villages appears to increase some 300 to 500 years ago, likely signaling the emergence of social relationships antecedent to the ethnographic *Hiri*. The *Hiri* involved annual trading voyages by Motu and Koita seafarers from villages near present-day Port Moresby. These voyages involved large fleets of trading vessels sailing to the Gulf of Papua to exchange pots (Plate 9.2) for sago.

10 Calibrated years before the present.

Plate 9.2 – *Hiri* Trade Pots

Photo: Robert Skelly.

The Ahia people originate from the middle reaches of the Vailala River southeast of Evara and have generally been known as the Kaura in the past. Residents of Evara are predominantly from the Uhe tribe. Their settlement history was not disclosed, possibly because they are involved in court cases connected to land ownership and logging.

All villages in the PAOI maintain ancestral oral traditions that detail ancestral migration stories and clan origins. Generally, ancestral migrations are thought to be due to social disruption and changing environmental conditions. In addition, coastal progradation is cited as a core theme in the oral traditions of ten villages (i.e., Kairimai, Kaevaria, Upaia, Harevavo, Kavava, Kaivukavu, Larihairu, Iuku, Marea and Mareke).

All communities trace clan origins inland, often to highland locations outside the PAOI except the villages of Marea, Iuku and Kavava located in eastern Orokolo Bay, where migrations reportedly commence from the Vailala River headwaters and track northeast. The migrations from the highlands generally tracked southward toward the headwaters of the Purari River.

Specific details of ancestral migrations are typically confidential within clans and are passed from father to son. The exception is Upaia where ancestral migration stories are passed on to both sons and daughters. The method of maintaining and protecting ancestral migration stories within each individual clan rather than sharing them across the broader community has the potential to increase their vulnerability to loss; this concern was specifically expressed by community members at Ere and Kilavi.

9.2.3 Land Ownership

The people's contemporary connection to their land is based in their ancestral origins. The majority (97%) of land in Papua New Guinea is under customary ownership, and most of the population resides on customary-owned land where it has a right to live and a means to produce. In the PAOI, all land is customary owned except Wabo Station, Muro Mission and Kapuna Health Center, which have been alienated. Alienated land is no longer held under customary ownership because it has been excised by the Government as either state land (2%) or private freehold land, including conditional freehold land (1%). Wabo Station is a government station. Muro Mission and Kapuna Health Center are mission stations on which services, such as education and health facilities, were established.

Land ownership in the PAOI is vested in clans or groups of families with a common lineage. Clan land generally includes common areas of land in which all clan members can fish, hunt and collect resources and specific land areas allocated to families where people will live and make gardens. Land areas allocated to families are most often the more fertile where gardens can be grown and, because of this fact, are generally close to where villages have been established.

The clan leader, almost always a male, grants usufruct rights on behalf of the clan to control, manage and use the land. The land is generally held on a patrilineal basis, passing from father to the first-born son; however, it is not the ownership of the land that is inherited, as the land remains with the clan, but the right to use the land.

9.3 Governance

9.3.1 Traditional Leadership

As described in Section 9.2, in the PAOI, people are unified by language. Some language groups have a leadership hierarchy, while others vest leadership at a clan level, e.g., among the Orokolo communities, there exist multiple clan leaders and a paramount chief, that is, a clan leader chosen to represent all the clans, not just the clan from which he originates.

A clan is a group of families with a common ancestor. A clan will identify themselves and their customary-owned land through oral histories, including genealogies, stories, beliefs, customs and practices. Most clan members live on their customary-owned land, although urban migration is changing this. Clan ownership of customary-owned land is recognized in the Constitution of the Independent State of Papua New Guinea. Clan leaders are usually older males and are often the first-born male of the previous clan leader.

Most rural Papua New Guineans have rights over land as part of a clan; therefore, they generally have the means to provide their basic needs and a sense of independence (Jones & McGavin, 2015). The clan, however, provides a broader safety net for its community. The *wantok* system reinforces the primary allegiance to one’s clan, placing the obligation of kinship, along with the expectation of reciprocity, on its members (Mohanty, 2011). At the same time, it can place pressure on its people to provide money or favors to *wantoks*.

Clans in the PAOI continue to practice, to varying degrees, some level of traditional leadership. Traditional clan leaders have the authority to speak on behalf of their community, although consultation among the group may be expected before decisions are made or shared with outsiders.

One of the most important roles of traditional leaders is to manage communally owned land. This may involve educating other members about the land boundaries and their history; defending the boundaries; allocating land to families or family groups, e.g., for food gardens; and overseeing any decisions that involve the use of communal land.

The role of traditional leaders has changed as government officials and church leaders have played more prominent roles in various aspects of village life.

9.3.2 Religious Leadership

The spread of Christianity in Papua New Guinea from the 1800s had a marked effect on traditional society, including introducing a new layer of village leadership. The churches played a major role in expanding plantation agriculture, in particular coconut and copra production in Papua New Guinea, and expanding schools and health services in rural areas. Church agencies continue to play an important role in delivering both health and education services. Church leaders participate in the functioning of the village in terms of leadership, e.g., maintaining the peace, resolving disputes, and providing youth leadership and support for the elderly and other disadvantaged groups.

Most (i.e., 97%) villages reported having religious leaders during baseline surveys.

9.3.3 Government Administration

Governance in Papua New Guinea is also the role of government, which, under the Constitution of the Independent State of Papua New Guinea, balances contemporary and traditional leadership. The constitution declares the underlying law to consist of the constitution, customary law and common law – indicating the importance and complexity of a governance system that prioritizes both traditional custom and a modern administration system.

Papua New Guinea's public sector includes three tiers of government (i.e., national, provincial and local) and the national public service, which has staff based at national, provincial, district and local government levels.

The top tier is the National Government, headed by a Prime Minister. The Prime Minister is appointed by the Governor-General on the proposal of having been elected by Parliament. The cabinet, known as the National Executive Council (NEC), is appointed by the Governor-General on the recommendation of the Prime Minister. At the national level, the country is divided into four regions: Highlands, Islands, Momase and Southern.

Papua New Guinean provinces are administrative divisions representing branches of the National Government rather than a federation of provinces. There are 20 provinces, one autonomous region (Bougainville) and one capital district (National Capital District). The upstream Project is in Gulf Province,[11] which is in the Southern Region with its capital located at Kerema. Appointed provincial administrators administer each province. The NEC makes appointments at the recommendation of the Provincial Executive Council and Department of Personnel Management.

The administrative divisions in the provinces are districts and, within the districts, LLG areas. For census purposes, each LLG area is divided into wards, and the wards are divided into census units. A ward may contain more than one village. Gulf Province is divided into two districts: Kerema and Kikori. The Project is in Kikori District, which has its capital in Kikori. The Provincial Administrator appoints the district administrators, who administer each district.

The Kikori District comprises the LLG areas of Baimuru Rural, East Kikori Rural, Ihu Rural and West Kikori Rural. The Project is in the Baimuru Rural and Ihu Rural LLG areas. Elected LLG presidents administer the LLGs. Baimuru Rural LLG area contains 23 wards and 45 census units, while Ihu Rural LLG area contains 22 wards and 76 census units. Eighteen wards occur in the PAOI, representing 39 villages; and an elected ward councilor represents each ward.

Following independence in 1975, Papua New Guinea's provinces were assigned responsibility for delivering core basic services, although the provinces remained under National Government control. In 1998, new legislation (*The Organic Law on Provincial Governments and Local-level Government 1998*) was introduced to achieve further decentralization. The reforms intended to relocate many public servants to outlying areas in an attempt to bring services to the people. The reforms also proposed to strengthen a bottom-up system of representation, where the people elected their ward representatives and one of the ward representatives was elected as the LLG President, a position often referred to as the councilor. Although the LLGs have broad powers, including the ability to make local laws, they receive limited funding from the National

11 Chapter 9 (this chapter) characterizes the social, health and cultural setting of the upstream Project components in the Gulf Province only. Baseline information on marine fisheries and resources is presented in Chapter 8.

Government and, in most parts of Papua New Guinea, face challenges in delivering services due to capacity constraints and a lack of support from national or provincial government.

The National Government has recently introduced several further changes to improve service delivery, including increased funding for the provincial, district and LLG services improvement programs.

A ward councilor is supposed to represent each village, have a ward development committee, and be represented by a village court and land mediator; however, only 13 of 35 villages surveyed[12] have all four positions in place. Orokolo villages are better organized from a government perspective, which may reflect the closer proximity and easier access of these villages to Kerema compared to some other villages in the PAOI. By contrast, relatively few Pawaia villages have a government presence, which is attributed to the relative isolation of the Pawaia villages. It may also be a consequence of smaller villages, particularly for Poroi 1, Poroi 3, Subu and Subu 2.

Other than education and health facilities, many of which are managed by church agencies, government agencies have a minimal presence in the PAOI villages and have limited influence on the villagers' day-to-day lives.

9.3.4 External Support

External support or assistance provided to a village for any public goods has been provided to all but five villages in the PAOI in the past. By far the most common source of external support has been for water supplies; however, assistance has also been provided for schools, health facilities and communications. According to the communities surveyed, assistance has been provided by the European Union, the Department of Foreign Affairs and Trade (formerly called AusAID), the Japanese International Cooperation Agency, the previous PRL-15 operator InterOil, PNG Energy Developments Limited (no longer operating), logging companies and the Kapuna and Muro missions.

No non-government organizations have a permanent presence in the PAOI, although Médecins Sans Frontières has recently established a base at Ihu, east of the PAOI, to implement a program to help combat tuberculosis and aims to establish another base at Kapuna.

9.4 Economy and Employment

9.4.1 Large-scale Industry

The formal economy in Papua New Guinea is dominated by resource exploration and production, commercial agriculture, tuna processing, logging and a small manufacturing sector. The informal economy, which supports approximately 85% of the population, is primarily dependent on subsistence agriculture (ADB, 2015).[13] Papua New Guinea has experienced strong growth in gross domestic product over the past decade, with much of the growth in 2014 and 2015 attributed to the PNG LNG Project.

The main large-scale industries in Gulf Province are oil production and petroleum exploration, prawn fishing and logging. Since 1998, oil has been extracted from the Gobe Main and South East Gobe oil fields located in the Kikori River catchment. Although not yet in operation, the

12 All 39 villages in the PAOI were surveyed as part of the social baseline surveys; however, at four locations, for the reasons described in Part 23 of Volume 2, a selection of key information, as opposed to the full suite, was collected. Therefore, for some topics in this section, the report describes the findings from 39 villages and for others for 35 villages.

13 The informal economy is not monitored by any form of government nor is it taxed. Unlike the formal economy, activities of the informal economy are excluded from the gross national product or gross domestic product.

Papua LNG Project has provided a source of local employment and various other services, particularly among Pawaia villages, during its exploration and development stages.

Most of PNG's prawns are captured in the Gulf of Papua; however, all are processed in Port Moresby. The province contains five large-scale logging operations; however, benefits from logging are not acknowledged at the community level, and the provincial government does not benefit financially (Gulf Provincial Government, 2011).

The only large-scale economic activity in operation in the PAOI is the Vailala Block (Blk) 3 logging project operated by Frontier Holdings. Activity in Vailala Blk 3 is reportedly winding down and Frontier Holdings is expected to move into Vailala Blk 2 within the next year or two (Part 7 of Volume 2). Turama Forest Industries has a permit to log in Baimuru Blk 3, which covers all of PRL-15, but no logging is occurring at present. Both Frontier Holdings and Turama Forest Industries are affiliates of the Rimbunan Hijau (PNG) Group, a Malaysian logging company. Vailala Blk 3 operates over 196,353 ha, some of which overlap the eastern part of the PAOI. Volumes available for harvesting from the forest are of relatively low quality and are the equal lowest in Papua New Guinea. The main commercial species (i.e., *Terminalia* spp. and *Pometia pinnata*) account for approximately 10% of the available saleable volume (Part 7 of Volume 2). Barges transport logs from the logging area on the Purari River distributaries. As shown in Table 9.2, only 6% of males over 16 years in the PAOI are currently employed in logging or milling. Previously, 9% of males and 8% of females over 16 years in the PAOI have worked in logging or milling.

Other high-value but small-scale forestry products are available from the PAOI. These include eaglewood, which is harvested across Papua New Guinea for its aromatic resin, and massoy bark. Massoy bark, harvested from *Cryptocarya massoia* trees, is likely to occur in the hill forests of the PAOI; however, there is no known commercial harvesting of these products in the PAOI.

Small-scale forestry is almost absent from the PAOI other than at Paevera where a portable sawmill is based.

9.4.2 Small-scale Industry

Until the 1980s, the Papuan coast was a major source of copra, and copra was the main source of income for coastal villages. Since coastal shipping services stopped, local people have turned to commodities that could be sold locally or commodities with higher unit values that could be transported economically outside the local area.

The most common sources of income in the PAOI are the sale of betel nut (Plate 9.3), fish, crabs, garden produce and sago (Plate 9.4); this is discussed further in Section 9.5.5.1. Small business activities such as selling fuel and operating trade stores also contribute to household income for some people (Section 9.5.5.1).

Plate 9.3 – Betel Nut is the Main Source of Income for Many PAOI Villages

Plate 9.4 – Garden Produce at Kaivukavu Market

Photos: ERIAS Group.

9.4.3 Employment

Most people in the PAOI are involved in subsistence activities and are not formally employed (see Section 9.8.7). During the household survey, only 15% of males and 7% of females reported to be in formal employment. The most common jobs include teachers, village court officials and ward councilors, carpenters and pastors (Table 9.2).

The main employers are the government, which employees 32% of people, church groups (19%) and TEP PNG (13%). Other employers are likely to be stores and business activities outside the PAOI. Most (60%) people, whether in formal or informal employ, work in the village in which they live.

Table 9.2 – Current and Previous Employment (People Aged 16 Years and Over) (%)

Employment Type	Current Employment Males	Current Employment Females	Previous Employment Males	Previous Employment Females
Laborer	6	5	15	8
Pastor	8	5	7	9
Policeman	5	0	0	0
Village court officials/ councilors	10	12	1	1
Logging/milling	6	0	9	8
Fisher	0	0	1	0
Driver	3	0	4	5
Carpenter	10	2	11	0
Mechanic	1	2	3	1
Electrician	1	0	2	0
Welder	1	0	2	0
Pipefitter	0	0	1	0
Loadmaster	3	2	4	2

Table 9.2 – Current and Previous Employment (People Aged 16 Years and Over) (%) (cont'd)

Employment Type	Current Employment Males	Current Employment Females	Previous Employment Males	Previous Employment Females
Stevedore	1	0	1	1
Supervisor	0	0	1	2
Operations/maintenance	0	0	2	0
Administration/office/clerical	2	5	6	17
Cook/catering	5	5	9	6
Security	4	5	8	1
Cleaner	2	0	0	2
Teacher	9	37	2	5
Health worker	4	2	0	2
Other technical jobs	0	0	5	3
Other*	19	19	8	26

* 'The Other' category contains any employment type that was mentioned by household survey participants that was not one of the 28 employment types listed on the survey form.

Approximately 46% of males and 14% of females aged 16 years and above indicated that they had some previous formal work experience. As shown in Table 9.2, the most common types of current employment are teachers, village court officials and ward councilors, pastors, carpenters and cooks, while the most common types of previous employment were laboring positions, logging/milling, and carpenters for males and administration/office/clerical, pastor, logging/milling and laborer for females; however, employment experience in a range of other technical jobs was also identified, including plumbers, plasterers, painters and surveyors.

9.5 Community Demographics

9.5.1 Population and Household Characteristics

9.5.1.1 Population

The combined population in mid-2016 of the 39 villages and one government station in the PAOI was 12,763 (ERIAS Group, 2016a). The population of each community[14] in the PAOI is shown in Table 9.3. The average population per village is 317; however, village size varies considerably between coastal and inland locations. The largest village is Kavava (Orokolo coast) with 962 residents, and the smallest settlement is Mapaio Fish Camp (PRL-15) with 32 residents. The PAOI includes 13 coastal villages and 27 inland villages.[15] Population density is much higher in coastal areas compared with inland areas. Coastal villages are also typically larger than inland villages and often coalesce, forming long strips of habitation along Orokolo Bay.

The average population density across Papua New Guinea is 15.7 people/km^2 and the total population is 7.321 million. The average population density is much lower in Gulf Province (i.e., 4.6 people per km^2, total population 121,128) and lower again in Kikori District (i.e., 1.9 people per km^2, total population 41,232). For Kikori District, the low population density reflects a relatively large area of land that is isolated and poorly suited to human habitation due to large expanses of

14 The term community is used as the generic term referring to villages, settlements and government station settlements in the PAOI. Hence there are 40 communities in the PAOI.

15 Coastal villages are those living on or within 1 km of the sea and whose subsistence is mainly from marine resources, and inland villages are those who do not live near the sea and whose subsistence is mainly from forest resources.

lowland swamp and mangrove that are frequently inundated and, therefore, are particularly unfavorable in terms of subsistence food production. The population density of Ihu Rural LLG (i.e., 6 people per km^2, total population 15,815) is substantially higher than that of Gulf Province and Baimuru Rural LLG (i.e., 1.5 people per km^2, total population 11,424) (NSO, 2013). Ihu Rural LLG supports a relatively densely settled population along the Papuan coast, whereas the Baimuru Rural LLG population is inland and sparsely settled, much of it being along the Purari River and its tributaries.

Table 9.3 – Population of Villages In the PAOI

Community	Population (Persons)	Households	Average Household Size
PRL-15			
Wabo	542	73	7.4
Wabo Station	108	22	4.9
Ura	229	42	5.5
Subu	62	11	5.6
Subu 2	97	13	7.5
Poroi 2	301	44	6.8
Poroi 1 (Rainbow)	34	10	3.4
Poroi 3 (Suarido)	45	8	5.6
Mapaio Fish Camp	32	5	6.4
Export Pipeline Corridor			
Evara	542	67	8.1
Hepere	297	51	5.8
Ere/Kilavi	396	75	5.3
Avavu	283	42	6.7
Huruta	246	45	5.5
Arehava 2	96	13	7.4
Paevera	294	47	6.3
Harevavo	651	100	6.5
Herakela	331	66	5.0
Hohoro	70	12	5.8
Iuku	514	80	6.4
Kaivukavu	640	101	6.3
Kavava	962	178	5.4
Larihairu	450	73	6.2
Mareke	808	145	5.6
Marea	435	79	5.5
Oru/Lariau	367	69	5.3
River Transport Corridor			
Apiope	301	45	6.7
Aumu	244	31	7.9
Aivai	107	13	8.2
Kaevaria	113	17	6.7
Akoma/Kairu’u	549	68	8.1
Mapaio	859	152	5.7
Upaia	227	41	5.5
Ara’ava	751	113	6.7

Table 9.3 – Population of Villages In the PAOI (cont'd)

Community	Population (Persons)	Households	Average Household Size
River Transport Corridor (cont'd)			
Aiere[#]	50	14	3.6
Kairimai	386	62	6.2
Ikinu	294	42	7.0

Source: ERIAS Group (2016a). [#] Source: NSO (2013).

9.5.1.2 Age and Gender

The average age of people in the PAOI is 19 years (ERIAS Group, 2016b), which is the same as for Papua New Guinea. A population pyramid for the PAOI is presented in Figure 9.3.

Results of the household survey indicate a sex ratio[16] of 105 compared to 108 nationally, 40% of people are less than 15 years of age compared to 36% nationally and 7% are aged 55 years and above, which is the same as for Papua New Guinea. The average household size for the PAOI is 6.7, compared to 5.3 for Papua New Guinea. The dependency ratio[17] is 89, compared to 75 for Papua New Guinea. Overall, the PAOI is characterized by a very young population and large household sizes (Table 9.4).

Table 9.4 – Population and Demographic Indicators by Language Group

Language Group	Sex Ratio	Average Household Size	Population Less Than 15 Years of Age	Population 55 Years of Age and Above	Dependency Ratio
Pawaia	123	7.9	45%	5%	100
Ahia	106	7.0	55%	2%	133
Koriki	92	9.2	39%	10%	96
Iare	102	7.6	33%	7%	67
Kaimare	95	3.8	43%	7%	100
Maipua	98	7.7	38%	5%	75
Orokolo	121	7.4	39%	9%	92
Total	**105**	**6.7**	**40%**	**7%**	**89**

Source: ERIAS Group (2016b).

Table 9.4 indicates differences in key demographic indicators between language groups:

- The Pawaia and Orokolo villages have a higher proportion of males than other villages.
- Household size is relatively low among the Kaimare villages (3.8 persons).
- Ahia has the largest proportion of people below 15 years of age and the fewest aged 55 years and above, resulting in an exceptionally high dependency ratio of 133.

9.5.1.3 Marriage and Divorce

In the past, polygamous marriages were common, particularly among the Koriki people (Williams, 1924). This has largely changed; results from the 2016 household survey indicate that only 3% of marriages are polygamous. The percentage of polygamous marriages by language group is:

- Pawaia: 8% of households.
- Iare: 5% of households.

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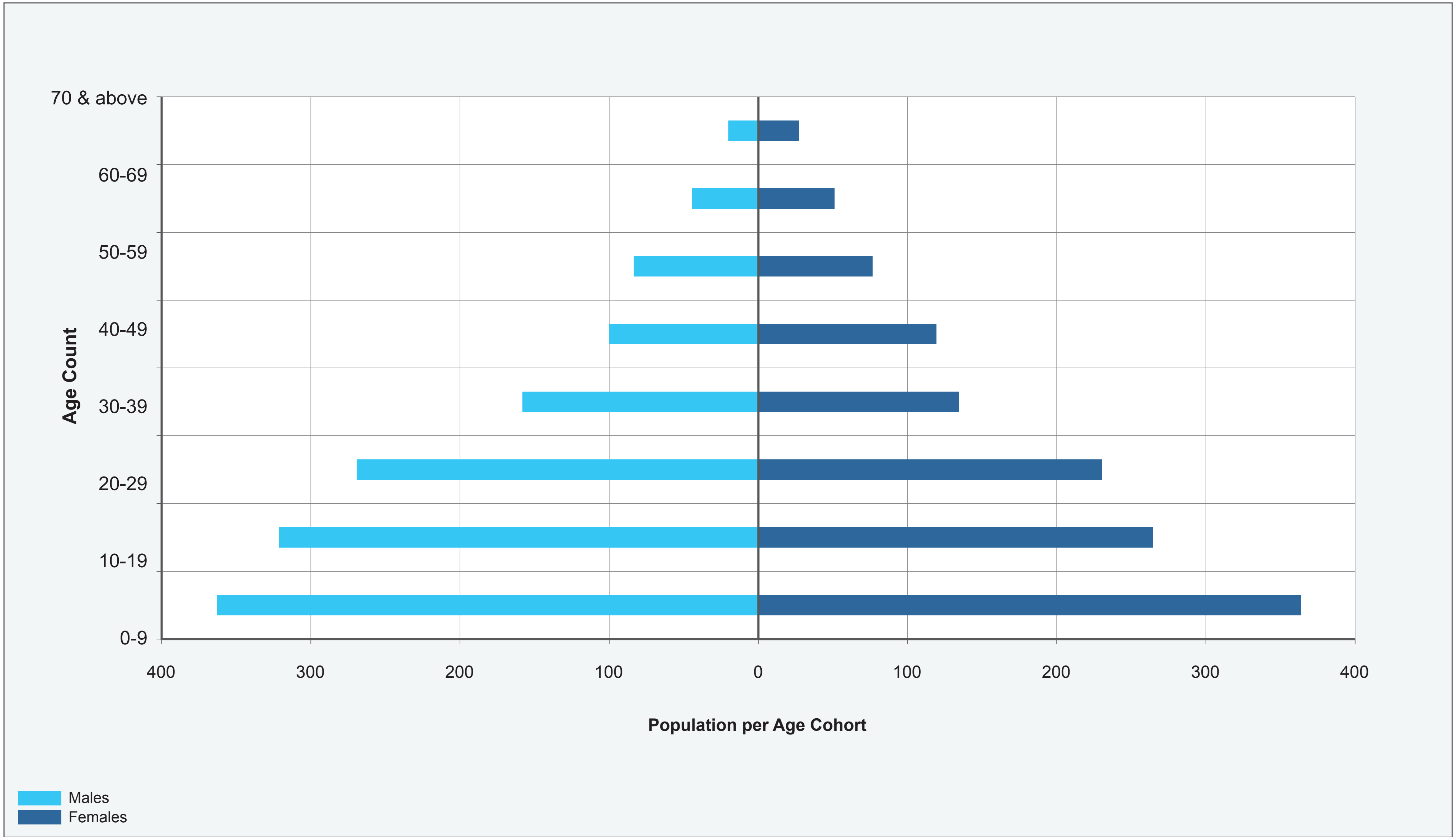
16 The number of males per females, i.e., there are 105 males for every 100 females.

17 The number of people aged less than 15 and those aged more than 55 years, as a proportion of the number aged between 15 and 55.

POPULATION PYRAMID FOR PAOI, 2016

Papua LNG Project | Environmental Impact Statement

FIGURE 9.3



ERIAS Group | 01215B_23_9.3_v1

- Maipua: 6% of households.
- Orokolo: 2% of households.
- Koriki, Kaimare, Ahia: 0% of households.

No males under 20 years of age were married, and 10% of females under 20 years of age were married. In Pawaia communities, females were married as young as 10 years old; and in the Koriki communities, it was not uncommon for women to marry as late as 40 years old. The average marrying age range for females is 15 to 22 years. The *Marriage Act 1963* has a minimum age of marriage of 18 years for men and 16 years for women, with judges able to allow marriages involving boys aged 16 years and girls aged 14; but this act is not applicable to customary marriages.

Divorce and separation is uncommon and, in the case of some Pawaias, has been alleged to lead to repercussions, including sorcery. Divorce may also involve negotiations between the families regarding the bride price and possible reimbursement, providing another disincentive for divorce among Pawaias and other language groups.

9.5.2 Religion

The main religious denominations in Gulf Province are the Catholic, United, Seventh-day Adventist and Lutheran churches. Several other churches are present, including Assemblies of God, New Tribes Mission, Reform Revival, Bahai, Pentecostal, Baptist and Christian Life Center. The churches have one representative in the Provincial Assembly. Church presence has contracted in Gulf Province over the past 40 years while remaining a central part of village life.

Christian churches in the PAOI were particularly active in coastal areas in the twentieth century, establishing bases such as Muro Mission; however, the churches were also influential inland, where, e.g., the Lutheran Church established Poroi Primary School.

9.5.3 Migration

Excluding people who in-migrate to marry, relatively few people have migrated into villages in the PAOI. Only 12 villages (39% of villages surveyed) contain people who have migrated into the PAOI. Of these, nine villages contain pastors, health workers or teachers (and their families) who have migrated specifically for employment purposes, while only three villages (Ura, Evara and Apiope) contain other migrants. In total, it is estimated that the PAOI villages include approximately 36 migrant families, which represents less than 2% of the households in the PAOI.

Around 17% of the villages included in the village leader focus group discussion, as part of the community-level surveys, indicated that they would allow unrelated families to relocate to their village on a permanent basis. The vast majority stated that outsiders could not come and live on their land unless they had a good reason, such as being pastors, health workers or teachers.

Approximately 70% of the villages providing an estimate of the number of people out-migrating from the PAOI to other parts of Papua New Guinea indicated that more than 100 people had migrated in the past. Given the average village size of 317, out-migration has been large. Discussion with village leaders indicated that many former villagers now reside in Port Moresby and other parts of Papua New Guinea, including Kerema, Lae, other provincial centers and various mining camps. Generally, out-migration was associated with the search for employment.

9.5.4 Housing and Community Infrastructure

9.5.4.1 Housing

Most (73%) houses are made of traditional materials, i.e., hardwood poles, split black palm floors, woven sago panels on the walls and a roof made of sago, nipa palm or grass (Plate 9.5). Twenty-five percent are semi-improved, incorporating sawn timber or sheets of roofing iron; and 2% are of modern design, i.e., completely made of sawn timber, iron roofing and other purchased building materials. More than 99% of houses are raised above the ground, particularly in the Purari River delta, to avoid inundation related to high tides or river flooding.

Most (97%) families live in their own house, with the remaining 3% staying with friends or relatives. If a house is destroyed, e.g., by flooding, the family will often stay with relatives until they have an opportunity to construct a new house. This may take several months or longer.

Plate 9.5 – Typical House (Kaevaria)

Photo: ERIAS Group.

9.5.4.2 Energy Sources

Twenty-eight percent of households have access to a generator, and 53% of households have access to solar panels providing electricity (Plate 9.6). Power from generators or solar panels is used predominantly for lighting and charging mobile phones; however, some households use the power to run refrigerators, freezers or other electrical appliances.

Plate 9.6 – Solar Panels and Battery at Maipenairu

Photo: ERIAS Group.

Other sources of lighting include firewood and *bom* torches (traditional torches made of palm fronds). Firewood is the main source of fuel for cooking throughout the PAOI.

9.5.4.3 Water and Sanitation

Water

The main sources of drinking water for households is from rainwater collected in containers (37% of households), rainwater collected in tanks (Plate 9.7) (32% of households), water from rivers and creeks (16% of households) and water from shallow wells (8% of households) (Table 9.5). Rainwater containers include drums, pots or other vessels that can be used to collect and store rainwater from a roof. The rainwater is not treated. The longevity depends on the rate of consumption and quantity of storage available for each family. People along the Orokolo coast are the most dependent on water from shallow wells, as they have more of a pronounced dry season, and tanks and other rainwater catchments dry up.

Table 9.5 – Main Source of Drinking Water (% of Households)

Language Group	Piped*	Well	Spring	River or Creek	Tank	Rainwater	Other
Pawaia	1	1	7	28	34	28	0
Ahia	0	0	0	36	43	21	0
Koriki	8	0	3	35	15	40	0
Iare	7	0	0	13	13	65	4
Kaimare	3	0	0	6	39	53	0
Maipua	0	6	0	50	6	38	0
Orokolo	2	24	0	0	47	25	4
Total	**3**	**8**	**2**	**16**	**32**	**37**	**2**

Source: ERIAS Group (2016a). * Water is piped from a nearby spring, creek or well.

Plate 9.7 – Water Tanks in Use at Upaia

Photo: ERIAS Group.

Sixteen percent of respondents who indicated that they relied on a river or creek as their main source of drinking water extracted water from the Purari River, while others extracted water from smaller creeks that flowed into the Purari River. People residing in Ura, Wabo, Subu, Subu 2, Poroi 2, Poroi 3, Upaia, Aiere, Kairu'u, Akoma, Evara, Kaevaria, Kairimai, Aivai, Apiope and Mapaio Fish Camp extract water from the Purari River or its tributaries for drinking. The extent that these people extract water from the Purari River for drinking depends on the availability of and distance to alternative (better) sources. Few people appear to boil water from the Purari River before drinking it.

People in most (76%) of the villages wash in a river or creek, and the remainder use well water.

A total of 88% of villages access their main source of drinking water within a 10-minute walk from the village. The villages that need to walk farther include Kairimai (10 to 20 minutes), Ara'ava (10 to 15 minutes) and Wabo (30 minutes).

Women from 74% of villages indicated that all household members collected water. Women were mostly responsible for collecting water in the other nine villages, i.e., Kairimai, Ara'ava, Poroi 2, Ere, Avavu, Hepere, Huruta, Oru and Aiere.

Sanitation

The most common types of toilets are traditional pit latrines and improved pit latrines. The traditional pit latrine is a hole dug in the ground, generally with a floor made of branches, logs or rough-sawn timber and often with roughly constructed walls and roof. Pit latrines are not universally accepted due to their unfavorable odor; in lowland areas, they are also susceptible to flooding during high tides, which can cause fecal matter being deposited in village areas.

Around 34% of households reported that they did not use a toilet but used the bush, river or sea. Few households in the villages of Harevavo, Iuku, Kapai 2 and Mariki had a toilet. Toilets built over the river (Plate 9.8) are not common in any particular village but are used by some households in Aiere, Akoma, Apiope, Kairu'u, Kapai 2, Maipenairu, Mariki and Upaia.

Plate 9.8 – Toilet Over the River (Ara'ava)

Photo: ERIAS Group.

9.5.4.4 Domestic Waste Management

Tins and batteries are thrown in the bush, sea or river (56%), buried (27%) or burned (6%) by villages. Most villages dispose of paper and plastic items by burning (50%), throwing in the bush, river or sea (27%) or burying (15%). Most food scraps are fed to pigs and chickens, but some are also discarded into the bush, river or sea, buried or burned.

Designated rubbish disposal areas were identified in only 19% of villages.

Poroi 1 demonstrated the best waste management practices. All rubbish was buried in pits around the perimeter of the village, and all residents washed their hands before cooking and eating, and after going to the toilet. It is likely that these good waste and health practices had been acquired and implemented by villagers employed by the previous and current operators of resource projects in the area, specifically InterOil and Total E&P PNG Limited.

9.5.4.5 Communications, Community Facilities and Commercial Services

Approximately 66% of the villages have mobile phone coverage,[18] and 62% of households have one or more mobile phones. Mobile phones are charged using solar power or generators. Some people charge a small fee for others to charge their phones, e.g., 50 toea or PGK1.00 (US$0.15 or US$0.30).[19] Mobile phones are not only owned by people living in villages with mobile phone reception, as some people who live in villages that do not have mobile phone reception will own a phone to use when they travel to Kerema or other locations.

Approximately 33% of households own a radio, 18% own a television, and only 4% own a computer or iPad. Radio therefore remains the main method of receiving news. Twenty five percent of households surveyed had used the internet, and 21% had used social media.

There are no postal services, and the nearest post office is in Kerema. Newspapers are not delivered to villages in the PAOI. Herd Base is the only location that has television regularly. This allows employees to watch news on PNG or Australian broadcasters. The only way to receive news for most of the population is from radio or by internet-based news using mobile phones.

Other than schools and health facilities, the only other community facilities are churches and sports fields. Most villages have a church, often shared by different denominations (see Section 9.5.2). Churches are typically made of traditional materials, with open sides, although some have sheets of iron on the roof (Plate 9.9).

Plate 9.9 – Church with Iron Roof (Ara'ava)

Photo: ERIAS Group.

Most villages also have one or more sports fields or courts. These typically include a sports field for playing soccer and touch rugby, and a basketball or volleyball respectively. The sports fields are basic and generally use local materials for goal posts, posts and backboards (Plate 9.10).

Compared to most provincial capitals in Papua New Guinea, Kerema has relatively few stores and provides little in the way of commercial services (e.g., agricultural inputs, freight services). Most people regard the stores in Kerema as too expensive and prefer to travel further to Port Moresby to make their purchases at lower cost.

18 Mobile phone coverage may not be comprehensively available in all areas across the villages noted; however, it is available from one or more locations either in the villages or close to them.
19 The PGK to US$ currency conversion of PGK100 = US$30 (7 March 2019) is used in this chapter.

Plate 9.10 – Typical Basketball Court (Kilavi)

Photo: ERIAS Group.

9.5.5 Household Wealth

9.5.5.1 Income

The median household income recorded was PGK80 (US$24) per fortnight. This equates to PGK2,080 (US$624) per annum or PGK312 (US$93.60) per annum per capita.

For most people, the main sources of income are the sale of betel nut (see Plate 9.3), fish, crabs, garden produce and sago. Betel nut is the main source of cash income in 14 villages (or 47% of villages surveyed) and was particularly prevalent among Orokolo villages. Sago is the main source of cash income in six villages (or 20% of villages surveyed), particularly for villages in the river transport corridor (i.e., Kairimai, Mapaio and Ikinu) and selected Orokolo villages (i.e., Harevavo, Kaivukavu and Kavava). A total of 48% of all income recorded in the two weeks before the baseline survey was derived from local products.

Wages provide the main source of income for 9% of households, and business activities are the main source for an additional 7% of households (Table 9.6).

Business activities include trade stores (11) and fuel retailers (22). The businesses are relatively small. Many operate on an intermittent basis, e.g., some business opportunities arise on an occasional basis, such as canoe or dinghy hire; and few are formally registered. Table 9.6 shows average annual incomes of small businesses in the PAOI.

Table 9.6 – Business Income

Business Type	Average Annual Income	
	PGK	US$*
Trade stores	12,000	3,600
Fuel sellers	9,000	2,700
Canoe/dinghy hire	29,000	8,700
Chainsaw hire	12,000	3,600
Clothes sales	6,000	1,800
Crocodiles	4,000	1,200
Other	20,000	6,000
Total	**92,000**	**27,600**

Source: ERIAS Group (2016a). *Applying PGK100 = US$29.64.

Income levels varied significantly in the fortnight before the survey. Figure 9.4 shows the distribution of household income. Seventy-five households (21%) recorded no cash income in the previous fortnight, 55% of households earned less than PGK100 (US$30), and 92% of households earned less than PGK1,000 (US$300). Thirty households (8.5%) earned more than PGK1,000 (more than US$300) in the previous two weeks, with the maximum for one household of PGK6,180 (US$1,854).

9.5.5.2 Expenditure

Median household expenditure was PGK76 (US$22.80) per fortnight, which equates to PGK1,976 (US$592.80) per annum or PGK286 (US$85.80) per annum per capita. Most household expenditure was allocated to food, transportation and basic household necessities. Costs to transport goods and passengers to and from PAOI villages are high because of remoteness, lack of transport infrastructure (e.g., no roads) and the challenging natural conditions (e.g., steep inaccessible terrain, high rainfall, and seasonally high winds making sea travel treacherous). The prices of fuel and store goods in the PAOI are high relative to Kerema or Port Moresby because of high transportation costs.

Inland communities indicated that Baimuru was a key destination to procure building materials, bulk store food, cooking items and other kitchen utensils, gardening equipment, clothes, mobile phones and other household items. Baimuru is connected by river and is relatively close compared to Kerema or Port Moresby. Coastal communities indicated a preference to travel to Port Moresby to buy building materials and other goods. Port Moresby offered a wider range of materials and lower prices, compensating for the travel cost.

Costs of Living

The price of store food products varied considerably in the PAOI and is high compared to the cost of the same products in Kerema. For example, one kilogram of rice varied from PGK10 (US$3.00) in Wabo and Poroi to PGK6.50 (US$1.95) at Evara. Tinned fish (180 grams) varied from PGK5.00 (US$1.50) at Wabo and Poroi to PGK3.50 (US$1.05) at Ara’ava. The prices of rice and tinned fish in stores in Port Moresby (PGK5.00 (US$1.50) and PGK2.25 (US$0.67) respectively) and Kerema (PGK6.50 (US$1.95) and PGK3.00 (US$0.90) respectively) are lower and there is also a variety to choose from. Rice averaged around 16% higher than in Kerema and 66% higher than in Port Moresby, while tinned fish averaged 41% higher than in Kerema and 64% higher than in Port Moresby.

The price of various food products sold in the market in Kaivukavu was determined. Although limited produce was weighed in the market at Kaivukavu, the price of freshly caught shark, salmon and catfish was quite similar, ranging from PGK11.90 to PGK13.75 (US$3.57 to US$4.13) per kg. The price of green vegetables was relatively uniform, varying from PGK1.59 (US$0.48) per kg for pumpkin leaves to PGK4.17 (US$1.25) per kg for aibika. The only staples weighed were cooking bananas, which averaged PGK2.04 (US$0.61) per kg, and cassava, which cost PGK2.63 (US$0.78) per kg. The price of chickens is generally around PGK20 (US$6.00), while pigs can cost from PGK70 to PGK500 (US$21 to US$150) depending on size.

Transport Costs

Charter flights from Wabo[20] to Port Moresby cost PGK900 (US$270) one way, while the cost from Wabo to Goroka is PGK400 (US$120) one way.

20 Flights out of Wabo are infrequent. Costs should be considered indicative only.

HOUSEHOLD INCOME DISTRIBUTION, PGK PER FORTNIGHT

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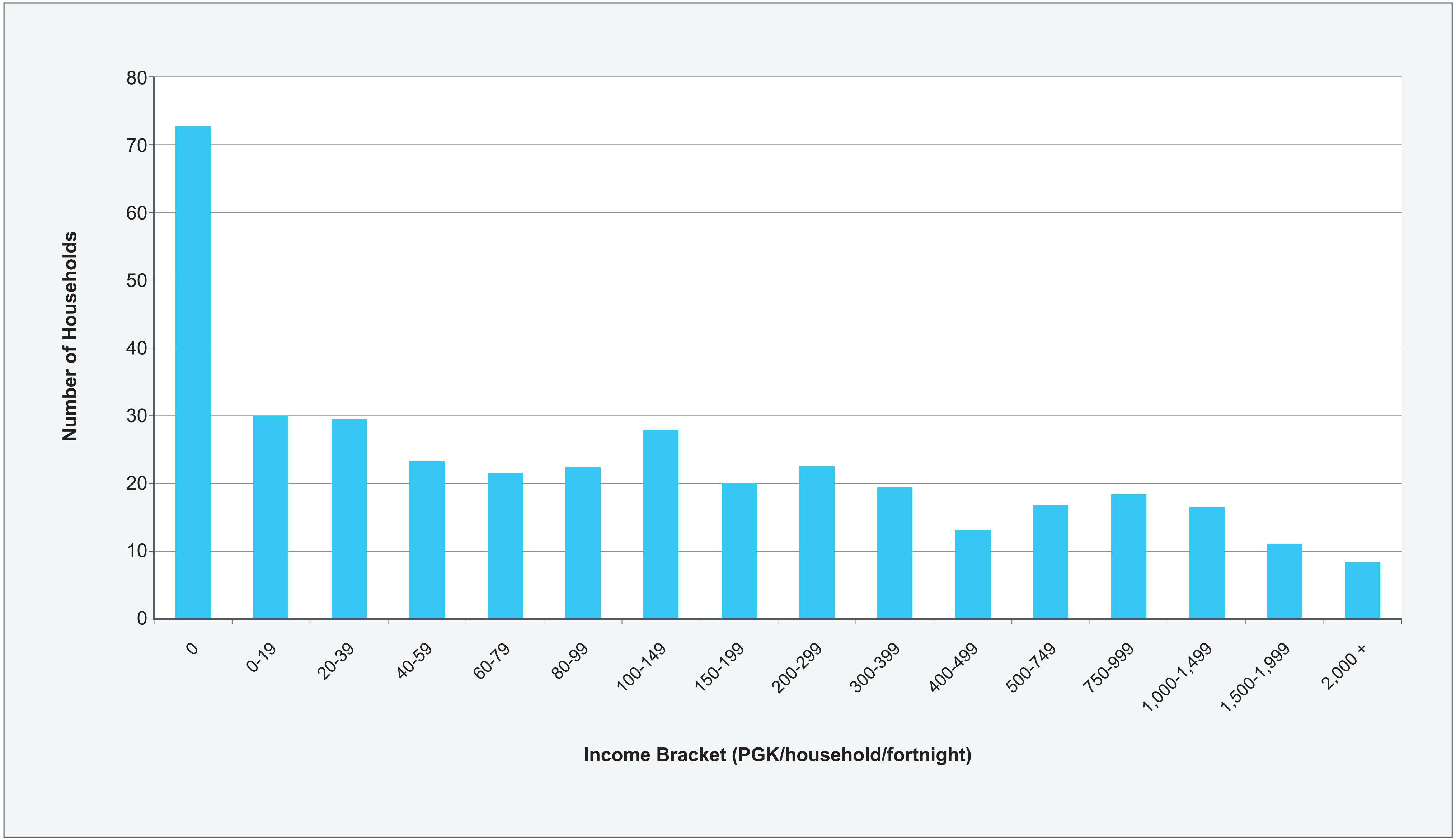
FIGURE 9.4



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The price of a dinghy fare from the Purari River delta coastal areas to Kerema is about PGK200 (US$60) per passenger, with extra costs for freight. The cost of a public motor vehicle fare from Kerema to Port Moresby is PGK50 (US$15) each way, again with extra charges for freight. The cost to reach Kerema from further up the Purari River is higher.

Outboard motor fuel, commonly referred to as ‘zoom’, is typically sold at PGK30 (US$9) per gallon in the Orokolo area to PGK40 (US$12) per gallon in more remote parts of the PAOI; however, sellers at both Ura and Wabo claimed to be selling zoom fuel for PGK60 (US$18) per gallon during the baseline surveys.

9.5.5.3 Savings and Banking

Despite the absence of banks and banking agencies in the PAOI, 31% of households surveyed indicated that they or at least one family member had a bank account. Although specific information was not collected on how often bank accounts were accessed, it is likely to be infrequently due to the need to travel considerable distance to access a bank; however, 75% of households indicated that they had access to other cash savings.

Sakura Osura Resources Limited, the Pawaian local business company, previously provided banking services at its store in Wabo. The service has since been suspended. The nearest bank to the PAOI is at Kerema. Some people from Maipenairu used short message service (SMS) banking to obtain cash supplied by the local trade store.

Of the households surveyed, 34% indicated that they had used electronic fund transfer point of sale (EFTPOS) facilities. The Iare, Kaimare, Maipua and Orokolo language groups have a relatively high proportion of households that have used EFTPOS facilities, probably because they are located closer to shops in Kerema and Orokolo with such facilities.

9.5.5.4 Ownership of Assets

Traditionally, key household assets include canoes, clothes and decorative items, axes, knives and other tools required for hunting, fishing, making sago, cooking, making mats and gardening. Some traditional items such as canoes and fishing nets continue to be used, while many others have been replaced.

Very few households own a refrigerator or freezer. Around 25% of households own a sewing machine. Those people owning a refrigerator or freezer generally operate a business and use it to sell cold drinks and ice-blocks. Sewing machines that are not electrical are used to make and repair clothes. Few people have chainsaws or a gun or rifle, instead choosing to use axes to fell trees or cut timber and traditional weapons to hunt. Another factor limiting the ownership of many items is the lack of commercial services, specifically those that could repair a chainsaw or sell shotgun cartridges or bullets.

Walking and using canoes are the traditional forms of transport; 67% of households own canoes, while only 15% of households own a dinghy. Twenty-one percent of households own an outboard motor, which could be attached to either a canoe or dinghy.

None of the communities reported owning motor vehicles or motorbikes, which would be of little benefit given the absence of public roads or tracks in the PAOI.

9.6 Education

9.6.1 Access to Education

The PAOI contains 32 functioning schools; 23 elementary and 9 primary schools[21] (Table 9.7, Plates 9.11 and 9.12). Figure 9.5 shows school locations. The government runs most of the elementary schools, while church agencies run most of the primary schools.

Table 9.7 – Number and Location of Schools in the PAOI

Project Area	Village	Language Group	Elementary Schools*	Primary Schools (Administration)
PRL-15	Poroi 2	Pawaia	✓ Poroi Elementary School	✓ Poroi Primary School (Lutheran Church Agency)
	Poroi 1	Pawaia	-	-
	Poroi 3	Pawaia	-	-
	Wabo	Pawaia	-	-
	Ura/Wabo Station	Pawaia	✓ Wabo Elementary School	✓ Wabo Primary School (Government)
	Subu	Pawaia	-	-
	Subu 2	Pawaia	✓ Subu 2 Elementary School	-
	Mapaio Fish Camp (Settlement)	Iare	-	-
River Transport Corridor	Mapaio	Iare	✓✓ Mapaio Aikavalavi Elementary School and Mapaio Elementary School	✓ Mapaio Primary School (Church, not specified)
	Kaevaria	Iare	-	-
	Aumu	Iare	-	-
	Aivai	Iare	-	-
	Ara’ava	Koriki	✓ Ara’ava Elementary School	✓ Ara’ava Primary School (United Church Missions)
	Kairimai	Koriki	✓ Elementary School	
	Akoma and Kairu’u	Koriki	✓ Elementary School	✓ Akoma Primary (Government)
	Ikinu	Koriki	✓ Ikinu Elementary School	
	Upaia	Kaimare	✓ Upaia Elementary School	-
	Apiope	Maipua	✓ Apiope Elementary School	Primary school under construction and due for completion in 2017
	Evara	Ahia	-	-
Export Pipeline Corridor	Hepere	Orokolo	✓ Hepere Elementary School	-
	Ere and Kilavi	Orokolo	✓ Kilavi Elementary School	-
	Muro Mission	Orokolo	-	✓ Muro Primary School (Catholic Agency)

21 Elementary includes preparatory to Grade 2. Primary includes Grade 3 to Grade 8.

Table 9.7 – Number and Location of Schools in the PAOI (cont'd)

Project Area	Village	Language Group	Elementary Schools*	Primary Schools (Administration)
Export Pipeline Corridor (cont'd)	Avavu	Orokolo	✓ Avavu Elementary School	-
	Huruta	Orokolo	✓ Huruta Elementary School	-
	Paevera	Orokolo	✓ Paevera Elementary School	-
	Harevavo	Orokolo	✓ Harevavo Marea Elementary School	-
	Kaivukavu	Orokolo	✓ Kaivukavu Larihairu Elementary school	✓ Arehava-Harevavo Primary School (Government)
	Larihairu	Orokolo	*see Kaivukavu*	-
	Marea	Orokolo	*see Harevavo*	-
	Iuku	Orokolo	✓ Iuku Elementary School	-
	Mareke	Orokolo	✓ Mareke Elementary School	-
	Kavava	Orokolo	✓ Miri-Muru Elementary School	✓ Orokolo Primary School (United Church Agency)
	Oru, Lariau and Herakela	Orokolo	✓✓ Oru-Lariau Elementary School, Herekela Elementary School	✓ St Anne Primary School (Catholic Church)
Total schools			**23**	**9**

Source: ERIAS Group (2016a).
✓ = School present.
* All elementary schools in the PAOI are government-run.

Plate 9.11 – Elementary Classroom at Subu 2

Plate 9.12 – Primary School Classroom at Oru

Photos: ERIAS Group.

EDUCATIONAL FACILITIES IN THE PAOI

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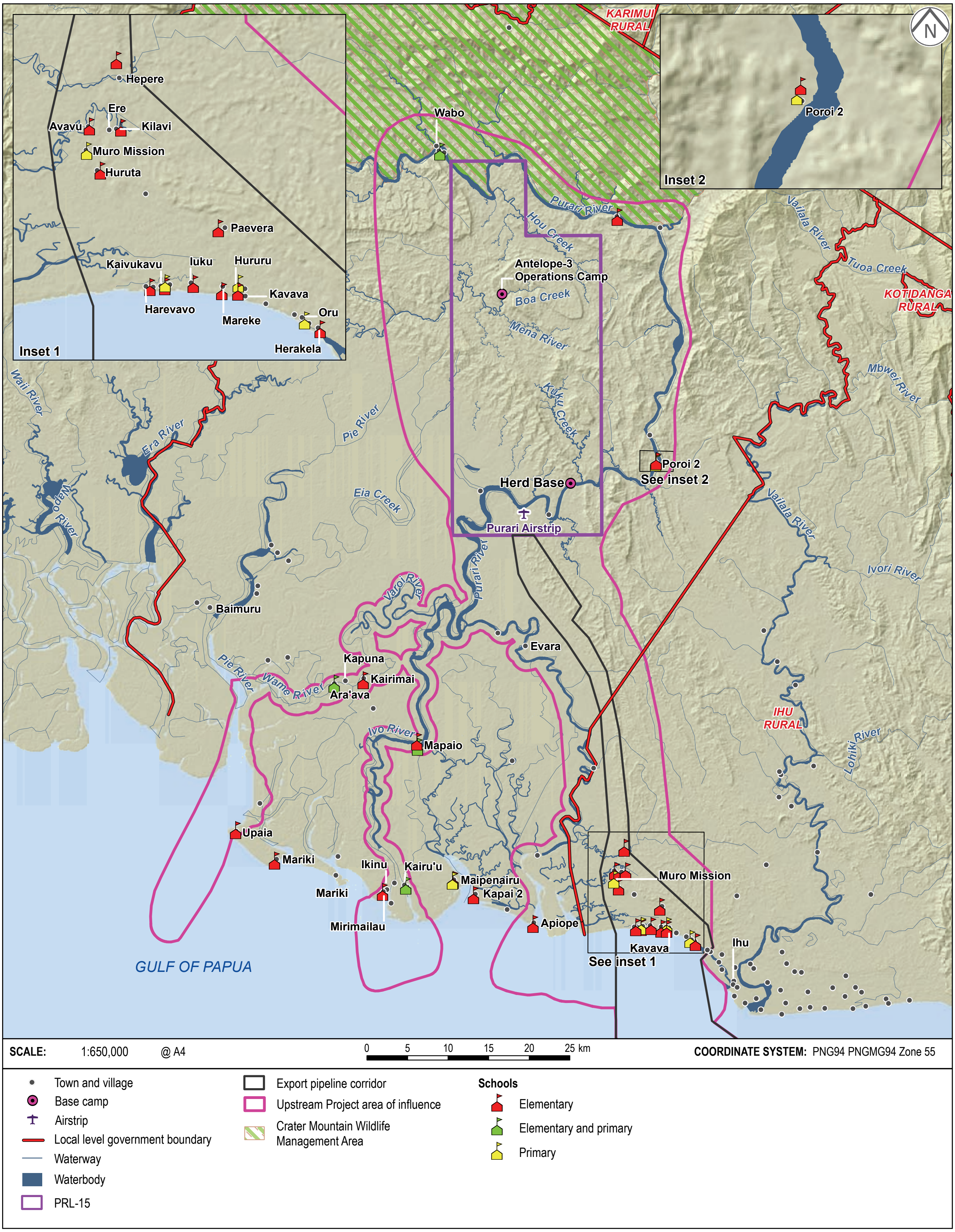
FIGURE 9.5



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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None of the elementary or primary schools has any boarding facilities, which means that access to school often relies on students staying with relatives in the village containing a school. An average of 57 elementary and 155 primary school students attend schools in the PAOI.[22] Elementary schools have an average of 1.9 teachers per school, and primary schools have an average of 4.6 primary teachers per school. Elementary schools offer an average of 2.4 grades, while primary schools offer an average of 5.3 grades. Elementary schools have an average of 38 students per teacher, and primary schools have an average of 37 students per teacher. There are teacher vacancies at most elementary and primary schools, indicating the difficulty for these rural schools of attracting and retaining teachers (ERIAS Group, 2016a).

The PAOI does not contain any secondary or vocational schools. The nearest secondary schools are at Ihu, Araimiri, Kerema and Kikori. Some students from Pawaia villages also attend secondary school in Kundiawa (Simbu Province) and Goroka (East Highlands Province). The nearest vocational schools are at Baimuru and at Araimiri, which is officially a technical secondary school, run by Don Bosco, with a focus on practical courses. A vocational school at Ihu has been closed for many years and is in a state of disrepair.

The total number of students in the schools surveyed is shown in Table 9.8. There are 116 male students per 100 female students in the PAOI.

Table 9.8 – Students in the PAOI

Grade	Male	Female	Total
Preparatory	190	189	379
Grade 1	167	150	317
Grade 2	228	170	398
Grade 3	163	129	292
Grade 4	148	136	284
Grade 5	146	137	283
Grade 6	128	87	215
Grade 7	97	92	189
Grade 8	65	62	127
Total	**1,332**	**1,152**	**2,484**

Source: ERIAS Group (2016a).

Extrapolating demographic data from the household surveys shows the gross enrolment ratio is 89% for boys and 87% for girls across the PAOI. This indicates mostly equal participation rates by boys and girls, and further highlights that at least 12% of the school-aged population is not attending school. Furthermore, given the late age that many children commence their education and the relatively older age of students relative to the grade they are attending, the net enrolment ratio is likely to be much lower and would indicate that more than 12% of the school-aged population does not attend school.

Results from the household survey indicate that just 31% of boys and girls aged from six to 15 years attend school. Many children attending school are older than the age recommended by the Department of Education. A net enrolment ratio of 31% in the PAOI compares poorly with Department of Education estimates for Papua New Guinea (53%) and Gulf Province (42%) for 2007.

22 Based on data collected for 20 elementary schools and 8 primary schools in the PAOI.

9.6.2 Education Levels and Literacy

Ten percent of males and 21% of females aged 16 years and above in the PAOI have never attended school, compared with an estimated 8% of males and 11% of females in Gulf Province. More than half of the females from Pawaia villages aged 16 years and above have never attended school.

Approximately half of all males and females aged 16 years and above across the PAOI have completed between Grade 1 and Grade 6. Approximately 32% of males aged 16 years and above have completed between Grade 7 and Grade 10, compared to only 24% of females of the same age category. Very few males or females from the PAOI have completed vocational or technical schooling or attended university.

A self-assessment of literacy conducted during the household survey showed that 19% of males and 33% of females aged 16 years and above cannot read or write in any language (Table 9.9). Individuals were asked whether they could read or write, but this was not validated by any testing. This is a better result than the census data for Papua New Guinea and Gulf Province from 2000;[23] however, a detailed assessment of literacy levels in Gulf Province revealed that the literacy levels stated by people were much higher than actual levels evidenced by a simple literacy assessment. The literacy levels reported during the household survey are likely to have been overstated.

Table 9.9 – Literacy Level in the PAOI (Age 16 and Above)

Language Group	Sample Size	Read and Write (%)	Read Only (%)	Illiterate (%)
Pawaia - males	178	69	6	25
Pawaia - females	121	28	6	66
Ahia - males	23	39	13	48
Ahia - females	21	19	24	57
Koriki - males	112	83	2	15
Koriki -females	108	71	6	23
Iare - males	136	87	4	9
Iare - females	134	77	5	19
Kaimare - males	30	87	0	13
Kaimare - females	41	59	5	37
Maipua - males	37	81	0	19
Maipua - females	34	74	0	27
Orokolo - males	243	77	5	19
Orokolo - females	253	71	3	27
Total - males/Average %	**759**	**77**	**4**	**19**
Total - females/Average %	**712**	**63**	**5**	**33**

Source: ERIAS Group (2016b).

9.7 Community Health and Safety

9.7.1 Access to Healthcare

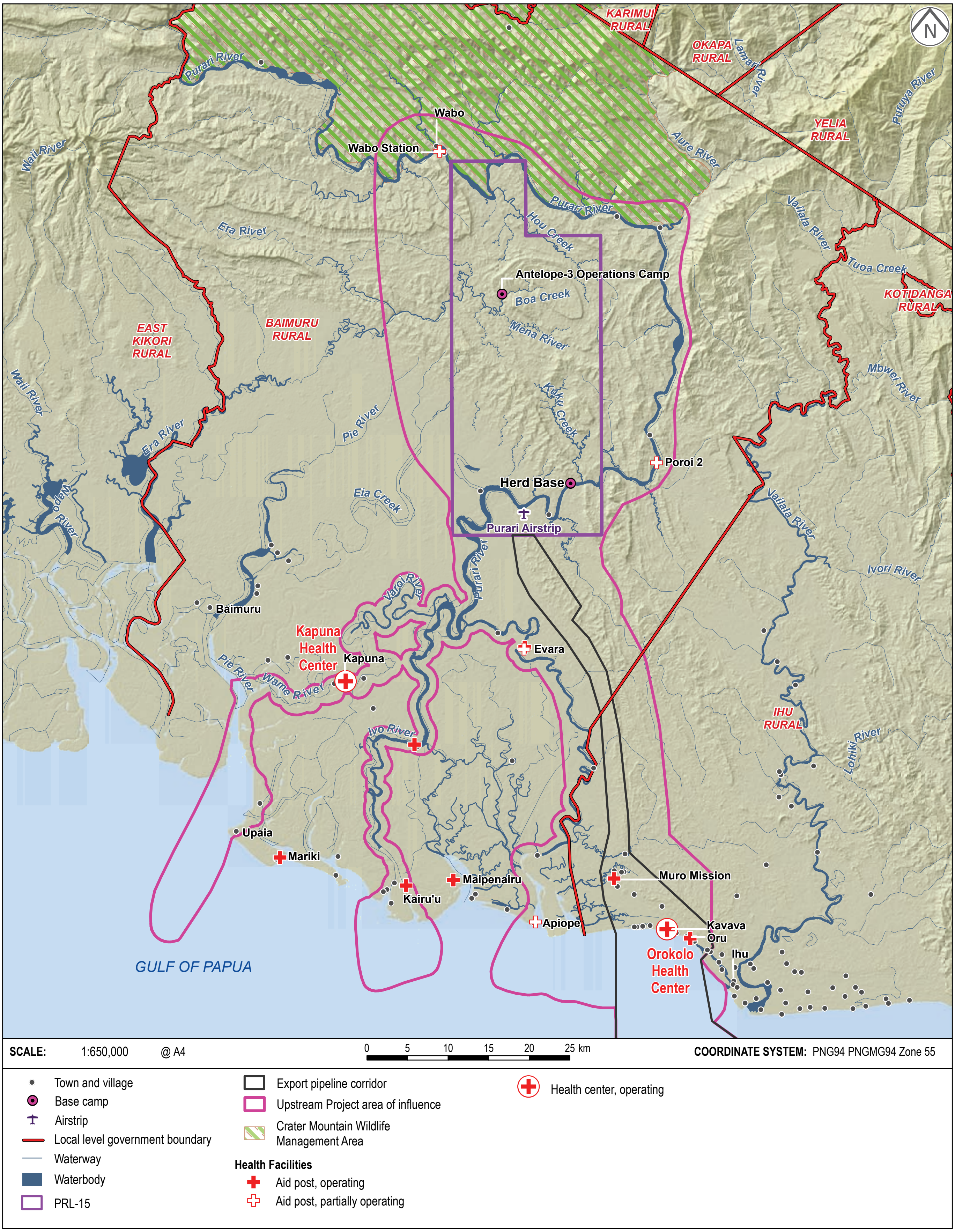
The PAOI contains nine operating and three partially operating healthcare facilities. The location of healthcare facilities is shown in Figure 9.6 and listed in Table 9.10.

23 Papua New Guinea - 39% of males and 49% of females were classified as illiterate. Gulf Province – 49% of males and 69% of females were classified as illiterate.

HEALTH FACILITIES IN THE PAOI

Papua LNG Project | Environmental Impact Statement

FIGURE 9.6



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Table 9.10 – Healthcare Facilities in the PAOI

Village	Health Facility	Operational Status	Staffing[#]	Sponsor	Facility
Akoma-Kairu'u	Aid Post	Operating	CHW	United Health Services	Building present with a water supply and a toilet. No electricity or radio.
Apiope	Aid Post	Partially operating	CHW	United Health Services	No building. CHW works from a house. No electricity, water, toilet or radio.
Ere-Kilavi	Aid Post	Operating	2 x CHWs	Catholic Health Services	Building is inadequate. No electricity, water, toilet or radio.
Evara	Aid Post	Partially operating	CHW* HEO (TEP PNG)	Government	Building is present but needs repair. Solar light, water and toilet but no radio.
Kavava	Orokolo Sub-health Center	Operating	7 x CHWs	United Health Services	Building is inadequate. Has water and toilet but no electricity or radio.
Kapuna	Kapuna Health Center	Operating	2 x Doctor 4 x Nurse 25 x CHWs	Gulf Christian Services	Building is present but needs repair. Has electricity, water, toilet, radio and refrigerator.
Maipenairu	Aid Post	Operating	2 x CHWs	United Health Services	Building is present but no electricity, water, toilet or radio.
Mapaio	Aid Post	Operating	2 x CHWs	United Health Services	Building is present but is unfinished and not used. No electricity, water, toilet or radio.
Mariki	Aid Post	Operating	CHW	United Health Services	Building needs repair. No electricity, water, toilet or radio.
Oru-Lariau-Herakela	Aid Post	Operating	CHW	Catholic Health Services	Building needs repair. Has water and a toilet but no electricity or radio.
Poroi 2	Aid Post	Partially operating	HEO (TEP PNG)	TEP PNG	Building needs repair. No electricity, water, toilet or radio.
Wabo	Aid Post	Operating	2 x CHWs HEO (TEP PNG)	Government	Building is present but needs repair. Has water, a toilet and electricity (connected to TEP PNG office).

[#] CHW – Community Health Worker, HEO – Health Extension Officer.
* CHW not regularly present.

As shown in Table 9.10, the healthcare facilities have very basic amenities and are often not consistently staffed or functional. Only the Kapuna Health Center has electricity (except for a solar light at Evara), an operating refrigerator in which to store medicines, a boat and a radio. Over half of the health facilities do not have a water supply or toilet facilities. The Kapuna Health Center (Plate 9.13) is the only facility staffed with doctors.

Plate 9.13 – Kapuna Health Center

Photo: ERIAS Group.

Healthcare facilities are usually reached by motorized canoe or dinghy or by walking. It can take days to reach a healthcare facility for some villages in the PAOI. Two to three days are required to walk, or a combination of canoe and walking, from Aivai, sometimes via Aumu, to the Orokolo Sub-health Center or the Kapuna Health Center. To travel to the Kapuna Health Center requires two days of travel by paddle canoe from Kaevaria (via Mapaio), from Kapai 2 or from Upaia. Other villages can access health care in less than one day’s travel by walking, paddle canoe, motor dinghy or a combination thereof. Often a village will have multiple locations at which its villagers will seek health care, as the operating or partially operating aid post may not be staffed when visited, requiring the villager to travel to another location (Part 16 of Volume 2).

9.7.2 Food Security and Nutrition

A diverse range of protein sources (e.g., red meat, fish, crustaceans, shellfish and invertebrates) with varied nutritional values is available across the PAOI (Section 9.8). Animal foods obtained by hunting and collecting are most important among the river transport corridor and inland villages; They are less important in the villages close to the mangroves or the coast. In the latter, crustaceans (e.g., crabs), shellfish and mangrove worms provide a large proportion of the animal food intake. Many villages have a perception that high-value animal resources, such as cassowaries and wild pigs, are locally depleted due to disturbance, usually attributed to logging and overhunting.

Communities in the PAOI perceived that adequate quantities of food were available for most people, most of the time, under normal environmental conditions. Food security could be threatened during significant flooding and drought (e.g., El Niño events), but generally there was considered enough to eat. The availability of certain plant and animal foods is, in many cases, seasonal; however, generally when one item is not available, another is; and most communities always have access to sago and coconuts (famine foods).

Anthropometric measurements to assess body size and composition were not conducted as part of the baseline characterization; however, data from two previous anthropometric studies conducted in the PAOI was analyzed. Between 1995 and 1997, Ulijaszek (2003) performed an analysis of mean height, weight and body mass index (BMI) of 292 adults in three villages in the Purari River delta (i.e., Koravake, Mapaio and Ara’ava); and in 2012, the previous operator of PRL-15, InterOil, sponsored a health survey of 853 people from eight Pawaia villages. Both studies found that most men and women in the PAOI have a BMI in the healthy range (Table 9.11).

Table 9.11 – Key Findings of Previous Anthropometric Studies in the PAOI

Ulijaszek (2003)	2012 InterOil Study
♦ 23% of males and 24% of females had a BMI* greater than 25. ♦ 1% of males and 6% of females had a BMI greater than 30. ♦ 13% of females had a BMI below 18.5 compared with 5% of males. ♦ Mean height of younger adults was greater than that of older adults. ♦ Female weights were positively associated with income and the number of years of education. ♦ BMI was positively associated with income and having urban relatives but not with urban dwelling per se.	♦ Most women (64%) and 47% of men had normal BMIs. ♦ Slightly more women (3%) than men (2%) recorded a BMI in the less than 18.5 BMI range. ♦ A greater proportion of men (47%) than women (27%) were overweight. ♦ For the obese category (i.e., BMI greater than 30), more women were obese (6%) than men (4%).

Source: Part 16 of Volume 2.
* A BMI below 18.5 is considered underweight; a BMI of 18.5 to 24.9 is considered healthy; a BMI of 25 to 29.9 is considered overweight; a BMI of 30 or higher is considered obese.

In addition to anthropometric measurements, the InterOil study measured hemoglobin in adults and children to determine levels of anemia. The study indicated a relatively high prevalence of mild to moderate anemia in children below the age of five and, to a lesser extent, in women aged 15 to 49 years. The study also showed high levels of intestinal parasitemia (e.g., ascaris and hookworm), which were thought to be a significant driver of the mild to moderate anemia.

Overall, both the community and household survey data and the results of previous studies indicate that food security and nutrition are not significant problems across the PAOI.

9.7.3 Maternal and Child Health

Across Papua New Guinea, maternal mortality is high, with obstetric hemorrhage, sepsis and eclampsia the main causes of maternal death. Less than half of all births occur in a hospital or health center; although, most women receive some antenatal care from a skilled health worker (UNDP, 2014).

In the PAOI, approximately 85% of mothers attend at least one antenatal clinic during pregnancy, either at an aid post, health center or mobile patrol; however, most do not travel to a health center to give birth. This attendance level is significantly better than the 2015 overall Gulf Province level of 54% (NDOH, 2015). Only 35% of the villages have trained village birth attendants; however, 94% of villages have a traditional birth attendant. A village birth attendant has formal training in delivery and management of complications, while a traditional birth attendant does not have this training.

Approximately 46% of children in the PAOI are born at a health center. The remaining 54% of children are born at an aid post, at home or in the bush for a range of reasons, including the excessive distance and cost of traveling to a health center or cultural preference. Of the children born at a health center, the Kapuna Health Center has the most deliveries (45%) followed by the Orokolo Sub-health Center (35%). Most women travel by canoe (61%) or walk (39%) to these centers. Fifty percent of women have a travel time greater than four hours to deliver their baby, including 18% who reported having to travel for more than one day.

9.7.4 Communicable Respiratory Diseases

Communicable respiratory diseases in the PAOI include lower respiratory tract illness such as bacterial and viral pneumonia, tuberculosis (TB), measles and chicken pox. Respiratory diseases are the leading cause of reported illness in the PAOI and are exacerbated by:

- High household occupancy and many children. The average household size in the PAOI is 6.7 compared to the national average of 5.3, and the PAOI has a large 0 to 9 years age population. Children under the age of 5 years in a household, bedroom sharing and high household occupancy are all significant risk factors for acute lower respiratory infections and pneumonia (Baker et al., 2013).
- Cooking or heating with wood as a primary source. One hundred percent of households use wood as the main cooking source and cook indoors. Indoor cooking with wood is a known risk factor for respiratory illness, particularly for children under age five (Ezzati & Kammen, 2002).
- Betel nut chewing. Betel nut is widely used in the PAOI. Betel nut chewing is associated with an increased rate of respiratory illness, particularly asthma (Garg et al., 2014) and could spread TB spread (Cross et al., 2014).
- Low immunization levels. Community immunization levels in the PAOI are low; e.g., immunization against measles is significantly lower in Gulf Province (19%) than the national level (40%) (NDOH, 2015).
- Poor hand washing practices.

The outpatient and inpatient data from the Kapuna and Kerema[24] health centers demonstrates the high burden of respiratory disease in the PAOI (Table 9.12).

Table 9.12 – Outpatient and Inpatient Data 2014 to 2015 (%)

Health Center	Other	Respiratory	Skin	Gastro-intestinal	Accident and Injury	Eye and Ear	Malaria	Anemia
Outpatient								
Kapuna	55	16	11	5	4	4	3	<1
Kerema	31	32	10	6	9	5	3	<1
Inpatient								
Kapuna	48	15	13	9	7	6	2	-
Kerema	72	13	10	<1	1	<1	1	-

Source: Part 16 of Volume 2. < = less than.

The community and household surveys indicate that malaria is the most common illness in households in the PAOI; however, at a community level in developing countries, it is common for respiratory symptoms to be conflated with malarial symptoms and that reports of cough or fever (without diarrhea) are more likely to be respiratory related rather than due to malaria (D'Acremont et al., 2010).

Tuberculosis

Tuberculosis (TB) is a communicable, airborne infection caused by the bacterial species *Mycobacterium tuberculosis*. It can lie dormant in the body for many years; however, for immuno-compromised individuals, including those with human immunodeficiency virus (HIV) or diabetes, TB can develop into a disease that destroys organ tissue, most commonly in the lungs. The most common symptoms of TB are a persistent cough and fever.

24 Although Kerema is outside the PAOI, the Kerema health center has been included in characterisation of community health given it is near the PAOI. People from the PAOI, especially coastal communities, may at times use this facility.

Tuberculosis is a significant issue in Papua New Guinea and is at epidemic levels in some locations, including Gulf Province (Cross et al., 2014). In a study undertaken in 2012, the estimated incidence of TB in the Kikori District was 1,290 per 100,000 people, which is almost four times higher than the PNG national rate reported to the World Health Organization (WHO) (Cross et al., 2014) (Table 9.13).

Table 9.13 – Comparative Tuberculosis Incidence Rates

Country	Per 100,000
South Africa	981.0
Papua New Guinea	303.0
China	80.0
Australia	6.3

Source: Cross et al. (2014).

Health professionals are increasingly concerned about the prevalence of TB in Papua New Guinea and the rise of drug-resistant strains of TB (i.e., MDR-TB and XDR-TB), which are difficult to treat and have a very poor prognosis. International organizations that deliver or support TB programs in Papua New Guinea include:

- The Global Fund to fight AIDS, TB and malaria: The Global Fund is a financing mechanism and not an implementation agency. Since 2004, the Global Fund has approved grants for Papua New Guinea worth approximately US$270 million (PGK910 million). The Government of Papua New Guinea's investment in Global Fund supported programs is also significant, with an estimated budget of US$110 million (PGK371 million) from 2015 to 2017.
- Australian Government: Australia allocated AU$60 million (PGK143 million)[25] toward TB programs from 2011 to 2017. Australia's support is implemented by such partners as the PNG National Department of Health (NDOH), the World Health Organization (WHO), World Vision, the Burnet Institute, Global Fund and Médecins Sans Frontières (MSF).
- The World Health Organization: WHO provides internationally recognized technical and policy oversight to the TB interventions of all partners in Papua New Guinea.
- World Bank Group: The World Bank Group has provided US$15 million (PGK51 million) for programs in the Western Province and National Capital District.
- US Agency for International Development (USAID): USAID announced a program in 2016 to provide targeted technical assistance to help detect and treat MDR-TB and XDR-TB.
- Médecins Sans Frontières TB Program Assistance: MSF runs a comprehensive TB diagnostic and treatment management program out of the Kerema Health Center. MSF's role is to support and work closely with the National TB Program of the NDOH.

Tuberculosis is the most significant infectious disease in the Gulf Province, and the Kapuna and Kerema health centers have documented many cases. In 2016, the case notification rate was recorded as 767 per 100,000, more than double the national level (Gulf Provincial Health Office, 2016). During the household survey, 58 individuals (27 males and 31 females) reported three or more symptoms associated with active TB; however, it is unknown what percentage (if any) of these individuals has active TB, as neither testing nor clinical evaluation was undertaken as part of the household survey.

25 The AU$ to PGK currency conversion of AU$100 = PGK238 (7 March 2019) was used.

Factors contributing to the high incidence of TB in Gulf Province most likely include delayed presentation and difficulties in managing patient follow-up. The late presentation of cases and inefficient treatment access and delivery may contribute to a prolonged transmission risk and very high infectious burdens of TB.

9.7.5 Vector-borne Diseases

Vector-borne diseases are infections transmitted by an insect bite, most commonly the mosquito. The dominant vector-borne disease in Papua New Guinea and the PAOI is malaria; however, other vector-borne diseases include lymphatic filariasis, the flaviviruses (e.g., dengue, Japanese encephalitis, Zika and chikungunya) and alphaviruses (e.g., Ross River fever). In addition, Burkitt lymphoma, an important adolescent malignancy caused by Epstein-Barr virus, is strongly associated with areas of malaria transmission (Moorman & Bailey, 2016; Lavu et al., 2005) and is well documented in the Gulf Province.

Two important malaria surveys were conducted in the Gulf Province in the past five years:

- PNG Institute of Medical Research (IMR) in 2014: 504 children from Gulf Province aged from 5 to 59 months were tested for the malaria parasites.
- InterOil in 2012: 366 people across all ages from eight Pawaia villages were tested for malaria using a rapid diagnostic test. A follow up study with 175 people was conducted using both rapid testing and slide microscopy.

The PNG IMR study indicated a prevalence rate of 0.02%, lower than the national results for children aged from 5 to 59 months (3%). The InterOil studies (Cross et al., 2014) also showed a very low (less than 1%) prevalence of malaria.

Community surveys documented malaria as a notable health problem in communities and households in the PAOI; however, as outlined in Section 9.7.4, it is not uncommon for general respiratory symptoms to be conflated with malarial symptoms.

Little is known about the prevalence of other vector-borne diseases in the PAOI; however, literature reviews of lymphatic filariasis indicate that the disease affects the Kerema and Kikori districts (Graves et al., 2013).

Nearly all households report owning bed nets (i.e., 50% report owning between three and six nets), and use is high. Mothers and children are usually prioritized when there is not a net for each household member.

9.7.6 Sexually Transmitted Infections

Papua New Guinea has among the highest prevalence of HIV, syphilis, and other sexually transmitted infections (STIs) in the Asia-Pacific region (Vallely et al., 2010, 2016). Adult HIV prevalence is currently estimated at 0.9%; however, prevalence of 12 to 17% has been reported among women and men who sell or exchange sex, and antenatal HIV prevalence of around 2% has been reported from several highland provinces. Papua New Guinea is among 12 high-burden countries selected by the WHO for intensified support to eliminate mother to child syphilis transmission. Papua New Guinea also has one of the highest estimated burdens of cervical cancer globally, with an age-standardized incidence of 23.7 per 100,000, compared to 5.0 per 100,000 in Australia. Cervical cancer is considered an STI caused by specific strains of the human papillomavirus (HPV) (CDCP, 2017).

While overall STI data across the PAOI is sparse, there is consistent data for HIV from antenatal and outpatient clinics for the Kapuna health center (0.4% rate). Outside of, but near the PAOI, there is also data for the Kerema health center (less than 0.5%). This health center data is consistent with national HIV data for rural locations (less than 1% prevalence rate), although it is likely to under-represent the actual STIs in the PAOI due to the cultural stigma associated with STI diagnosis.

9.7.7 Accidents and Injuries

Injuries are estimated to cause more than five million deaths each year in developing countries, which is roughly equal to the number of deaths from HIV/AIDS, malaria and TB combined (Gosselin et al., 2009).

More than 90% of injury deaths occur in low- and middle-income countries, where preventive efforts are often nonexistent and health care systems are least prepared to meet the challenge, as is the case in Gulf Province and Papua New Guinea more broadly. Injuries contribute to the cycle of poverty and impact individuals, communities, and societies. Injuries have many dimensions: human (e.g., victim, caregiver), environment (e.g., infrastructure, legislation) and vector (e.g., motor, marine and river vehicles for injuries; weapons for violence open fires for burns). The documented outpatient burden of accidents and injuries in PAOI and in nearby Kerema is similar (i.e., Kapuna Health Center) or higher (i.e., Kerema Health Center and Orokolo Sub-health Center) than the Gulf Province 2015 rate of 4.9% (compared with the national rate of 3.6%). Outpatient data shows:

- Kapuna Health Center: 4% of total caseload.
- Kerema Health Center: 8.6% of total caseload.
- Orokolo Sub-health Center: 8% of total caseload.

Data from aid posts is generally consistent with the health center percentages of 2 to 10%. Some facilities show an artificially higher percentage due to the caseload denominator being small. Nevertheless, provincial data from 2011 to 2015 shows a 27% worsening of injury presentations to health facilities in Gulf Province (NDOH, 2015).

The types of injuries and accidents noted or observed during social field surveys included:

- Wounds (e.g., lacerations, bruises, incisions, crush wounds).
- Burns and scalds.
- Fractures and sprains.
- Snakebite.
- Insect and animal bites.
- Drowning.
- Assault injuries.
- Sexual injuries.

Women also reported that laborious tasks, such as beating sago and working gardens, contributed to muscular-skeletal injuries and general aches and pains.

Gulf Province has minimal emergency services, and less than 3% of health centers have an ambulance (Howes et al., 2014). None of the PAOI villages has any emergency response services.

9.7.8 Alcohol and Drug Dependency

Information from the community-level survey on the consumption of alcohol, marijuana and harder drugs, such as heroin, cocaine, amphetamine and ecstasy, in the PAOI indicates:

- Male alcohol consumption is common. Alcohol consumption is much lower for females.
- Home brew is made and consumed locally, while other alcohol is brought in from Port Moresby or other urban areas. There are no alcohol off-license premises in the PAOI.
- Alcohol abuse is regarded as a law and order problem, particularly as it is associated with various activities that communities consider to be illegal, including fighting, domestic violence, and obscene or abusive language.
- Most communities contain males who smoke marijuana. Village leaders and the women interviewed indicated that the use of marijuana is common and widespread, particularly among young males. Relatively few females reported smoking marijuana.

9.7.9 Domestic Violence

Domestic violence and sexual assault are pervasive problems in the PAOI. Women from every village reported a past incident of domestic violence either from their husband or another family member. In addition, sexual assault was reported as a problem in 22% of the villages surveyed.

Women from 12 villages (40% of villages) indicated an assault had occurred in the past two weeks (Table 9.14). Over the past 12 months, women from 26 villages (87%) indicated an assault had occurred, compared with 67% of women nationally who are believed to have been the victims of domestic violence (Amnesty International, 2010).

Table 9.14 – Last Time a Woman was Assaulted (No. of Villages)

Language Group	Total Number of Villages*	Last 2 Weeks	<1 Year	>1 Year
Pawaia	4	2	1	1
Ahia	1	1	0	0
Koriki	4	1	3	0
Iare	5	0	2	3
Kaimare	2	1	1	0
Maipua	1	0	1	0
Orokolo	13	7	6	0
Total	**30**	**12**	**14**	**4**

* Indicates the total number of villages for which a response to this question was provided. < = less than; > = more than.

9.7.10 Community Safety

Aspects of community safety are included in the Sections 9.7.1 to 9.7.9 and in Sections 9.9 and 9.10. Specifically:

- A community's sense of safety was reasonably high in the PAOI (Section 9.9.3). Most village leaders and women's groups indicated that it was safe in their village.
- A community's perceptions of whether its safety had changed over time indicated that, generally, the sense of safety had either stayed the same or improved, which is attributed primarily to the reintroduction and strengthening of the village court system in most of the PAOI.
- The main safety concerns expressed by the village leaders were sorcery and naturally occurring safety risks such as snakes, crocodiles, and floods. Women's groups indicated that they were not safe because of sorcery and because of social or cultural norms that put them at risk of domestic violence, sexual assault or other forms of violence (Section 9.9.3).
- Accidents and injuries contribute a significant morbidity burden in the PAOI, as outlined in Section 9.7.7.

- The PAOI has no operable roads; thus, it has no incidence of motor vehicle accidents or injuries caused to passengers or pedestrians from motor vehicles.
- Community members travel in small watercraft, predominantly dugout canoes but also dinghies, alongshore of Orokolo Bay and along the three Purari River distributaries and smaller riverways. Such travel constitutes risks to an individual's safety such as drowning, and exposure to water-borne parasites and dangerous animals (e.g., crocodiles and snakes during embarking and disembarking). Community-level surveys indicated that some villagers were concerned about the safety of dugout canoes passing larger vessels that cause bow waves or propeller wash that could inundate canoes and cause them to capsize (Part 22 of Volume 2).
- Violence is a factor jeopardizing community safety and can occur within clans and communities, and between different communities, sometimes in relation to land disputes, or in retribution for perceived grievances. Village leaders, women and youth groups cited 'fighting' as the most or one of the most significant law and order issues (Section 9.9.2 and Part 14 of Volume 2).
- Gender-based violence jeopardizes community safety, with domestic violence and sexual assault prominent (see Section 9.7.9).
- No community emergency medical response is available in the PAOI.

9.8 Livelihoods and Natural Resource Use

9.8.1 Ecological Zones

Ecological zones were used to characterize the heterogeneity of natural resource uses in the PAOI. Each zone only partly overlaps the PAOI; however, the ecological zones provide a guide to the natural environment around each of the surveyed villages. As described in Section 9.2.1, the environmental setting influences people's day-to-day activities. Ecological zones influence how different clans and villages behave similarly in their day-to-day physical activities (see Figure 9.2).

9.8.2 Land and Natural Resource Setting

The land-based portion of the PAOI covers approximately 269,393 ha of the Purari River catchment and encompasses a wide variety of land resources (e.g., vegetation types) and freshwater ecosystems, which both contribute to provisioning ecosystem services. Forests (78%) are the dominant land use area in the PAOI followed by wild stands of sago (9%) and mangroves (7%). The remainder comprises grassland and herb land, and areas dominated by anthropogenic land use (e.g., villages, subsistence agriculture, abandoned coconut plantations and planted sago). The water-based portion of the PAOI incorporates rivers and waterbodies, such as lakes and lagoons, and the ocean. A breakdown of the dominant natural resource land use categories in the PAOI is provided in Figure 9.7 and Table 9.15.

NATURAL RESOURCES IN THE PAOI

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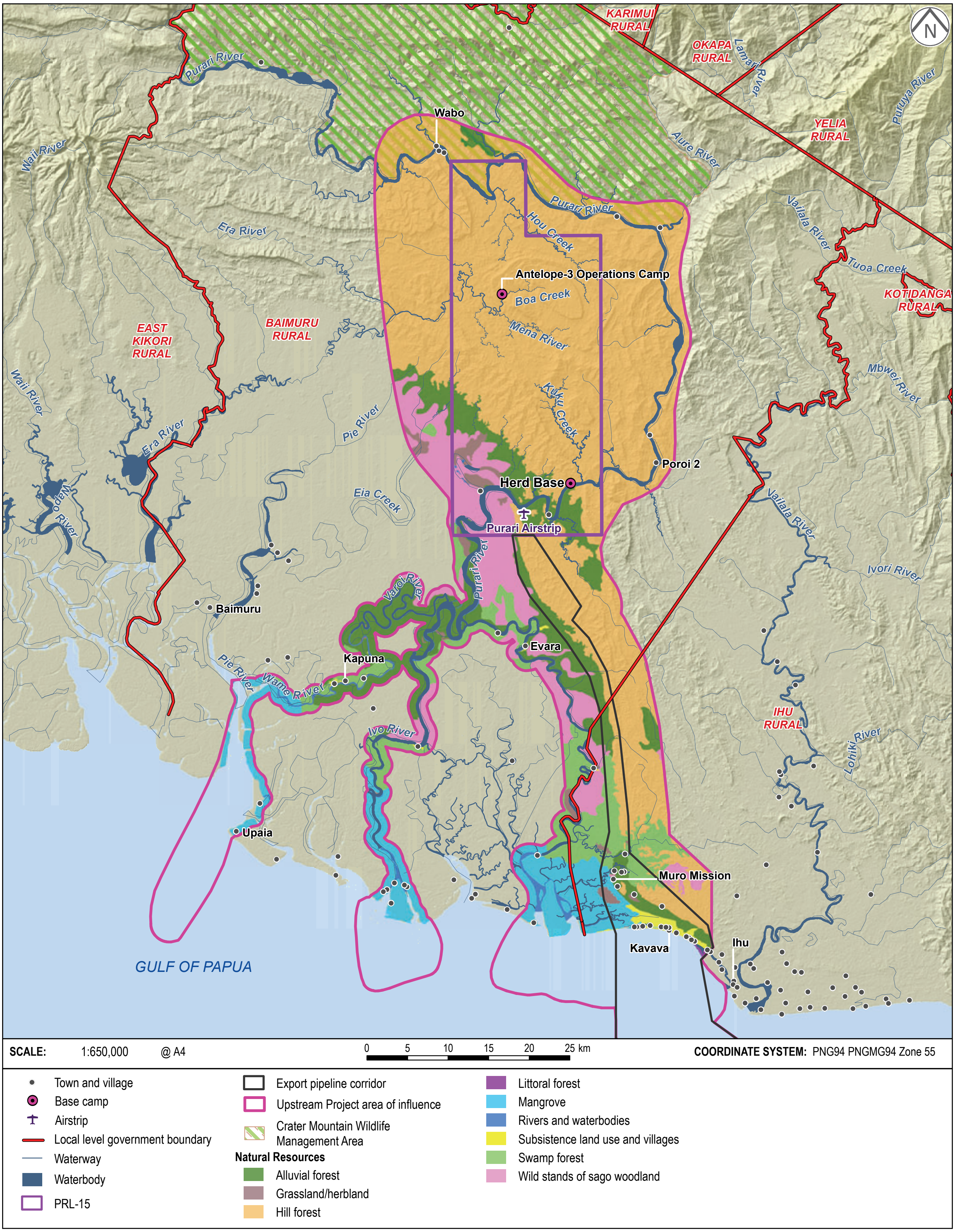
FIGURE 9.7



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Table 9.15 – Dominant Natural Resource Land Use Categories in the PAOI

Resource*	Area (ha)	%
Forest		
Hill forest	159,483	59
Alluvial forest	32,477	12
Swamp forest	18,979	7
Littoral forest	97	<1
Sub-total	*211,037*	*78*
Other		
Wild stands of sago woodland[#]	25,332	9
Mangrove	18,453	7
Grassland/herbland	3,164	1
Subsistence land use and villages	1,729	1
Rivers and waterbodies	9,679	4
Subtotal	*58,357*	*22*
Ocean[†]	**231,589**	
Total (forest and other (excluding ocean))	**269,393**	**100**

* Resource categories and areas are derived from the floristic information management system (FIMS) mapping units based on vegetation mapping terminology and are coded for resource type.
[#] Wild stands of sago woodland are those dominated by sago rather than being a component of other vegetation types. These are termed Swamp woodland under the vegetation mapping terminology.
[†] The Ocean portion of the PAOI covers the area from the Purari River delta to Caution Bay.

9.8.3 Land Tenure

Most land in Papua New Guinea is under customary ownership as described in Section 9.2.3.

The usual approach to commercializing land in Papua New Guinea, without alienation, is leasing from the customary owners. This process involves forming an incorporated land group to represent the interests of the landowners, make commercial agreements with developers and manage any income generated.

Existing leases in the PAOI include:

- Forestry leases: Frontier Holdings Limited is currently logging Vailala Blk 3 southeast of the Purari River, and Turama Forest Industries has a forest management agreement for Baimuru Blk 3, which lies northwest of the Purari River and covers all of PRL-15. Further information about forestry activities is provided in Section 7.7 and Section 9.4.1. Logging concessions are shown in Figure 7.24.
- Mining and petroleum leases: The PAOI overlaps three petroleum prospecting licenses and eight mining exploration licenses.
- Special Purpose Agricultural and Business Lease (SABL): In 2010, 656,034 ha of land in Gulf Province was granted to the Purari Development Association for agreed agricultural or other business activity (Figure 9.8); however, the process under which this SABL was granted is under investigation for not aligning with the formal process (Numapo, 2013).

The land dispute and resolution process is outlined in Section 9.9.

9.8.4 Agriculture

Subsistence agriculture dominates in the PAOI and consists of swidden agriculture, sago cultivation, and planted fruit and nut trees or palms.

PURARI SPECIAL PURPOSE AGRICULTURAL BUSINESS LEASE

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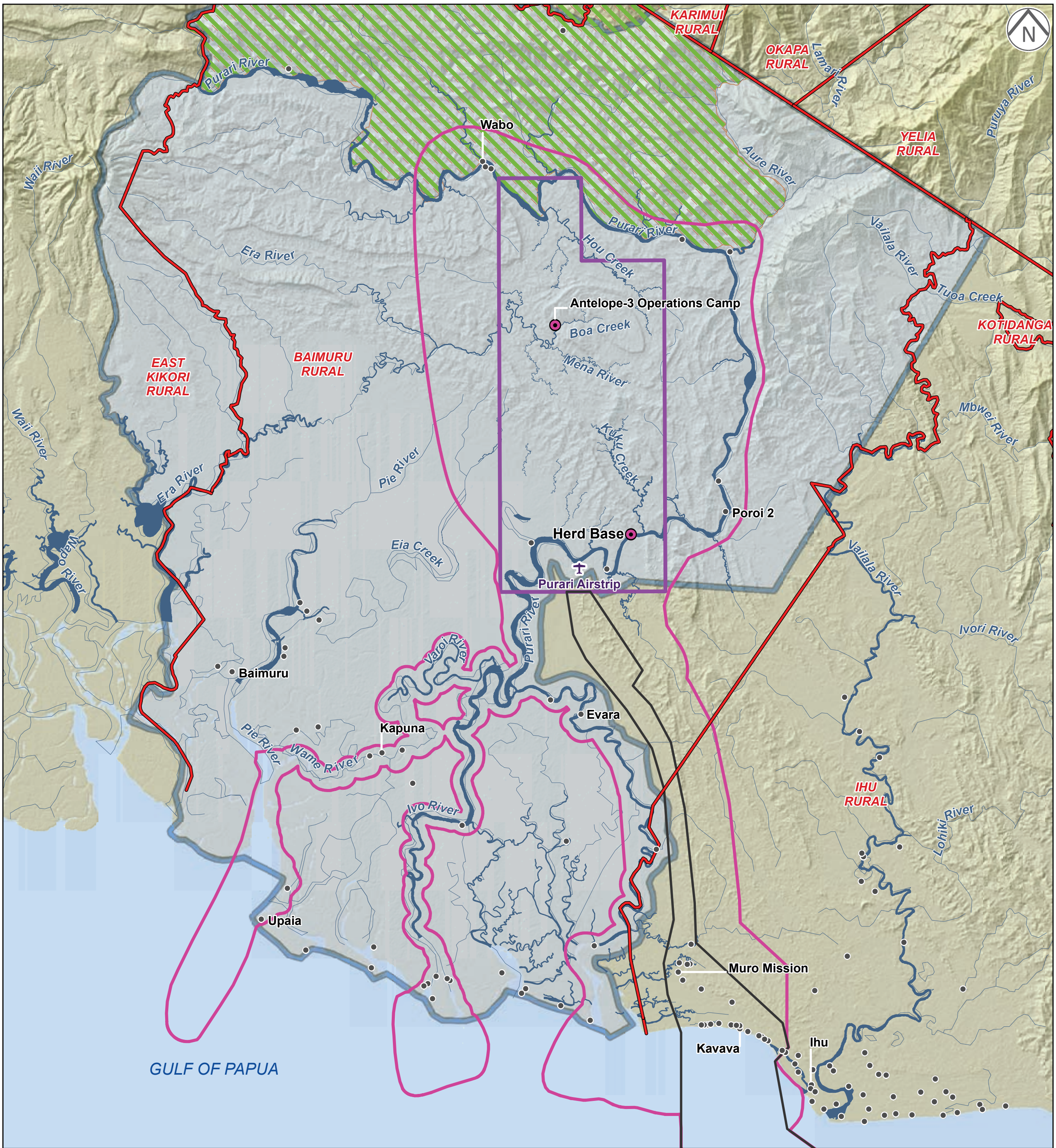
FIGURE 9.8



SCALE: 1:650,000 @ A4 | 0 5 10 15 20 25 km | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Airstrip
- Local level government boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- Upstream Project area of influence
- Crater Mountain Wildlife Management Area
- Special Agriculture and Business Lease (SABL)

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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9.8.4.1 Swidden Agriculture/Gardens

In swidden agriculture, land is cleared to create space to plant crops, is used for typically 4 to 12 months until soil fertility declines and then is left to regenerate. Typical crops planted are sweet potato, taro, cassava, cooking bananas, sugarcane, pumpkin, sweet corn, green leafy vegetables (e.g., aibika and aupa), peanuts, snake bean, Chinese cabbage, pitpit, eggplant, cucumber, ginger, chilies, passion fruit, paw paw, pineapple and watermelon.

Gardens are made on hillsides, along the banks of the Purari River and other waterways, in logged-over alluvial forest, across old sand dunes in coastal areas and occasionally in small cleared patches of nipa palms in the mangroves where crops are planted on raised mounds. Bush gardens vary in size but are mostly less than 0.5 ha. The larger and more widespread bush gardens occur toward the coast and are mostly located on extensive alluvial plains. Larger gardens occur at Avavu (inland of Orokolo Bay), many of which have been established after logging of the alluvial forest. The most intensive area of garden cultivation occurs across the Orokolo Bay hinterland where gardens and planted sago extend over at least 1,344 ha and much of the original alluvial forest has been cleared (Figure 9.9).

The four most important community-based income-generating activities from plant-based natural resources are sales of betel nut, sago, surplus garden produce and coconuts. The main source of betel nut is the inland Orokolo villages and Evara (Ahia language group) where dense stands of the betel nut palm have been planted. Average annual household incomes for these villages exceed PGK4,000 (US$1,200).

9.8.4.2 Sago Cultivation

Sago planting and harvesting is the most important food production activity in the PAOI. Sago is the main staple food for all the villages. Sago and coconuts are the most important famine foods. Both are resilient to floods and drought. Sago is harvested from both planted and wild sago stands. Harvesting from planted stands is more common and preferred due to better accessibility and because favored cultivars that have better texture (less watery) and flavor are planted. Sago is planted in three main types of locations that are easily accessed:

- Along the riverbanks of the Purari River and its tributaries from the limit of sago’s salt tolerance in the lower Purari River to beyond Wabo.
- On the margins of small creeks and swampy sites inland from the main rivers.
- Throughout the swales of the Orokolo Bay hinterland.

The other main source of sago is the wild stands of sago, which cover approximately 25,351 ha (9%) of the PAOI (Figure 9.10). Yields of between 100 and 150 kg per sago palm are possible and are usually sufficient for a family for a month. Sago palm byproducts are used in all villages for roofing and building.

Sago is sold in 5 or 10 kg blocks (Plate 9.14); Evara had the highest annual household income from sago sales. A range of other items derived from natural resources is sold, including mustard (fruit of the *Piper betel* vine) for chewing with betel nut; mats and small *bilums* made from pandanus; occasionally sedge, bush tobacco, canoe trees and house posts; and rarely copra.

SUBSISTENCE AGRICULTURE IN THE OROKOLO COAST HINTERLAND

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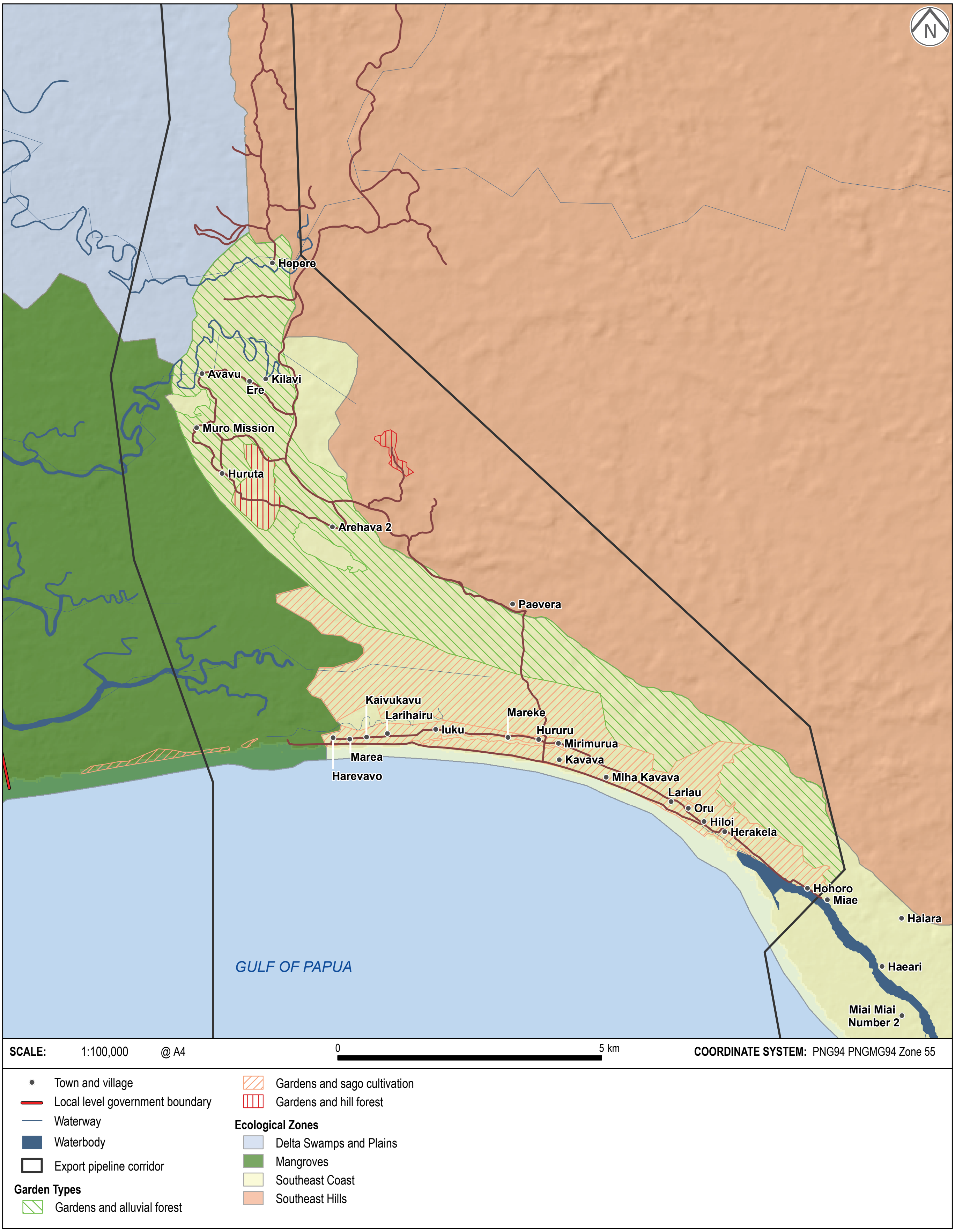
FIGURE 9.9



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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WILD SAGO

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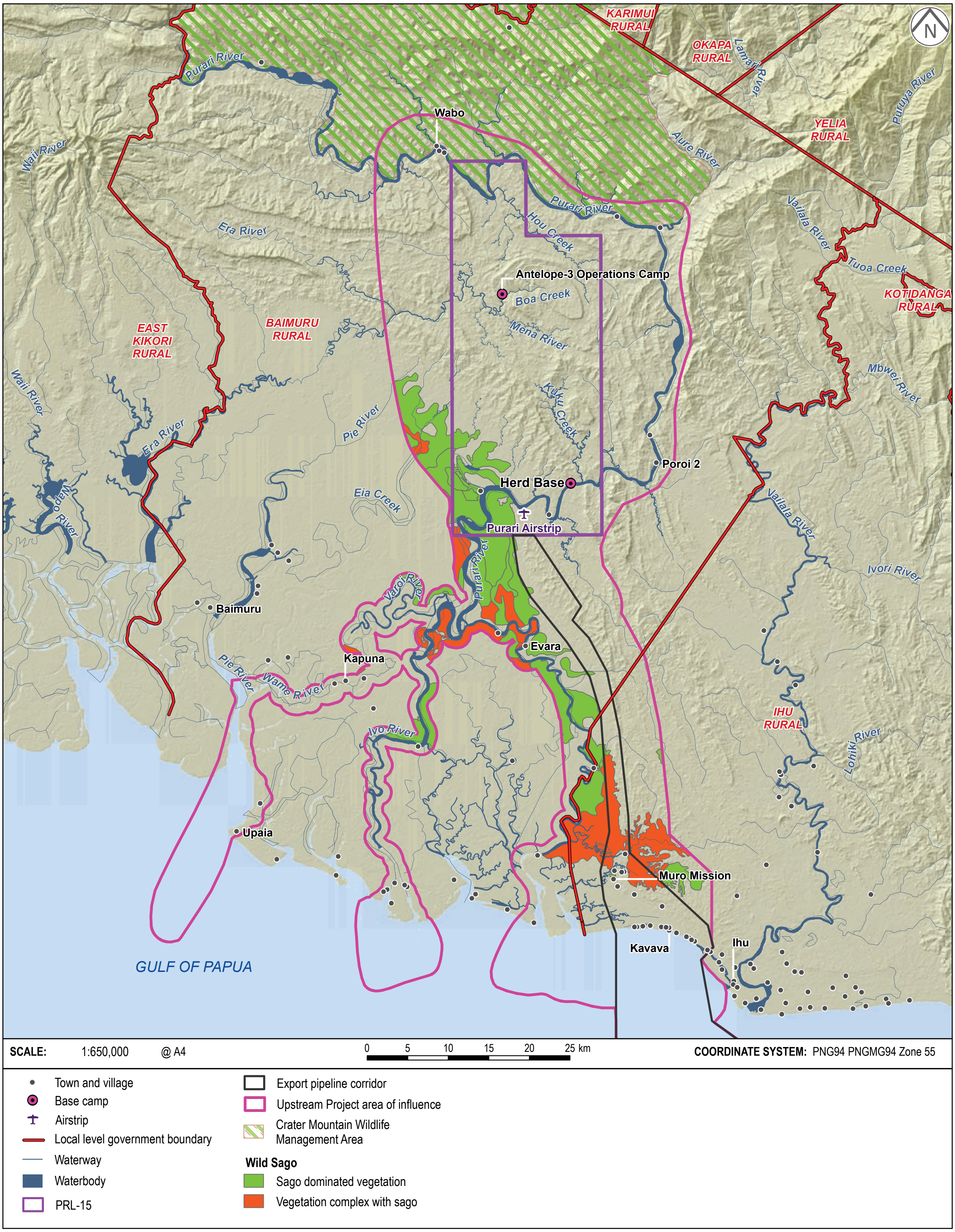
FIGURE 9.10



Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Plate 9.14 – Sago

Photo: ERIAS Group.

9.8.4.3 Planted Fruit and Nut Trees or Palms

Fruit and nut trees are planted in villages but are particularly important in coastal and lowland areas. Okari nut and breadfruit are the most widespread tree species planted. Okari nut is widely eaten and sold seasonally in local markets. Breadfruit is grown wild or in village gardens from seedlings or by propagating root cuttings or suckers. In some varieties of breadfruit, both the fruit pulp and seeds are eaten.

Coconut trees are planted in coastal areas and the inland Orokolo villages. Coconut is an important famine food, particularly in the wet season when gardens and sago plots cannot be accessed due to flooding. The meat can be eaten at all stages of development, and the milk of the green coconut can be consumed during drinking water shortages.

9.8.4.4 Livestock

The only domestic livestock encountered were pigs and chickens; one or both are kept to some extent in all surveyed villages. Pig husbandry practices are broadly similar in the PAOI. Rates of pig ownership differ strikingly between the coastal and Purari River delta villages and the villages located further inland. The highest rates of pig ownership (i.e., more than 60% of households) and the largest groups were reported in the Kaimare, Koriki and Maipua villages. Average group sizes were usually between five and six. The lowest rates of pig ownership were rarely above 10% of households and were recorded among the Iare villages living along the Purari River. The Ahia village of Evara and some Pawaia villages had no pigs at all.

The sale of pigs was sometimes mentioned as an important source of income, although it always ranked below the sales of garden produce, fish or seafood and sago, e.g., by the coastal Orokolo villages, while in other villages the sale of pigs was not rated at all, e.g., all the inland Orokolo villages.

Most households (42 to 86%) keep chickens. The lowest rates of chicken husbandry were recorded in the Pawaia (42%) and Koriki villages (48%), and the highest rates were recorded in the Kaimare villages (83%) and the Ahia village of Evara (86%). The average flock size was 14 birds. The stated importance of chicken sales as a commercial activity varied among villages from no importance to a significant source of income. The household survey indicated that 8.2% of households in the two weeks prior to the survey sold chickens, with average earnings of PGK44 (US$13.20). Only two households reported significant annual earnings from chicken sales, one at Kairu'u (Koriki) with PGK760 (US$228) and one at Upaia (Kaimare) with PGK2,400 (US$720).

9.8.4.5 Non-domesticated Animals

Several kinds of wild animals are occasionally reared from juveniles until large enough to sell or consume. The most common are cassowaries and cuscuses, with crocodiles and wallabies also occasionally reared. Smaller birds are also sometimes kept, with a proportion of these sold.

Data from the household surveys indicated that:

- Sixteen of the 354 households were rearing a total of 22 cassowaries.
- Six out of 354 households reported keeping crocodiles.
- Nine out of 354 households reported noteworthy annual sales from crocodile skins, with sales of PGK300 to PGK800 (US$90 to US$240).

9.8.5 Fishing

Most households in all villages fish. Fishing provides a variable but usually important proportion of the animal food intake and represents an important opportunity to generate income for some villages. In four coastal and delta villages (i.e., Aumu, Variki, Upaia and Ara'ava), the sale of fish and seafood was ranked as the primary source of village income. In other villages, it was ranked behind betel nut, processed sago and garden produce; however, in these villages, women and youths consistently identified fish and seafood products as one of the major opportunities for them to contribute to family incomes. Fifty-three percent of all households claimed annual earnings from PGK360 to PGK21,600 (US$108 to US$6,480). The overall annual average for all vendors was PGK1,722 (US$517), with 9 of the 27 villages recording above-average earnings.

Fishing is focused on the ocean along the Orokolo Bay coast. Fishing also takes place in the tributaries of the Purari River and the network of interconnected channels that make up the delta. Since access to these habitats often involves several hours' travel, fishing typically takes place in combination with other activities such as sago production and hunting. Travel from villages to these locations is usually by paddle canoe. Fishing grounds are reportedly mostly under customary ownership, although sections of the main channels of the Purari River and the coastal marine resources are said to be available to anyone from the local villages.

Fishing methods used are, for the most part, traditional (Plates 9.15 and 9.16), albeit with the addition of modern techniques and equipment, including gill nets and store-bought fishing line and steel hooks.

Sharks, sawfish and rays, barramundi, threadfin salmon and mullet are caught in the marine and brackish river estuary habitats. Black bass, emperors and many catfish species are caught in the brackish estuarine and freshwater river zones. Prawns are common throughout the system, but there is a change from freshwater prawns to saltwater prawns in the estuarine and marine habitats.

Communities in the PAOI believe that increased boat activity on the rivers has led to a reduction in fish stocks over the past decade or so. Many landowners of the freshwater sections of the river point to a near complete decline of several species in these habitats, including barramundi and black bass. Over the same period, people have observed the spread of exotic fish species through the catchment, some of which are now regularly eaten.

Further description of marine fisheries and resources is provided in Chapter 8.

Aquaculture

No examples of aquaculture have been observed in the PAOI. Some exotic species used for aquaculture elsewhere in Papua New Guinea (e.g., tilapia) have established feral populations in PAOI rivers (West & Glucksman, 1976) (Section 7.6.5).

Plate 9.15 – Poison Vine (Growing on Trunk) Used for Fishing

Plate 9.16 – Woman in Orokolo Bay Fishing with Y-net

Photos: ERIAS Group.

9.8.6 Hunting and Collecting

9.8.6.1 River and Coast Animal Resources

The most important riverine and coastal resources hunted and collected in the PAOI are freshwater and saltwater crocodiles, freshwater and estuarine soft-shelled and pig-nosed turtles, the Australian snubfin dolphin and a variety of mollusks and crabs. Additional coastal resources harvested include mangrove worms and crabs, and various small clams, oysters and mussels. Individuals or family groups visit localities where river and coastal resources are known to occur to harvest those resources. Crocodiles are hunted with guns, although many smaller crocodiles are caught collaterally in gill nets.

Seasonal and environmental conditions influence river and coast animal resource availability. For example, each September to December, pig-nosed and soft-shelled turtles migrate upriver from the marine and estuarine zone to lay their eggs in sand banks in the freshwater reaches of the Purari River and its tributaries, and inland inhabitants actively pursue them during this period. Crocodiles are said to lay their eggs at the same time of year. Seasonal breeding also occurs among many bat species. Access to some other animal resources, including wild pigs and cassowaries varies in accordance with water levels in the Purari River catchment., High water levels can restrict access to some areas and resources due to flooding of riverine areas, but they can improve access to other areas, such as inland oxbow lakes that are impossible to access unless water levels are high. Some terrestrial animals, including wild pigs and bandicoots, are said to become concentrated on elevated ground during and after floods, making them easier to hunt.

9.8.6.2 Land Animal Resources

A broad range of resources are hunted and collected in the PAOI, including mammals, reptiles, birds, frogs and insects, and their produce related to life stages and reproduction (i.e., eggs and larvae) (Table 9.16). Consumption of the larger animals (i.e., wild pigs, cassowaries, wallabies and pythons) occurs more frequently in the inland villages than in the near coastal villages; however, monitor lizards, bandicoots and cuscuses are consumed more evenly across all villages. Sago grubs are consumed in all villages.

Table 9.16 – Common Land Animal Resources Hunted and Collected

Habitat	Animal Resource
Forest*	♦ Wallabies, tree kangaroo, echidnas ♦ Cassowaries and eggs ♦ Wild pigs ♦ Pythons and monitor lizards ♦ Bush fowl and eggs ♦ Smaller mammals (rats), birds, reptiles, frogs ♦ Land crabs ♦ Beetle larvae ♦ Honey
Sago plantations	♦ Sago grubs ♦ Eels ♦ Smaller fish ♦ Frogs and tadpoles
Gardens	♦ Small mammals (such as rats and bandicoots) ♦ Bats
Caves	♦ Bats

Source: ERIAS Group (2016a). * Includes hill forest and alluvial forest.

Hunting and collecting methods include:

- Active pursuit: The animal is run down or shot, with bow and arrow or gun, often with the assistance of a trained hunting dog.
- Ambush: Waiting patiently at locations that wild animals are known to frequent.
- Snaring: Setting of noose snares or deadfall traps.
- Harvesting: Collecting animal resources at localities where they are known to occur in regular numbers (e.g., turtle nests).
- Chance encounters: Hunted or collected during other activities, such as clearing gardens, traveling or collecting forest products.

9.8.6.3 Plant Resources

Plant resources are of high value and are universally used in the PAOI. Interviews identified 48 to 94 useful plants from different forest types.[26] The dominant plant uses are house construction, domestic food and domestic medicinal purposes. Of the various useful plants, trees are the most useful, with 580 recorded uses, followed by palms, which have 157 uses. Other useful plants have comparatively few recorded. The main plant uses are:

26 The range in the number of plants identified reflects differences in the plant availability between communities and what they find and recall as useful.

- Hunting and fishing: Plants are used to make hunting and fishing tools. Plants that produce seed and fruit that attract animals are used as hunting sites. Other plants are used as fish poison.
- Medicine: Medicinal plants are used to treat cuts, wounds, skin disease, sores, respiratory infections, general body pain, toothache and malaria. The Pawaia villages have a greater reliance on medicinal plants than other villages.
- Construction: A range of tree species are used in house construction and fencing. Kwila tree logs are a preferred timber for house posts due to their strength and resistance to decay. Roofing thatch is commonly made from sago or nipa palm leaves.
- Food (plants other than garden plants): Hill forest, alluvial forest and, to a lesser extent, swamp forest provide at least 46 plant species that are used to supplement sago and garden food crops.
- Canoes, paddles and rafts: At least 27 tree species are used to make canoes. The most widespread canoe species is a light timber that is easy to hollow out but has a low durability due to attack by insect borers.
- Domestic items: A range of plant species are used to make domestic utensils and coverings and products, such as brooms, floor mats, containers, washing tools and shampoo. The most widely used plants for domestic items are bamboo, palm, rattan and the *Trichospermum* tree.
- Firewood and torches or matches: Firewood is an essential resource for cooking food in the PAOI. Almost any tree species can be used; however, several species are preferred. Firewood is collected from as close to the village as possible to shorten the distance that the wood is carried; however, Orokolo village inhabitants also collect driftwood from the beach for firewood (Plate 9.17).
- Cultural: Plants are used in celebrations, sorcery, dyes and to make *bilums* and mats. The forests provide the greatest range of cultural plants.
- Famine resources: Plants such as wild sago and wild yams are harvested in drought or if food crops fail due to flooding or disease.

Plate 9.17 – Firewood Collected from the Beach

Photo: ERIAS Group.

9.8.7 Subsistence Labor

Village leaders and women were asked about their main responsibilities and how frequently the main activities were undertaken. The division of labor between men and women varies among language groups. Table 9.17 describes the key subsistence activities undertaken by men and women and the results from the household survey, which indicate the proportion of households that performed the activity in the past two weeks. Those activities marked with 'N/A' indicate that the activity was not performed in the past two weeks, but it may be that the activity is not considered a discreet activity that was specifically performed in the period, but rather is an ongoing duty.

Table 9.17 – Activities and Responsibilities Undertaken by Men and Women

Activity	Responsibility	Undertaken in the Last Two Weeks (% of Households)	
		Males	Females
Making sago	Men generally fell and transport the log and sometimes scrape it. Women more often scrape and then beat and wash the sago.	50%	68%
Making gardens	Men are primarily responsible for felling trees, but both males and females clear and burn.	57%	44%
Tending gardens	Women primarily undertake this task, but males are also active. Women in Mariki indicated that it wasn't an important task, as gardens contribute less food in coastal villages of the Purari River delta than in other areas, due primarily to the shortage of suitable gardening land.	66%	56%
Hunting	Primarily men and boys hunt. Hunting occurs less frequently in coastal villages.	42%	5%
Fishing	Both men and women are active. Men set nets and fish with lines, while women use traditional baskets and nets, and also use lines. Fishing generally occurs daily.	75%	72%
Collecting seafood	Primarily women collect seafood; although, men sometimes participate. Collecting seafood is more important in coastal areas.	31%	42%
Collecting edible plants	Primarily women collect edible plants, although men sometimes participate. It can be a designated activity when okari, galip or other foods are in season; more often it is a supplementary activity. Collecting edible plants is more important for inland villages that have access to larger forest areas.	51%	50%
Building a house	Primarily men are responsible for cutting logs, preparing timber and erecting the house frame. Both men and women can make woven wall panels or mats from nipa or sago palms, and women can assist men during construction.	31%	5%
Making canoes	Predominantly men make canoes. Canoes typically last two to three years, so this task occurs relatively infrequently.	51%	16%
Community work	Both males and females undertake community work, generally on a designated day during the week.	59%	56%

Source: ERIAS Group (2016a).

Making sago (Plate 9.18), making and tending to gardens, fishing, collecting seafood, collecting edible plants and community work are all important tasks performed by both men and women.[27] Hunting, making canoes and building houses (Plate 9.19) are tasks that are primarily the responsibility of men, while women spend more time making sago and performing duties around

27 The household survey was undertaken in September/October, a relatively dry period when many people were making new gardens. This may bias the results toward making new gardens to some degree.

the house, including caring for children, collecting water, cleaning and cooking. While both men and women may be involved in an activity, such as making a new garden or making sago, the respective activities may be quite different, e.g., men may fell trees while women clear the underbrush. For sago, men may fell the palm and transport it to a suitable location, where the women will assume responsibility for processing. Young married couples appear to perform many activities together, including, e.g., making new gardens and fishing.

Plate 9.18 – Woman Making Sago Near Evara

Photo: ERIAS Group.

Plate 9.19 – Men Making Roof Thatch From Nipa Palm at Avavu

Photo: ERIAS Group.

The labor burden is shared when either males or females are sick or have limited time due to other responsibilities, and some traditional differences in the division of labor may be eroding.

The following roles and responsibilities are undertaken:

- Protecting the family: this is seen as primarily men's responsibility.
- Caring for children: shared by men and women, although women are often more actively involved.
- Raising livestock: both men and women share the responsibility, although 25% of surveyed households did not have livestock (i.e., pigs, chickens, cassowary or crocodiles).
- Collecting water: shared among men, women and children of all ages in the family, although women and girls are mainly responsible. Women were primarily responsible for collecting water in Kairimai, Ara'ava, Poroi 2, Ere, Avavu, Hepere, Huruta, Oru and Aiere.
- Collecting firewood: shared among men and women of all ages in the family, although men in Larihairu and Iuku said it was not an important task for men.
- Cooking and cleaning: women primarily undertake these tasks.

9.9 Community Security (Law and Order)

9.9.1 Law and Order System and Resolution

In Papua New Guinea, the national judicial system includes the Supreme Court of Justice, the National Court of Justice and various other courts, including district courts and land courts. The Chief Justice has administrative responsibility over the supreme and national courts. The national court has exclusive jurisdiction over human rights and is responsible for protecting fundamental rights to life, freedom from inhuman treatment, and liberty of the person or property. District courts are the frontline of the formal justice system for addressing legal rights, providing a mechanism for administering justice and resolving disputes.

As the national and district courts operate predominantly in urban areas and are not easily accessible to PNG's rural population, village courts, established in 1975, have the primary role of ensuring peace and harmony in the communities in which they operate.

Village Court

The village court system is the main mechanism for dealing with local crimes and disputes. Most village courts appear to be functioning, although to a lesser extent in the Pawaia villages. Some historical issues concerning the payment of officers are yet to be resolved. The village court magistrates are paid a small stipend for their work (e.g., PGK300 to PGK400 (US$90 to $120) per month), but they do not receive transport or phone allowances and do not have offices or office facilities.

Village courts deal with disputes relating to stealing garden produce, disputes over gardens, general bad behavior (e.g., arguments, noise and gossip) and domestic disputes. Village courts are obliged to attempt to resolve disputes with mediation. Traditional or church leaders often play a supportive role to the village court officials. Disputes that cannot be resolved in the village court are referred to the provincial court in Kerema.

More serious crimes, including rape and murder, are referred to the police in Baimuru, Ihu or Kerema, but limited resources mean a considerable delay can intervene between reporting a crime and police attendance.

Land Mediators

Under the law and order system, each local level government in Gulf Province should have four land mediators. Their role is to try and mediate and resolve land disputes between conflicting parties, and they are also involved in any government land purchase. Parties that cannot resolve a land dispute may take their dispute to a local land court hearing, which will include a magistrate and at least two land mediators; if the dispute can still not be resolved, it could go to the provincial or national land courts. The land court operates under the *Land Disputes Settlement Act 1975* specifically to settle disputes relating to customary land.

The role of land mediators appears to be poorly understood, and few villages indicated that they had a land mediator.

9.9.2 Law and Order in the PAOI

Village leaders identified the main law and order problems in the PAOI to be stealing, followed by fighting, domestic violence and marijuana use. Women report a higher level of domestic violence than portrayed by the village leaders who were generally male (Figure 9.11). Youth groups report fighting, domestic violence and stealing as the main law and order problems.

There appeared to be little difference in the type of law and order events occurring in different language groups. While several of the Orokolo villages identified more occurrences of law and order incidents than many of the other villages, this was largely attributed to the involvement of village court officials in the village leaders' meetings during the surveys and the officials' willingness to communicate openly about law and order problems.

The nearest police stations to the PAOI are located at Ihu and Baimuru, with limited logistical resources to maintain a presence in the PAOI. Community members have raised concerns about the violent behavior of reserve police and private security guards stationed at the various logging sites (DIHR, 2017). While not verified during the study, the claims were considered consistent with reports related to logging activities in other parts of the country.

TEP PNG has been working with security forces in alignment with the Voluntary Principles on Security and Human Rights. There have been no significant security incidents at Project sites prior to the assessment.

9.9.3 Sense of Security

Most village leaders (68%) and women's groups (74%) indicated that residents felt safe in their villages. The main safety concerns noted by the village leaders were sorcery and natural hazards, including snakes, crocodiles and floods. Seven of the women's groups indicated that they were not safe; four due to sorcery and three due to social or cultural norms that put them at risk of domestic violence, sexual assault or other forms of violence.

Village leaders and women's groups were asked if the level of security had changed in recent years. While most women indicated no change in the level of security had occurred, 45% of the village leader groups assessed the level of security as improved. This was attributed to the reintroduction and strengthening of the village court system.

The groups of men and women that indicated a declining level of safety and security were from the following villages:

- Aumu, Wabo, Ura, Mareke, Ere and Kilavi (village leaders).
- Evara, Kaivukavu and Larihairu (women's groups).

WOMEN'S GROUP – LAW AND ORDER PROBLEMS

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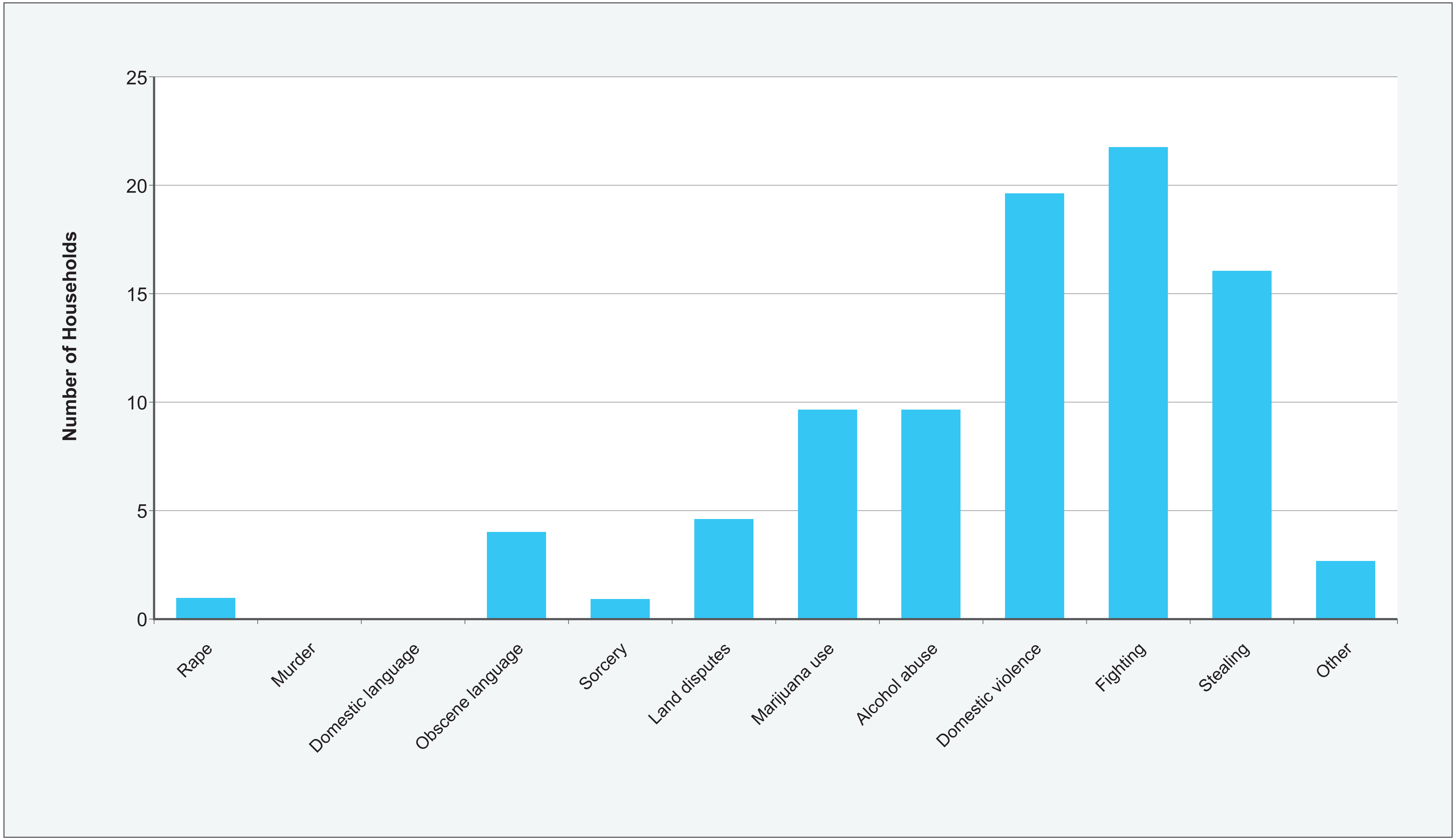
FIGURE 9.11



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The only villages reporting in-migration during the social baseline study were Ura and Wabo. Youth leaders from Wabo indicated that problems resulting from in-migration included domestic violence, fighting, stealing and increased marijuana consumption. Gambling was also attributed to people who had migrated to Wabo Station.

9.9.4 Tensions

In the PNG context, the primary drivers of tension include:

- Disputes regarding land ownership and associated benefit sharing arrangements, complications associated with incorporating land groups, representation, and participation in agreement-making processes.
- Intergenerational tensions, especially as new opportunities emerge for asserting leadership, combined with rapid social and economic changes and the need for younger educated leaders to engage with resource extraction projects and their legal and bureaucratic structures.
- Community dissatisfaction regarding local employment and business opportunities.

There had been no significant tensions related to TEP PNG activities in the PAOI; however, in relation to the primary drivers the following was noted:

- Several landowner representative organizations were in place in the PAOI. Land disputes were a major cause of conflict among Pawaia groups during an earlier social baseline study for a proposed hydropower dam. To some extent, this held for most of the PAOI, as land disputes were a primary source of localized conflict.
- In Gulf Province, logging activities are a cause of adverse impacts and have been linked to new forms of inequality and violence from state and non-state security forces. Many focus group participants registered strong concerns over logging activities.

9.10 Community Transport and Access

9.10.1 River and Sea Travel

Transport around the PAOI is mainly undertaken on rivers with dugout canoes, motorized dugout canoes or dinghies (Plates 9.20 to 9.25). Most trips involve one to four hours' travel from villages to access food gardens, sago processing sites and hunting and gathering sites or to go fishing; but it is not uncommon for people to travel longer and stay overnight or for several nights.

Plate 9.20 – Motorized Canoe

Plate 9.21 – Canoes Moored at Mapaio

Photos: ERIAS Group.

Plate 9.22 – Children Travel by Paddle Canoe near Wabo

Plate 9.23 – Family and Goods Travel by Dugout Canoe with an Outboard Motor

Plate 9.24 – Family and Goods Travel by Paddled Dugout Canoe

Plate 9.25 – Dinghy Departing Harevavo for Sea Travel

Photos: ERIAS Group.

Villagers living along Orokolo Bay regularly transit along the coast to sell marine produce, purchase inland produce and access fishing areas in mangroves, and in nearshore and offshore waters.

Sea travel mostly occurs outside of the trade wind season when the water is relatively calm. The main destinations are Kerema, Kikori, and the Daru and Kamusi logging camps in Western Province.

9.10.2 Roads, Walking Tracks and Airstrips

No public or government roads exist in the PAOI. The only roads are temporary logging roads, which are developed to link harvesting operations to logging camps and export wharfs. Once logging stops, these roads become inoperable due to erosion and vegetation regrowth. The Herd Base—Gas Field Road passes north–south through PRL-15 and connects the now decommissioned Hou Creek Base with Herd Base.

Most villages have walking tracks around their village to access hunting areas, gardens and forest resources. One main coastal walking track connects the Orokolo villages to Kerema; however, it involves crossing the Vailala River. A well-established track connects the inland Orokolo villages of Avavu, Ere and Kilavi with Huruta, Arehava 2 and Paevera in the center and with the coastal Orokolo villages of Harevavo, Kaivukavu, Marea, Larihairu and Iuku. The track is used to access health services and to trade food.

Airstrips are located near Herd Base (Purari Airstrip) and at Wabo (Wabo Airstrip); although, flights from the latter are infrequent. The airstrip near Herd Base services the petroleum drilling operations, and the Wabo Airstrip connects Wabo with the highlands. The airstrips do not have regular commercial air services, but TEP PNG and some private charter flights use them.

9.10.3 Access to Markets

The PAOI has limited organized markets and lacks buyers or market infrastructure to enable sales to other areas. Most sales are casual within villages or with nearby villages. Other local opportunities include selling goods to workers at the Evara logging camp, the Kapuna Health Center and Herd Base. The main organized market in the PAOI is at Kaivukavu; and it operates on Saturday, Monday and Thursday mornings. Other markets are located at the Kapuna and Muro missions. Some villagers travel to remote organized markets outside the PAOI at Baimuru and further west in the Kikori River catchment; however, the cost and time involved in traveling to regional markets deters most potential vendors in the PAOI.

9.11 Cultural Heritage and Archaeology

The historical context of the PAOI is described in Section 9.2.2.

9.11.1 Tangible Cultural Heritage Sites and Materials

Tangible cultural heritage values have a physical presence that can be seen or touched; they include archaeological sites where physical remains of past cultural activity are present (e.g., pieces of pottery or shell on the ground surface); landscape features, such as hills, caves and river mouths; and individual trees or stands of vegetation or other landscape or biogeographic manifestations of spiritual, sacred or ritual significance. In addition, tangible cultural heritage values include movable material cultural items (e.g., ancestral heirlooms and traditionally made items used in day-to-day subsistence or leisure activities).

International Finance Corporation’s Performance Standard 8 (IFC, 2012b) defines tangible cultural heritage as:

> (i) tangible forms of cultural heritage, such as tangible moveable or immovable objects, property, sites, structures, or groups of structures, having archaeological (prehistoric), paleontological, historical, cultural, artistic, and religious values; (ii) unique natural features or tangible objects that embody cultural values, such as sacred groves, rocks, lakes, and waterfalls.

Twelve tangible cultural heritage sites were formally recorded during the baseline study. A further cultural heritage site in the PRL-15 oxbow wetlands was documented but not formally recorded due to a lack of access to the site; however, aerial imagery was used to determine its location. These sites and sites recorded from previous studies in the PAOI (i.e., Popo and Irapuipiarumirie) are shown in Figures 9.12 and 9.13.

9.11.1.1 Ancestral Village Sites

All villages have oral traditions that recall the names and locations of their ancestral villages. In some, the exact location of the ancestral villages is not known and in others the names and location of such sites remain confidential to protect ancestral knowledge and limit potential challenges to land rights, e.g., the four Pawaia-speaking villages chose not to provide the names or locations of their ancestral villages.

Eighty ancestral villages were named during the community-level surveys. Nine have known locations, and three were formally recorded during the surveys (Table 9.18).

TANGIBLE CULTURAL HERITAGE SITES (PRL-15)

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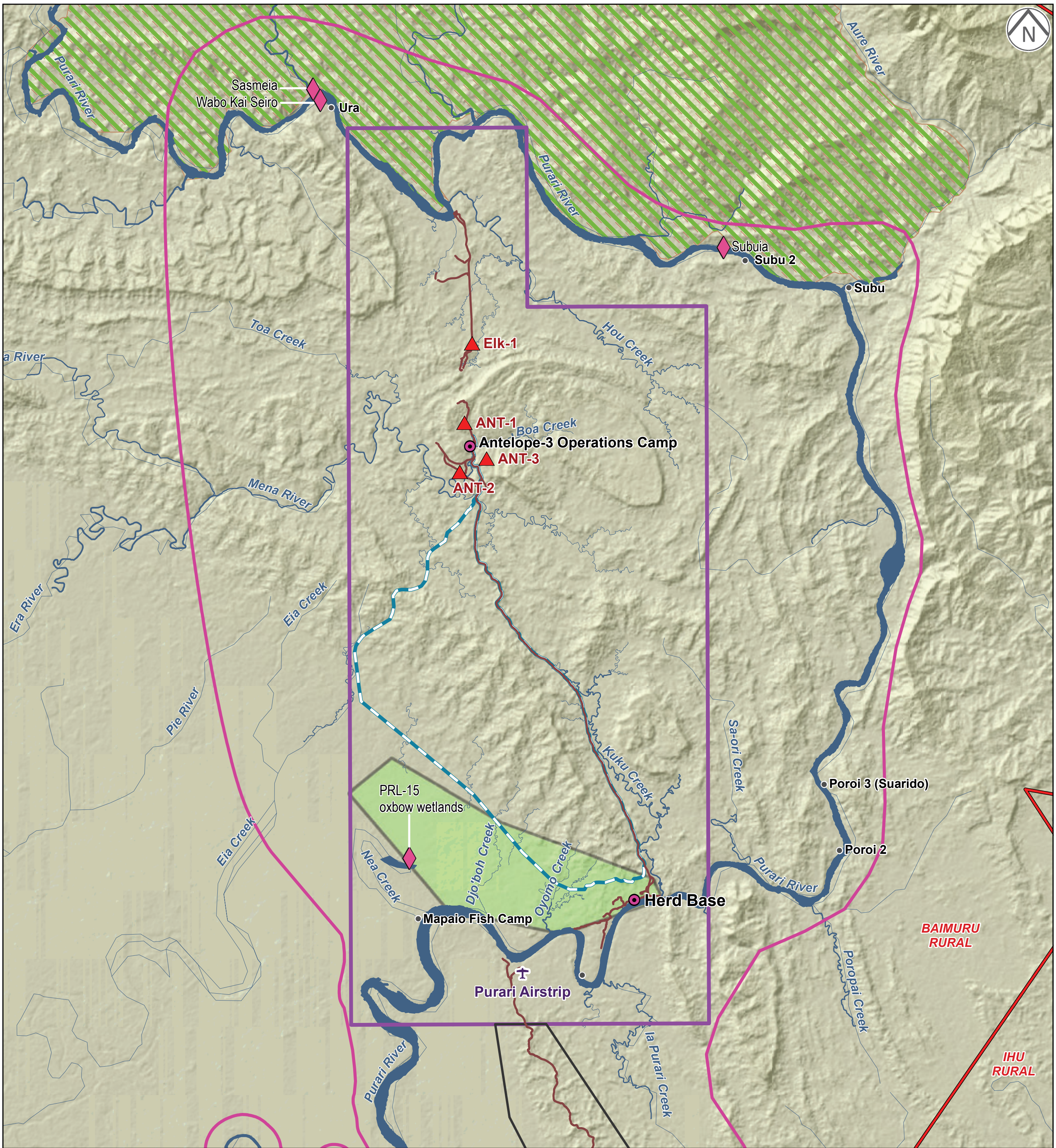
FIGURE 9.12



SCALE: 1:300,000 @ A4 — 0 5 10 15 km — COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Airstrip
- Local level government boundary
- Track
- Waterway
- Waterbody
- PRL-15
- Upstream Project area of influence
- Crater Mountain Wildlife Management Area

Existing Facilities

- Base camp
- Wellpad

Proposed Facilities

- Trunkline corridor
- CPF, logistics base and airstrip area
- Export pipeline corridor

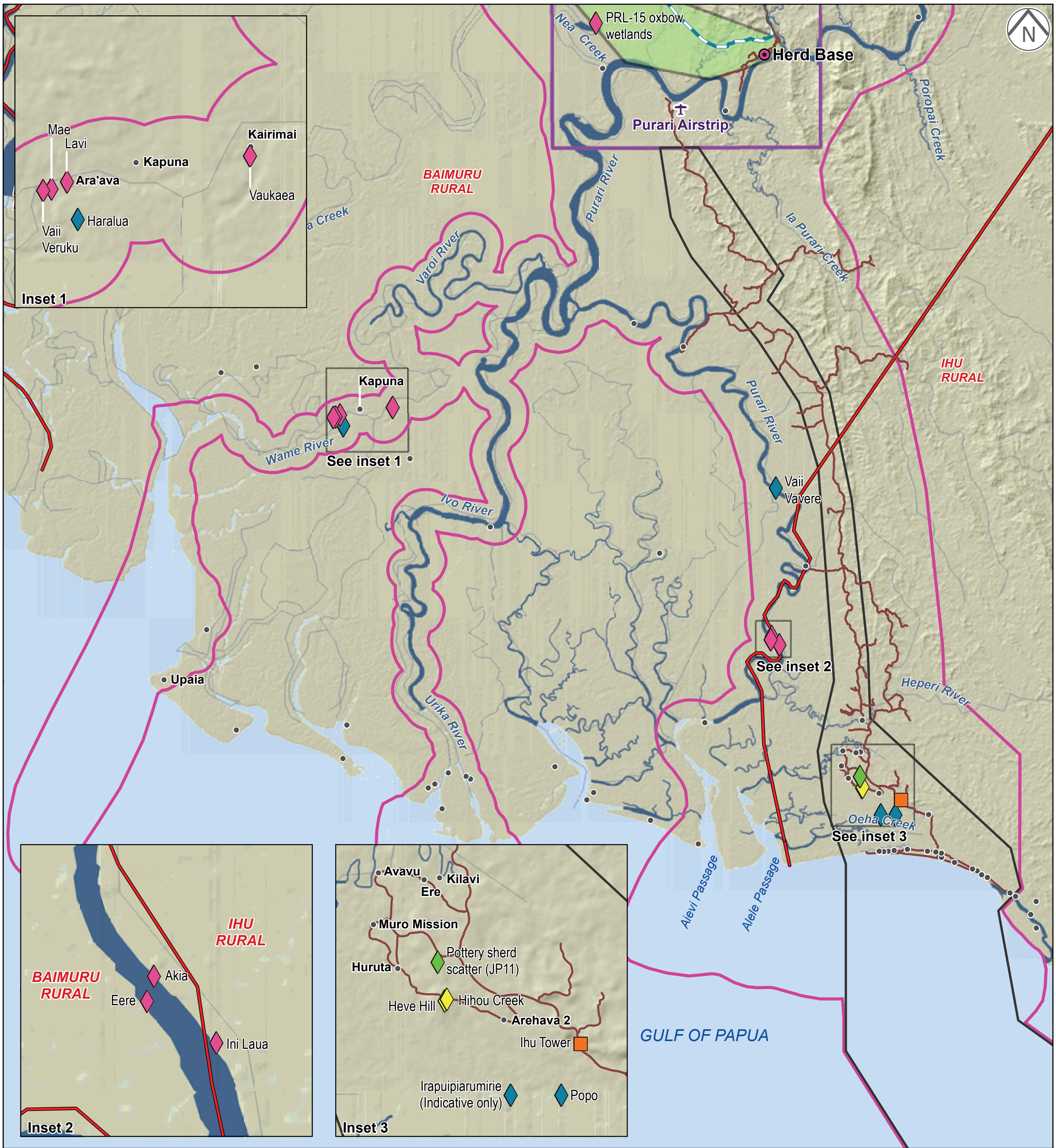
Cultural Sites - Community-Level Social Baseline Study

- Spirit/ritual site

TANGIBLE CULTURAL HERITAGE SITES (EXPORT PIPELINE CORRIDOR AND RIVERWAYS)

Papua LNG Project | Environmental Impact Statement

FIGURE 9.13



SCALE: 1:400,000 @ A4 | 0 5 10 15 20 km | COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Airstrip
- Local level government boundary
- Track
- Waterway
- Waterbody
- PRL-15

- Upstream Project area of influence

Existing Facilities

- Base camp

Proposed Facilities

- Trunkline corridor
- CPF, logistics base and airstrip area
- Export pipeline corridor

Cultural Sites - Community-Level Social Baseline Study

- Ancestral village
- Archaeological site
- Cultural site complex
- Landmark
- Spirit/ritual site

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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Table 9.18 – Importance Ratings for Ancestral Village Sites

Present-day Villages with Connections to Ancestral Villages Recalled in Oral Traditions	Ancestral Village Site	Recorded	Importance			
			Local*	Regional#	National#	International#
Ara'ava	Haralua	Yes	High	Medium	Low	†
Aivai	Vaii Vaivere	Yes	High	Medium	Low	†
Ara'ava, Kairimai, Akoma	Kauri Nu Poke	No	High	High	Medium	†
Aumu	Old Iare	No	High	High	Medium	†
Huruta, Paevera, Ere, Kilavi, Avavu, Hepere, Marea, Harevavo, Kaivukavu, Iuku, Larihairu, Mareke, Kavava, Herakela, Lariau	Heve	Yes	High	High	†	†
Huruta, Paevera, Ere, Kilavi, Avavu, Hepere, Marea, Harevavo, Kaivukavu, Iuku, Larihairu, Mareke, Kavava, Herakela, Lariau	Popo	**	High	High	High	†
Marea	Irapuipiarumirie	No	High	†	†	†
Ere, Kilavi	Kaukpa Horo	No	High	†	†	†
Kaivukavu, Larihairu	Maiaro	No	High	Medium	†	†

* Local importance ratings are based on opinions provided by local informants. # Regional, national and international importance ratings are preliminary and are attributed by Skelly in Part 17 of Volume 2. † There is insufficient information to assign a preliminary importance rating. ** Popo was recorded during a previous study.

9.11.1.2 Spirit Sites

Eight spirit sites have been formally recorded in the PAOI (Table 9.19). Pawaia-speaking villages value spirit sites, and many formally unrecorded sites were in remote locations. Fewer spirit sites were reported closer to the Orokolo Bay coast due to missionary activity and the introduction of Christian beliefs.

Table 9.19 – Importance Ratings for Tangible Spirit Sites

Present-day Villages with Connections to Spirit Sites Recalled in Oral Traditions	Spirit Site	Recorded	Importance			
			Local*	Regional#	National#	International#
Ura	Wabo Kai Seiro	Yes	High	Low	Low	Low
Wabo	Sasmeia	Yes	High	Low	Low	Low
Subu, Ura	Subuia (Plate 9.26)	Yes	High	High	Low	Low
Ara'ava	Lavi	Yes	High	Low	Low	Low
Ara'ava	Mae	Yes	High	Low	Low	Low
Ara'ava	Vaii Veruku	Yes	High	Low	Low	Low
Kairimai	Vaukaea	Yes	High	Low	Low	Low
Aivai	Akia Ini Laua	Yes	Medium	Low	Low	Low

* Local importance ratings are based on opinions provided by local informants. # Regional, national and International importance ratings are preliminary and are attributed by Skelly in Part 17 of Volume 2.

Plate 9.26 – Subuia Spirit Site

Photo: Robert Skelly.

9.11.1.3 Archaeological Sites

Small-sized settlements, frequent relocations and a tropical environment that is not conducive to preserving archaeological materials have combined to leave little or no trace of previous settlements. No known archaeological sites were recorded in PRL-15.

Archaeological sites are known to five of the eleven river transport corridor villages. These occur as shells, stones or pieces of pottery at ancestral village sites. None of the river transport corridor villages reports discovering archaeological materials while gardening. This suggests sites are either rare or deeply covered by sediments in the deltaic landscape.

Conversely, the Orokolo-speaking villages report regularly uncovering archaeological materials when gardening. This suggests considerable cultural activity in the area over a prolonged period (Section 9.2.2), e.g., Larihairu village informants reportedly find pottery sherds all over when gardening inland from the coast. Kaivukavu and Iuku village informants report an abundance of pottery sherds in gardens in the Popo area. A scatter of pottery sherds (Plate 9.27) was identified on one archaeological site during the social baseline study. This site was recorded in an area cleared for gardens north of Heve Hill. The site was given the field code JP11, as the garden area did not have a local name (see Figure 9.13).

Plate 9.27 – Heve Hill Rock Face and Scatter of Pottery Sherds

Photos: Robert Skelly.

9.11.1.4 Women's Sites

Women were invited to participate in all cultural heritage consultations at 34 villages and were represented during consultations at seven villages.[28] Informants from Ura village, where women were not represented during consultations, identify and describe a traditional birthing site, Moiwailedsa, which is attributed high local importance. Women participated in consultation at Apiope village and identified one site, Vaea; however, it is attributed low local importance. Additional women's sites are known but were not named by the villages of Paevera, Aivai and Hepere; and women were not represented at these consultations.

9.11.1.5 Ancestral Heirlooms

Nineteen villages reported keeping ancestral heirlooms in the form of stone tools, shell valuables and clay pots. Possession of shell valuables is more common nearer the coast. Upaia, Ere and Kilavi villagers keep examples of *Hiri* trade pots. Ancestral heirlooms are usually stored away; although, women wear shell valuables as part of the traditional dress in the villages of Evara, Paevera, Harevavo, Iuku and Mareke (Plate 9.28), and they are exchanged as part of the traditional bride price in the villages of Evara, Apiope, Huruta and Mareke.

Plate 9.28 – Shell Valuables (Evara Village)

Photo: Robert Skelly.

28 Women were invited to participate in consultations at all villages but at some villages, they declined for reasons not disclosed. They were involved in women's group discussions about cultural heritage.

9.11.2 Intangible Cultural Heritage Values

Intangible cultural heritage is defined as the practices, representations, expressions, knowledge and skills, and the instruments, objects, artifacts and cultural spaces associated therewith that communities, groups and, in some cases, individuals recognize as part of their cultural heritage (UNESCO, 2003). Fifteen types of intangible cultural heritage values were recorded during the baseline study and are discussed under the classifications of language; oral traditions; song, dance and traditional dress; traditional subsistence knowledge and traditional medicines.

9.11.2.1 Traditional Language

Language groups are discussed in Section 9.2.1.

Traditional language is seen as fundamental in maintaining cultural values and thus the cultural identity of each village; however, informants from Ura, Evara, Mariki, Maipenairu, Aumu and Kavava expressed concerns about the future maintenance of their traditional languages. The main causes of language decline are cited as in-migration, economic change due to local logging activities, marriage to non-village members, the preference among youths to use Tok Pisin and English, and the movement of youth away from the region to seek better education and employment opportunities.

9.11.2.2 Ancestral Oral Traditions

Ancestral oral traditions are discussed in Section 9.2.2.

9.11.2.3 Spirit, Ritual and Sacred Oral Traditions

All four Pawaia-speaking villages and the three Koriki-speaking villages maintain intangible cultural heritage values via oral traditions with traditional spiritual themes. Coastal Koriki-speaking villages are the exception, as missionaries have been most active there. In addition, villages speaking Ahia (Evara), Kaimare (Upaia and Mariki) and Maipua (Apiope) report maintaining oral traditions with spiritual themes.

Missionary activity increases nearer Orokolo Bay; therefore, oral traditions with spiritual themes are reportedly less commonly maintained; only six of the 15 Orokolo villages teach their oral traditions to their youths. Villagers may have maintained more traditional spiritual values than were disclosed during social baseline consultations, given the reported conflict between traditional spirit values and Christian values.

9.11.2.4 Song, Dance and Traditional Dress

Intangible cultural heritage values, such as song and dance, are maintained in 65% of villages.

In PRL-15 and river transport corridor villages, traditional men’s song and dance (Plate 9.29) is still practiced in the Koriki-speaking villages of Ara’ava, Kairimai, Kairu’u, Akoma and Ikinu; in the Kaimare-speaking village of Upaia; and in the Maipua-speaking village of Apiope. The four Pawaia-speaking villages and three of the five Iare-speaking villages no longer practice men’s song and dance but have knowledge of them, which suggests these practices may only have diminished during the lifetime of the current adult generation. Of the Orokolo-speaking villages, three villages (Marea, Larihairu and Kavava) report no knowledge of traditional men’s song and dance; in Huruta village, men’s song and dance is remembered but no longer performed.

Plate 9.29 – Traditional Dancing

Photo: Robert Skelly.

Women's song and dance is reportedly performed in 85% of villages, and women from 47% of villages maintain traditional forms of dress (Plate 9.30).

Plate 9.30 – Traditional Dress

Photo: Robert Skelly.

9.11.2.5 Traditional Knowledge: Subsistence Activities

All villages maintain traditional knowledge related to making the tools and materials used for processing sago (Plate 9.31). Sixty-five percent of villages also report using rituals to enhance sago yields. This practice is most common in Orokolo Bay, with 14 of 15 villages reportedly using rituals.

Plate 9.31 – Tools and Materials used for Processing Sago

Photo: Robert Skelly.

Ninety-five per cent of villages use traditional knowledge when making tools and materials and for hunting rituals or hunting magic. Eighty-five per cent of villages have maintained traditional fishing knowledge.

9.11.2.6 Traditional Medicines

All villages place high importance on maintaining ancestral knowledge related to traditional medicines. Traditional medicines are perceived to be highly effective and, for the villages of Larihairu, Marea and Harevavo, are more reliably obtained than western medicines. This is particularly evident when medical aid posts are not easily accessible or are poorly staffed. Some villages (i.e., Aumu and Apiope) reported a complete reliance on traditional medicines when viable alternatives were unavailable.

9.12 Ethnic Groups

The term 'indigenous peoples' is used in this section to recognize the common use of the term in regulatory guidelines and international standards; however, the term masks cultural diversity when used in reference to peoples living in the PAOI. The Project prefers to use the term ethnic groups when referring to indigenous peoples living in the PAOI, other than in this section of the report.

International law provides guidance on the criteria that can be applied to identify indigenous peoples when protecting their rights. In Papua New Guinea, additional characteristics, such as the existence of customary laws and attachment to lands and territories, can also be used to identify indigenous people.

Sections 9.2 to 9.11 describe the cultural and linguistic diversity of the PAOI; its inhabitants' connection to land; their social, cultural and economic status; and their social, cultural and political institutions. The data presented herein and a review of other independent research and documentation confirm that the communities inhabiting the PAOI can be classified as indigenous according to international criteria.

The term indigenous is not widely used in Papua New Guinea, an independent nation where customary land rights have been retained. The Government of Papua New Guinea does not formally recognize its citizens as indigenous; however, in the 1975 constitution of Papua New Guinea, the fifth National Goal on Papua New Guinean ways states that 'the cultural, commercial and ethnic diversity of our people is a positive strength' and that 'traditional ways of life and culture, including language, in all their richness and variety' must be appreciated. It further states that traditional villages and communities should 'remain as viable units of Papua New Guinean society' and that steps should be taken to 'improve their cultural, social, economic and ethical quality'.

In national legislation, the customary law of indigenous inhabitants is intended to be applied by default unless it is deemed incompatible with written laws or the constitution.[29] In addition:

- A National Cultural Commission was established in 1994 to preserve and promote traditional cultures of the indigenous peoples.[30]
- The *Environment Act 2000* includes provisions to preserve traditional social structures.
- The *Land Act 1996* upholds the propriety rights of customary landowners.
- The *Oil and Gas Act 1998* requires developers to identify customary landowners of license areas.

In 2016, the Papua New Guinea Government accepted the 2011 Universal Periodic Review recommendations to 'take measures to guarantee full respect of human rights to indigenous peoples', to 'review the state policy that affects indigenous lands', and to 'dedicate more resources to ensuring access to basic facilities to indigenous peoples'.

Three prominent instruments relate to the rights of indigenous peoples at international level:

- International Labor Organization Convention 169 on Indigenous and Tribal People (ILO, 1989).
- United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007).
- International Finance Corporation's Performance Standard 7 Indigenous Peoples (IFC, 2012c).

The standard international approach to identifying indigenous people is to apply a range of criteria to identify, rather than define, indigenous peoples.

Table 9.20 outlines the baseline data that has been used to demonstrate the international criteria that identify indigenous people in the PAOI.

29 Schedule 1.2(1) of the constitution defines custom as 'the customs and usages of indigenous inhabitants of the country existing in relation to the matter in question at the time when and the place in relation to which the matter arises, regardless of whether or not the custom or usage has existed from time immemorial'.

30 *National Cultural Commission Act 1994*, Article 4(a).

Table 9.20 – Indigenous People in the PAOI

Indigenous People International Criterion	Evidence from PAOI	Report Section
The existence of numerous languages used by different groups for daily communication within and between different communities.	♦ Seven language groups. ♦ Eighty three percent of people speak their local language. ♦ Each village identifies with a single tribe or language group. While clan members may reside in different villages, they only reside in villages speaking the same language.	9.2.1
The presence of different ethnic or tribal groups and basic details on traditional and contemporary forms of leadership, kinship structures, social organization and group formation.	♦ Tribal groups continue to practice traditional leadership. ♦ Two thirds of villages have traditional leaders.	9.3.1
	♦ People are united by language group and clan with a common ancestor or common lineage. ♦ Clans identify themselves and their customary-owned land through oral histories, including genealogies, stories, beliefs, customs and practices.	9.2
Information on the traditional ownership and current occupation and use of specific lands by these groups, and basic details concerning customary land tenure practices or the non-state mechanisms for transmitting land to future generations.	♦ Customary landownership is recognized and fiercely protected across Papua New Guinea; customary landowners have the power to decide what happens on their land. ♦ Ninety seven percent of land in Papua New Guinea remains under customary ownership. ♦ Customary-owned land is held and managed by a range of different customary groups; common among these groups is that this form of ownership is recorded in local knowledge and tradition and recounted orally, rather than recorded in a system of government records.	9.2.3 9.3.1
Basic details concerning the customs and traditions of different groups, including the presence or absence of certain forms of tangible and intangible cultural heritage.	♦ Twelve tangible cultural heritage sites formally recorded, representing the site types that are present in the PAOI: ancestral village sites, spirit sites, women's sites, archaeological sites and ancestral heirlooms. ♦ Important cultural heritage site called PRL-15 oxbow wetlands. ♦ Fifteen types of intangible cultural heritage values identified, including language; ancestral oral traditions; spirit or sacred oral traditions; song, dance and traditional dress; traditional subsistence knowledge; and traditional medicines.	9.11

9.13 Gender

Exploring gender distinctions and the contemporary relationships between males and females in the PAOI was a specific focus of the social baseline studies.

Women's focus groups, facilitated by female researchers, were conducted in all communities, using a dedicated, semi-structured instrument. A range of topics was explored with the women's groups, including the role of women, their part in livelihoods and income, their safety and security, their health, their marriage and their role in decision making. Each session lasted approximately two hours. A summary of the findings is presented in this section, along with the findings of the human rights baseline assessment (DIHR, 2017) related to gender.

Gender distinctions exist in all communities. While there is some variation between the more remote, inland communities and the larger, coastal communities, in general women and girls do not enjoy the same social status nor are they afforded the same rights or able to exert the same influence as men and boys. Some inequalities stem from traditional gender relations, while others are due to more contemporary experiences and influences, including changes to traditional social structures, low levels of governance, and land ownership and livelihood influences. Women are generally less informed about the Project, compounding their historical lack of knowledge about other development and resource extraction projects in the region.

Cultural practices reinforce the lesser status of women in most communities, particularly the Pawaia communities, as follows:

- Men and women have specific roles, e.g., as described in Section 9.8.7, men clear gardens while women are responsible for their ongoing maintenance, men cut sago palms while women process sago, and women attend to most domestic chores. Labor is often shared between husbands and wives; and while some traditional divisions of labor may be eroding, women in some communities maintain that they have a disproportionate workload and receive little support from men and boys with the hard labor of looking after the family.
- Certain prohibitions apply only to women, such as prohibitions against traveling on their own outside the village and prohibitions against care and sanitation surrounding childbirth that require women to give birth in the bush with limited assistance, as described in Section 9.7.3, which states that 9% of births occur in the bush. Women from the Pawaia villages also face cultural barriers that are not generally experienced in the other villages, e.g., married Pawaia women are not allowed to look at other men, let alone talk to them. This may affect the ability of Pawaia women to seek medical assistance from male health workers, or it may prevent them from traveling or selling goods in markets (Part 14 of Volume 2).
- Opportunities are extended mainly to males, such as education beyond the early primary grades and the opportunity to partake in income-generating activities. Section 9.6.2 states that 32% of males aged 16 years and above have completed Grade 7 compared with only 24% of females. Section 9.4.3 states that 15% of males are formally employed compared with 7% of females.
- Some cultural practices are performed by or apply only to women, such as their exclusion during menstruation.
- Domestic violence against women is widespread, occurring in every village, as described in Section 9.7.9.
- Polygamy, whereby a male can marry more than one female, is practiced in 3% of marriages. As described in Section 9.5.1.3, this is higher (8%, 6% and 5% respectively) in Pawaia, Maipua and Iare communities.
- Strict marriage arrangements persist, especially the betrothal of young females to older males.
- Females' participation in alcohol, tobacco or marijuana consumption is generally considered taboo, yet such consumption is acceptable for males.

Across the PAOI, almost 5% of women aged over 20 years are either divorced or separated, compared to 0.8% of men.[31] Although uncommon, in some communities, separation may lead to accusations of sorcery, placing women further at risk (Section 9.5.1.3).

The average starting age for marriage for girls or women is between 12 and 17, depending on the village (Section 9.5.1.3). This is in contravention of the *Marriage Act 1963*, which stipulates a minimum marriage age of 18. In Pawaia and Ahia villages, women marry especially young.

31 The difference in the proportions of women versus men who are divorced or separated may reflect that more men have remarried or have more than one wife.

Across the PAOI, few women are formally employed or involved in business enterprises; and yet most women from 71% of villages earn income for the household, while some (as opposed to 'most') women from the remaining 29% of villages earn income for the household. No villages responded that women do not contribute to household income. The lowest apparent contribution to household income occurs in the Pawaia villages. In 68% of villages, women have their own money to spend. A further 22% of villages indicated that some women had their own money to spend, while the remaining 10% of villages indicated that women did not have their own money to spend. These villages included Kairimai, Ara'ava and Subu 2. Most women from 71% of villages contributed to household spending decisions, with some women from the remaining villages contributing to spending decisions (Part 14 of Volume 2).

Access to basic healthcare and education is limited, and sexual and gender-based violence resolution is low. Women's groups, which exist in many communities, are often established around church activities and are limited in resources. According to the surveyed women's groups, people that are disadvantaged are primarily cared for by their families. While some civil service organizations, particularly women's and youth groups, appear to play an important role in supporting disadvantaged people, the government provides no services or facilities to assistance. The care provided by the groups includes not only providing shelter, food and clothing, but also the integration of the disadvantaged members of the community into everyday society as much as possible (Part 14 of Volume 2).

The children of single mothers are often cared for and integrated into the mother's family. This ensures the child is cared for and provides the mother an opportunity to participate in other aspects of village life; although, young mothers often withdraw from school and experience some level of discrimination (Part 14 of Volume 2).

9.14 Pre-existing Vulnerability

TOTAL's general specifications (see Section 2.5), the IFC's Performance Standards on Environmental and Social Sustainability (IFC, 2012c), good international industry practice and guidance notes from respected industry and human rights organizations[32] require the identification of vulnerable people and groups that may be potentially and adversely impacted by Project development.

No policy or legislation in Papua New Guinea specifically addresses vulnerability; however, the PNG constitution declares five goals that relate to human development, equality and participation, the collective benefit of natural resources and environment, and the development of PNG ways, which includes recognizing ethnic and cultural diversity.

The constitution also states the entitlement of all Papua New Guineans, irrespective of race, tribe, place of origin, political opinion, color, creed or gender, to basic rights including freedom from inhuman treatment and forced labor.

There are two types of vulnerability:

- Pre-existing vulnerability, where groups or individuals find it difficult to sustain themselves or their families under everyday conditions, irrespective of project development. Groups and individuals with pre-existing vulnerability typically fit within the categories[33] of:

32 Consistent with IPIECA guidelines and DIHR (2017)
33 Social Good Practice Note (IFC, 2003).

- Indigenous people.
- Ethnic or religious minorities.
- Women.
- Youth and elderly.
- Disabled or chronically ill.
- Land users without formal rights.

♦ Project-induced vulnerability, where groups or individuals have a diminished capacity or lack of capacity to understand, anticipate, cope with, resist or recover from the consequences of a potential impact or other threat. In this respect, a person or group may not belong to a pre-existing vulnerable group but may be vulnerable to project development because of the direct and indirect impacts resulting from a project.

The Project focus will be on identifying pre-existing and Project-induced vulnerable groups and individuals. Identification of these people will be discussed in Chapter 13. The process for identifying vulnerable groups and individuals is summarized in the following sections. This section examines potential sources of pre-existing vulnerability in the PAOI from baseline data so that the Project can take steps to consider potential impacts related to those sources in the early stages of impact identification and assessment.

9.14.1 Approach to Identifying Vulnerability in the PAOI

The following approach has been adopted for identifying potential pre-existing vulnerable people and groups in the PAOI and, later, vulnerable people in relation to the Project:

1. **Local identification:** In a context where a majority of people could be construed as vulnerable or disadvantaged, the criteria used by community members to discriminate those among them that are particularly vulnerable is often a useful starting point for identifying those that need particular attention, as required by IFC Performance Standard 1 and reiterated in Guidance Note 5 Land Acquisition and Involuntary Resettlement (IFC, 2012c). This stage was conducted during the upstream community-level field surveys when participants in village leaders' and women's focus group discussions were asked a series of questions about the presence of individuals, families or groups in the village who were worse off, the aspects that made them worse off and where those people found support, if any.

   These questions resulted from extensive dialogue among the community survey team, including its PNG resources, about the meaning and intent of the concept of vulnerability in the PNG social context. The wording and combination of questions were selected as the best ways to elicit the intended information. One issue was the lack of a Tok Pisin term for vulnerable or vulnerability; thus, the survey focus group discussions had to explore alternative concepts, such as worse off and disadvantage.

   Vulnerability is differentiated from disadvantage, which refers more generally to people with a low level of wellbeing. The concept of disadvantage is easier to explain and more readily understood in Papua New Guinea and was discussed with participants involved in consultations for the baseline surveys.

   The results from the upstream community-level surveys are described in Section 9.14.2.

2. **Pre-existing vulnerability:** The baseline data was assessed to identify potential sources of pre-existing vulnerability in the PAOI, i.e., the indicators that may point to the presence of vulnerable people or groups in the PAOI. Data assessed included self-determination,

household composition, food security, livelihood security, status of women, and levels of literacy and health including disability and impairment. The assessment results are described in Section 9.14.2.

3. **Project-induced vulnerability:** The impact assessment (Chapter 13) identifies groups that may be vulnerable to Project development, i.e., groups and individuals that may be coping day-to-day on their own but that may not cope when changes to their day-to-day lives are caused by the Project's direct and indirect impacts.

4. **Household or individual vulnerability:** Household or individual vulnerability will be identified during more detailed displacement planning when 100% of potentially affected households will be surveyed, as opposed to the approximate 30% surveyed for the baseline studies. This process will be guided by IFC performance standards (IFC, 2012a) and associated guidance notes and handbooks.[34]

9.14.2 Preliminary Vulnerability Criteria

Based on the review of selected vulnerability literature, extractive industry best practices and the findings of social baseline studies, Table 9.21 outlines the preliminary criteria for identifying potential sources of pre-existing vulnerability and, later, pre-existing vulnerable individuals and groups, as part of displacement census and future social surveys. It includes a brief description of the findings for the PAOI.

Potential sources of pre-existing vulnerability were identified by assessing the baseline data against the criteria outlined in Section 9.14.3.

9.14.3 Pre-existing Vulnerability

Tables 9.22 and 9.23 present baseline data on the locations, types and numbers of potential pre-existing vulnerability based on the preliminary vulnerability criteria in Table 9.21. The tables do not infer that the communities listed are vulnerable but rather that the potential source of vulnerability is present among households in those communities to the extent indicated.

Criterion 1: Local Identification

Community-level social baseline surveys asked communities to identify whether any people in their communities were vulnerable.[35] The question was asked of village leaders (leader groups) and women's focus groups. The results are shown in Tables 9.22 and 9.23.

Presence of Disadvantaged People

Women's groups from 58% and leader groups from 81% of villages indicated that their village contained people who were disadvantaged (Table 9.22). Consensus occurred in 10 communities (indicated in Table 9.22). Women's groups from Subu 2, Ura, Wabo, Kairimai, Aivai, Mapaio, Upaia, Apiope, Avavu, Ere-Kilavi, Hepere, Huruta and Paevera believed disadvantaged people were not present in their communities. Leader groups from Ura, Subu, Evara, Avavu, Huruta and Iuku believed disadvantaged people were not present in their communities. Consensus on a lack of disadvantaged people occurred in Ura, Avavu and Huruta.

34 Such as the Handbook for Preparing a Resettlement Action Plan (IFC, 2002).

35 Although the survey instruments used the word 'vulnerable', the questions focused on disadvantaged groups or disadvantaged people when asked in Tok Pisin.

Table 9.21 – Preliminary Vulnerability Criteria and PAOI Findings

No.	Category	Criterion	Pre-existing Vulnerable Groups or Individuals in the PAOI
1	Local-identification	Community views	♦ Women's and leaders' groups from 31 communities identified the presence of vulnerable people in 18 and 25 communities respectively. ♦ Women's groups identified households headed by women, single mothers and widows to be the main disadvantaged groups. ♦ Leaders' groups identified people with a disability and households headed by women as the main disadvantaged groups.
2	Poverty	Households below the national poverty threshold Households reporting no income	♦ Households living below the national poverty line are present in all participating communities in the PAOI (21% to 63% of households). ♦ Most communities have households that did not receive any income in the previous two weeks.
3	Food security	Households reporting regular shortages of food Households reporting more than 40% expenditure on food	♦ Almost two thirds of communities from most language groups (except the Maipua people from Apiope) had households that regularly went a day without eating. ♦ In the Iare, Koriki, Orokolo and Pawaia language groups, 30% of communities had households that spent more than 40% of their income on food.
4	Housing	Households that are severely overcrowded Housing that is of notably poorer quality or condition than the rest of the village	♦ Pawaia and Orokolo language groups had the greatest percentage (46%) of households above the average village household size followed by the Iare communities at 41%.
5	Livelihood security	Households without ownership or user rights to land Households with all members who did not participate in subsistence activity in the past two weeks	♦ Only one or two households from the Orokolo communities of Harevavo and Herekela and the Kaimare community of Mariki did not participate in subsistence activity in the previous two weeks.

Table 9.21 – Preliminary Vulnerability Criteria and PAOI Findings (cont'd)

No.	Category	Criterion	Pre-existing Vulnerable Groups or Individuals in the PAOI
6	Household composition	Households headed by women Households with all female members Households headed by single parents Households with all members greater than 60 years of age Households with a member who is chronically or terminally ill or has a mental or physical disability	♦ Households headed by women were present in all but one language group, especially in Iare communities where they made up almost 10% of households. ♦ Households with all female members were present in five of the seven language groups, except the Koriki and Maipua communities. ♦ Single parent households were present in all language groups except the Ahia community of Evara. ♦ Only the Iare (2% of households), Kaimare (3%) and Orokolo (3%) language groups contained households with all members greater than 60 years of age. ♦ Households with members who were chronically or terminally ill or had a mental or physical disability were present across all language groups (6% to 39% of households).
7	Access to infrastructure	Households without access to electricity	♦ Most communities had households that did not have access to electricity across all language groups; the greatest was among Koriki communities (55% of households).
8	Education	Households with no members literate	♦ 19% of males and 33% of females aged 16 years and above indicated that they could not read or write.
9	Women	Households with women: With no access or rights to land With no access to income-generating activity With no money of their own to spend Who appear to have been ostracized by their family or community	♦ In 68% of villages across all language groups, most women had their own money to spend or save.

Women's groups identified households headed by women (leader groups agreed), single mothers and widows to be the main types of disadvantaged people in communities (Table 9.23). Village leaders identified disability as a main type of disadvantage, second to households headed by women. Subsequent findings of the household survey indicated that 7% of households are headed by women and approximately 8% of people had a disability of some kind.

For those villages in which women's groups identified people that were disadvantaged, the number of disadvantaged people was generally described as 'some'.

Both groups indicated that people who are disadvantaged are overwhelmingly cared for by their families. While some civil service organizations, particularly women's and youth groups, play an important role in supporting disadvantaged people, no government services or facilities provide assistance. The care provided by the families includes not only providing shelter, food and clothing, but also integrating the disadvantaged members of the community into everyday society as much as possible.

The children of single mothers are often cared for and integrated into the mother's family. This provides care for the child and allows the mother an opportunity to participate in other aspects of village life; although, young mothers often withdraw from school and experience some level of discrimination.

Criterion 2: Poverty

Household-level social baseline surveys asked each participating household to recall the income received by their households in the previous two weeks (Section 9.5.5.1). This data, when compared with the national poverty line of PGK3.82/day (US$1.15/day), shows that households in all participating communities are living below the national poverty line, from 21% among the Ahia people at Evara to 63% among the Maipua people at Apiope. Most communities had households that did not receive any income in the previous two weeks, and a greater percentage of these occurred among Iare people, followed by the Maipua people at Apiope. More than half of the households in most communities received some income in the period except for the Iare communities of Mapaio Fish Camp and Kapai 2 and the Pawaia communities of Subu and Subu 2. Poverty is identified as a potential source of pre-existing vulnerability among many households in most communities when income levels are compared with the national poverty line criterion.

Criterion 3: Food Security

Food security is described in Part 18 of Volume 2 and Section 9.7.2. Households were asked if the family regularly went a day without eating anything, and almost two thirds of communities from most language groups, except the Maipua people from Apiope, had households that answered positively. Of those communities in which households responded positively, the greatest number of households was from the Ahia people from Evara (21%), followed by 12% of households in the Kaimare and Pawaia communities. Comparing answers to two questions asked in the household survey relating to income received and food expenditure indicates that 30% of communities from the Iare (31% of households), Koriki (13%), Orokolo (16%) and Pawaia (11%) language groups had households that spent more than 40% of their income on food. A notable cohort of households across most communities do not have food security; this is a potential source of pre-existing vulnerability.

Criterion 4: Housing

The average household size was determined from community-level surveys (mapping) in each community, and households that were larger than the average household size in their village were identified as a proxy for overcrowding. Household size is shown in Table 9.3 in Section 9.5.1.1.

Table 9.22 – Villages with Disadvantaged People Present

Language Group	Villages Surveyed	Number of Villages with Disadvantaged People		Name of Villages with Disadvantaged People	
		Women's Groups	Leaders Groups	Women's Groups	Leaders Groups
Pawaia	5	2	3	Subu, Poroi 2	Poroi 2, Wabo*, Subu 2
Ahia	1	1	0	Evara*	N/A
Koriki	4	3	4	Akoma-Kairu'u, Ara'ava, Ikinu	Kairimai*, Ara'ava, Akoma-Kairu'u, Ikinu
Iare	5	3	5	Aumu, Kaevaria, Maipenairu	Mapaio*, Kaevaria, Aivai, Aumu, Maipenairu
Kaimare	2	1	2	Mariki	Upaia*, Mariki
Maipua	1	0	1	N/A	Apiope*
Orokolo	13	8	10	Harevavo, Iuku*, Kaivukavu, Kavava, Larihairu, Marea, Mareke, Oru-Lariau-Herekela	Ere-Kilavi*, Hepere*, Paevera*, Harevavo, Kaivukavu, Kavava, Larihairu, Marea, Mareke, Oru-Laria-Herekela
Total	**31**	**18**	**25**		

* Communities where consensus existed between womens groups' and leaders groups' responses.

Table 9.23 – Types of Disadvantaged People

Language Group	Household Headed by Women		Household Headed by Elderly		Single Mothers		People with a Disability		Widows		Orphans		Other	
	Women	Leaders	Women	Leaders	Women	Leaders	Women	Leaders	Women	Leaders	Women	Leaders	Women	Leaders
Pawaia	1	1	2		1	1	1	1			1			
Ahia	1		1				1							
Koriki		1	1		1	1		2	2					
Iare	2	4			2	1	2		1				1	
Kaimare	1	1			1									1
Maipua		1												
Orokolo	2	4		2	2		1	3	4		3		1	1
Total	**7**	**12**	**4**	**2**	**7**	**3**	**5**	**6**	**7**	**0**	**4**	**0**	**2**	**2**

The Pawaia and Orokolo language groups had the greatest percentage of households above the average village household size at 46% each, followed by the Iare communities at 41%. Overcrowding is likely to exist to some extent in all language groups and is a potential source of pre-existing vulnerability.

Criterion 5: Livelihood Security

The proxy for livelihood security was derived from the household survey question relating to householders’ participation in subsistence activity in the previous two weeks. Only one or two households from the Orokolo communities of Harevavo and Herekela and the Kaimare community of Mariki did not participate in subsistence activity in the previous two weeks (i.e., 11% of communities and 3% of each of those two language groups). Given the extent and importance of subsistence activity in the PAOI, failure to participate in subsistence activity over an extended period of time is likely to contribute to hardship and vulnerability, but they are not present at this time.

Criterion 6: Household Composition

Criterion 6 addresses the presence of households that are headed by women, that have all female members, that are headed by single parents, that have all members aged more than 60 years of age or that have a member who is chronically or terminally ill or has a mental or physical disability. These characteristics were identified in both literature and case studies as potential contributors to pre-existing vulnerability.

The Ahia community of Evara had no households headed by women. Households headed by women were present in all other language groups, especially in Iare communities where they made up almost 10% of households. In other communities, households headed by women made up between 1% and 6% of households.

Households with all female members were present in five of the seven language groups, excluding the Koriki and Maipua communities. Orokolo communities contained 19% of households with all female members, whereas Pawaia communities contained just 1% of households that comprised all women. Households with all female members were from 3% to 14% of households in other communities.

Single parent households were present in all language groups except in the Ahia community of Evara. Orokolo communities contained 16% of single parent households, whereas Pawaia communities contained just 4% of single parent households. Single parent households were from 6% to 13% of households in other communities.

Only the Iare (2% of households), Kaimare (3%) and Orokolo (3%) language groups contained households with all members greater than 60 years of age.

Households with members who were chronically or terminally ill or had a mental or physical disability were present in all language groups (6% to 39% of households). Rates were highest among Orokolo communities (39% of households) and high in Iare communities (23%).

As potential sources of pre-existing vulnerability, households that are headed by women, that have all female members, that are headed by single parents, that have all members aged more than 60 years of age or that have a member who is chronically or terminally ill or has a mental or physical disability, exist in all communities.

Households headed by women, single mothers and widows are among the most vulnerable and disadvantaged people in the PAOI (DIHR, 2017). Pawaia women have been described as marginal, subordinate, disadvantaged, vulnerable and second class, and they face numerous cultural barriers that may not be experienced by other women.

Criterion 7: Access to Infrastructure

Access to electricity is discussed in Section 9.5.4.2. Most communities across all language groups had households that did not have access to electricity. The absence of access to electricity was greatest among Koriki communities (55% of households), followed by the Ahia people at Evara (50%). Other communities without access to electricity were from 11% of households (Kaimare) to 45% among Orokolo communities. No or limited access to electricity is a source of potential pre-existing vulnerability, e.g., it prevents people from fulfilling basic needs, generating income and communicating.

Criterion 8: Education

Forty-one percent of communities had households in which all members were illiterate. About one third of households in Aiere (Kaimare) and Wabo (Pawaia) had no literate members. Literacy levels are shown in Table 9.9 in Section 9.6.2.

As discussed in Section 9.6.2, in the PAOI, 19% of males and 33% of females aged 16 years and above indicated that they could not read or write. Literacy levels were particularly low among males and females from the Ahia language group at Evara and for females from the Pawaia and Kaimare communities.

Criterion 9: Women

Gender is discussed in Section 9.13. As one indicator of potential pre-existing vulnerability, community-level surveys asked women’s groups if women in their community had money to spend or save. Women indicated that in 68% of villages, across all language groups, most women had their own money to spend or save. A further 22% of villages indicated that some women had their own money to spend or save, while the remaining 10% of villages, i.e., the Koriki communities of Kairimai and Ara’ava and the Pawaia community of Subu 2, indicated that women did not have their own money to spend.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 10: Existing Environment – Amenity

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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10. Existing Environment - Amenity

This chapter has been prepared from information generated by a series of independent studies (where more detailed information can be found) that have involved detailed bibliographical reviews, numerical modeling and field surveys (both when required). Based on this information, a description is provided of the following components of the amenity setting:

- Air quality (Section 10.2), derived from the Upstream Air Quality Baseline Report (Part 19 of Volume 2).
- Noise (Section 10.3), derived from the Upstream Noise Baseline Report (Part 20 of Volume 2).
- Landscape and visual amenity (Section 10.4), derived from the Upstream Landscape and Visual Amenity Baseline Report (Part 21 of Volume 2).
- Commercial transport (both marine and river) (Section 10.5), derived from the Marine and River Traffic and Transport Baseline Report (Part 22 of Volume 2). Information on community travel and transport is presented in Section 9.10.
- Waste (Section 10.6), providing an overview of the waste-receiving environment in Papua New Guinea.

10.1 General Setting

Onshore Project components are mainly in the Purari River catchment, which is in a remote part of Gulf Province.

The inland terrain in the Project area is characterized by rugged mountainscapes of dense tropical forest that descend to densely vegetated deltaic and coastal lowlands covered in swamp forests and grasslands and to mangroves located at or below sea level. The Gulf Province climate, as described in Section 7.3, is characterized by high rainfall and low wind speeds.

In relation to the amenity baseline and setting, human settlement, infrastructure and development have been limited primarily due to the difficulty in accessing the deltaic, floodplain and inland terrains. Thus, population density remains low across most of the Project area, except for the coastal villages, which are generally larger and more accessible than the inland villages. Inland villages located in the river transport corridor are generally smaller than the coastal villages but are more accessible (by boat) than other inland villages.

Human activity includes subsistence farming, with small areas of forest cleared for swidden agriculture and gardens. Nearly all villages burn firewood for cooking and lighting.

In this setting, industrial activities in the Project area comprise discreet areas of logging operations (Section 9.4.1) and ongoing gas exploration activities in PRL-15.

Public or government roads do not exist in the Project area; however, logging tracks do occur. None of the communities reports owning motor vehicles or motorbikes: and transport is generally by boat or on foot, although logging operators use vehicles. Helicopters transport Project personnel between Herd Base and the gasfield wellpads and temporary operations camp.

The Purari, Ivo-Urika and Wame-Varoi rivers, in the river transport corridor, facilitate access for Project barges between Herd Base and further upstream and the Gulf of Papua. These rivers are also used by villagers from the river transport corridor for transport and subsistence purposes and by log ships and barges accessing the logging camp near Evara.

Current sources of pollution are negligible due to the sparse population and limited industrial development in the onshore Project area.

The offshore export pipeline traverses Orokolo Bay and the Gulf of Papua to a landfall at Caution Bay (Central Province). Small watercraft owned by coastal villagers primarily use the nearshore areas of Orokolo Bay for subsistence fishing and to access other coastal villages for trade (Section 9.10), while larger commercial vessels use the Gulf of Papua for prawn trawling and transporting crude oil and LNG (Section 10.5).

This chapter characterizes the baseline amenity of the Project area in terms of air quality, noise, landscape and visual amenity, and commercial transport and waste, considering this setting.

10.2 Air Quality

10.2.1 Study Overview

A baseline air quality study was undertaken in the upstream Project area to characterize the existing ambient air quality and meteorological patterns that have the potential to affect the dispersion of Project-related air emissions.

The air quality is likely to be good due to minimal anthropogenic development in the Project area to date. In the study area, it is expected that gaseous pollutants levels are negligible, and particulate levels are low. Therefore, field monitoring of gaseous pollutants (i.e., nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), volatile organic compounds (VOCs) and particulate concentrations (i.e., $PM_{2.5}$, PM_{10}[1] and total suspended particulate matter (TSP)) was not undertaken. The baseline air quality characterization was completed, as a desktop study incorporating a detailed bibliographic review and modeling. Existing particulate matter concentrations have been estimated based on:

- Information in air quality baseline and assessment studies for other projects in Papua New Guinea.
- A review of ambient particulate monitoring data in Papua New Guinea and in remote and undeveloped areas in other countries, considering the local land use and high rainfall in the study area.

This approach is consistent with the guidance note for the International Finance Corporation's Performance Standard 1 (IFC, 2012).

The study area for the air quality baseline assessment is defined as any area where air quality may be directly impacted due to Project activities, including construction and operation of Project facilities and infrastructure. It includes PRL-15; the onshore and offshore export pipeline corridor; and locations along the Purari, Urika-Ivo and Wame-Varoi river transport routes in which potential sensitive receptors (e.g., villages) are located. In the study area, the air quality baseline study focused on the Central Processing Facility (CPF) as the main source of air emissions in the upstream area and on the onshore export pipeline corridor. Other emission sources will include the wellpads and associated gathering system, trunkline and transport routes.

Existing long-term baseline meteorological data available for Wabo was insufficient for the study area due to extended gaps in the data record. Modeling was therefore required to establish meteorological conditions that will be used in the dispersion model to predict potential air quality

1 $PM_{2.5}$ – particulate matter less than or equal to 2.5 µm in diameter; PM_{10} – particulate matter less than or equal to 10 µm in diameter.

impacts at a later stage. The data from Wabo was instead used to validate the performance of the model.[2] Two models were used:

- Weather Research and Forecasting: A next generation mesoscale numerical weather prediction system used in the baseline study to produce the meteorological data required as an input to the CALMET model. Two modeling domains were used:
  - Domain 1 – a coarse run with a 30 km grid resolution, the geographical extent of which was chosen to best cover the area of interest, including the effects of large-scale weather events, while keeping the computational requirements for the atmosphere model as low as possible.
  - Domain 2 – a finer run with a 10 km grid resolution, using the input from Domain 1.
- CALMET: A meteorological model that develops hourly wind and other meteorological fields on a 3-dimensional gridded modeling domain. Four modeling domains were used:
  - Outer domain: A 60 x 60 km grid, modeled with a resolution of 3 km using the 3D output from the Weather Research and Forecasting model.
  - Mid domain 1: A 40 x 40 km grid, modeled with a resolution of 1 km using the 3D output from the CAMLET outer domain.
  - Mid domain 2: An 18.8 x 18.8 km grid, modeled with a resolution of 0.4 km using the 3D output from the CAMLET mid domain 1.
  - Inner domain: A 15 x 12 km grid, modeled with a resolution of 0.1 km using the 3D output from the CAMLET mid domain 2.

Figure 10.1 shows the modeling domains used to generate the meteorological model.

Meteorological data was extracted from two locations (Figure 10.1) in the study area:

1. The center of the CPF site, which shows nearby villages (sensitive receptors).
2. Halfway along the onshore export pipeline corridor.

The meteorological data predicted by the modeling at the onshore export pipeline corridor location is only indicative of the types of conditions experienced along the onshore export pipeline and river transport corridors. Both of these areas cover large distances and include a range of topographical features; consequently, wind patterns, rainfall, ambient temperatures and humidity levels can be expected to vary along the corridors. The types of activities proposed in these corridors will only have potential for very localized and temporary impacts on air quality. A detailed analysis of meteorological conditions along each corridor is therefore unwarranted. Indicative baseline conditions, at a point halfway along the export pipeline corridor, provide the information required for the impact assessment of potential air quality impacts from activities in these corridors.

Additionally, detailed meteorological modeling was only undertaken for the parameters related to dispersion modeling (Section 10.2.2).

2 This could not be undertaken if the data was used in the model, as the results would be identical. Using data excluded from the model to validate the model's performance is a more robust approach to validating the model's performance.

AIR QUALITY MODELING DOMAINS AND POTENTIAL RECEPTORS

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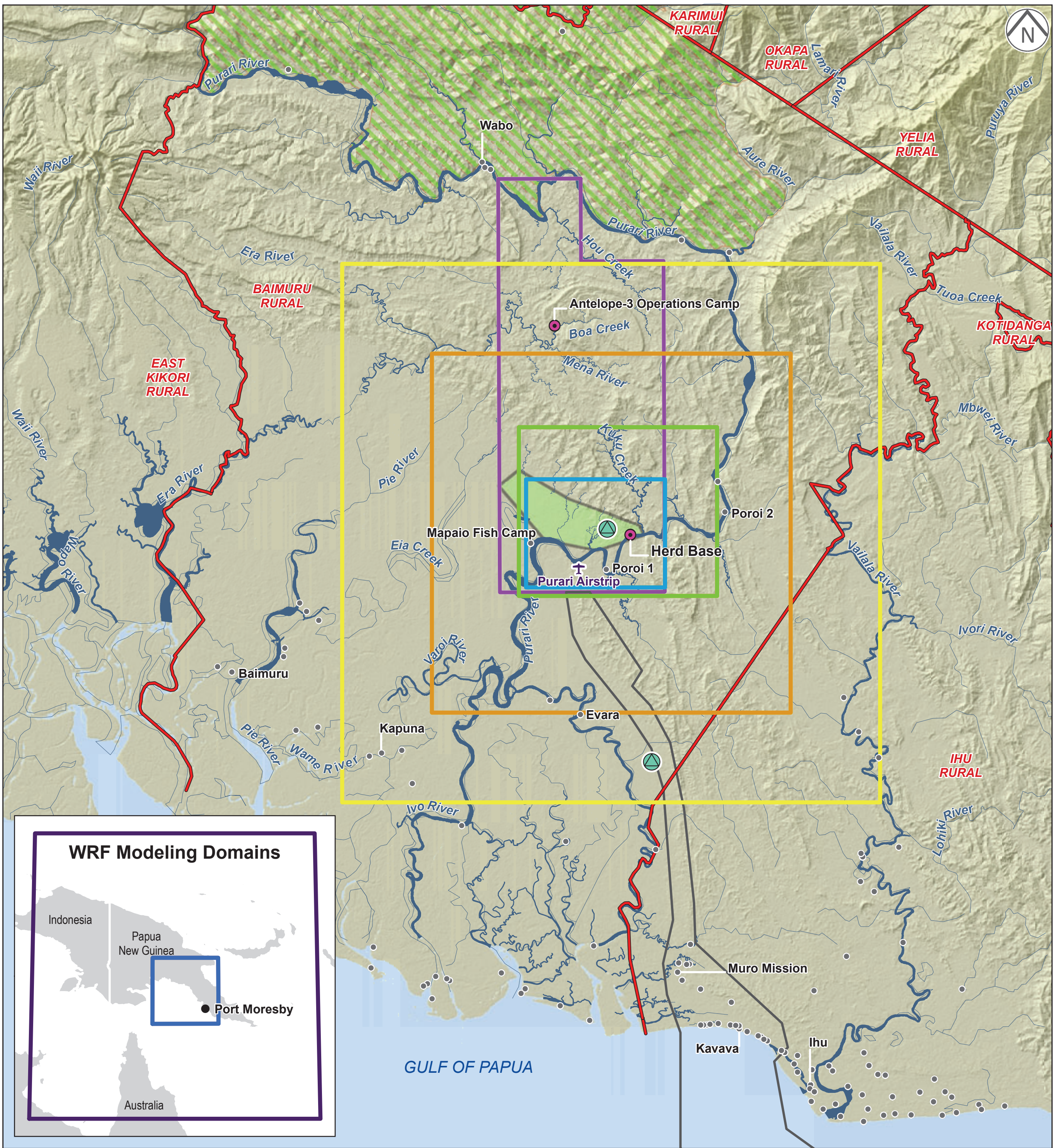
FIGURE 10.1



SCALE: 1:650,000 @ A4

0 5 10 15 20 25 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Airstrip
- Meteorological modeling point
- Local level government boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- Crater Mountain Wildlife Management Area
- CPF, logistics base and airstrip area

Weather Research and Forecasting (WRF) Modeling Domains (see inset map)

- Domain 1
- Domain 2

CALMET Modeling Domains

- Outer domain
- Mid domain 1
- Mid domain 2
- Inner domain

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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10.2.2 Factors Affecting Air Quality

The key meteorological parameters of interest for air quality modeling are wind speed, wind direction, stability class, mixing height and ambient temperature. Information on these is presented in Part 19 of Volume 2, while rainfall and temperature are detailed in Section 7.3.

The study area topography and land use can impact on the baseline air quality and air pollutant dispersal. Hills and valleys channel winds, which influences local wind patterns. During the night, drainage flows create downslope winds, which also influence the direction in which air pollutants are dispersed. In addition, the natural vegetation in the study area can affect wind speeds and atmospheric turbulence through changes in surface roughness associated with variations in canopy height. Vegetation also affects ambient particulate levels, which reduces wind erosion, and can contribute to increased pollen levels. Further information about the study area terrain can be found in Section 7.2, while vegetation is described in Section 7.7.5.

Community activities, e.g., cooking and fires, provide an anthropogenic source of particulate matter; and the anthropogenic setting of the area has been discussed in Chapter 9.

10.2.3 Air Quality Baseline Characterization

10.2.3.1 Production, Processing and Related Facilities (PRL-15)

Figure 10.2 presents wind roses showing the wind data predicted by the modeling at the CPF site for 2014 and 2015. The site generally experiences low to moderate wind speeds (i.e., less than 5.5 m/s), predominately from the north-northeast and northeast. Calm wind conditions (i.e., wind speeds less than 0.5 m/s) were predicted to occur 4% to 5% of the time. While not evident from the wind roses in Figure 10.2, the bibliographic review of available meteorological data has shown that wind speeds are typically highest during October to January, coinciding with the start of the northwest monsoon season.

Atmospheric stability refers to the atmospheric tendency to resist or enhance vertical motion. At the CPF site, stability class F (i.e., moderately stable conditions) was predicted to occur approximately 40 to 44% of the modeled year which is indicative of very stable nighttime conditions (i.e., low winds), leading to a low level of mechanical mixing and poor dispersion. Stability class B (i.e., moderately unstable conditions), predicted to occur 22% to 23% of the year, is associated with low to moderate wind speeds and strong to moderate solar insolation, giving rise to a moderate level of atmospheric turbulence and mixing. Figure 10.3 presents the frequency of each atmospheric stability class predicted by the model for the CPF site.

The height of the turbulent layer of air near the earth’s surface is referred to as the mixing height. Ground-level emissions from the proposed CPF will be rapidly mixed in this layer. This baseline information has been used in the dispersion model to predict potential air quality impacts. The height of this layer is controlled mainly by convection (i.e., resulting from solar heating of the ground) and by mechanically generated turbulence, as the wind blows over the rough ground. After the onset of vertical mixing at sunrise, the mixing height at the CPF site increases over the morning. It reaches the maximum mixing height around the mid to late afternoon, i.e., approximately 3.00 p.m., at a height of around 1,700 to 1,900 m, occurring around this time due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer. In the early evening, the mixing height rapidly drops back to night-time levels. Figure 10.4 shows the variation in mixing height as would be expected for the diurnal variation of mixing heights.

CPF SITE WIND ROSES

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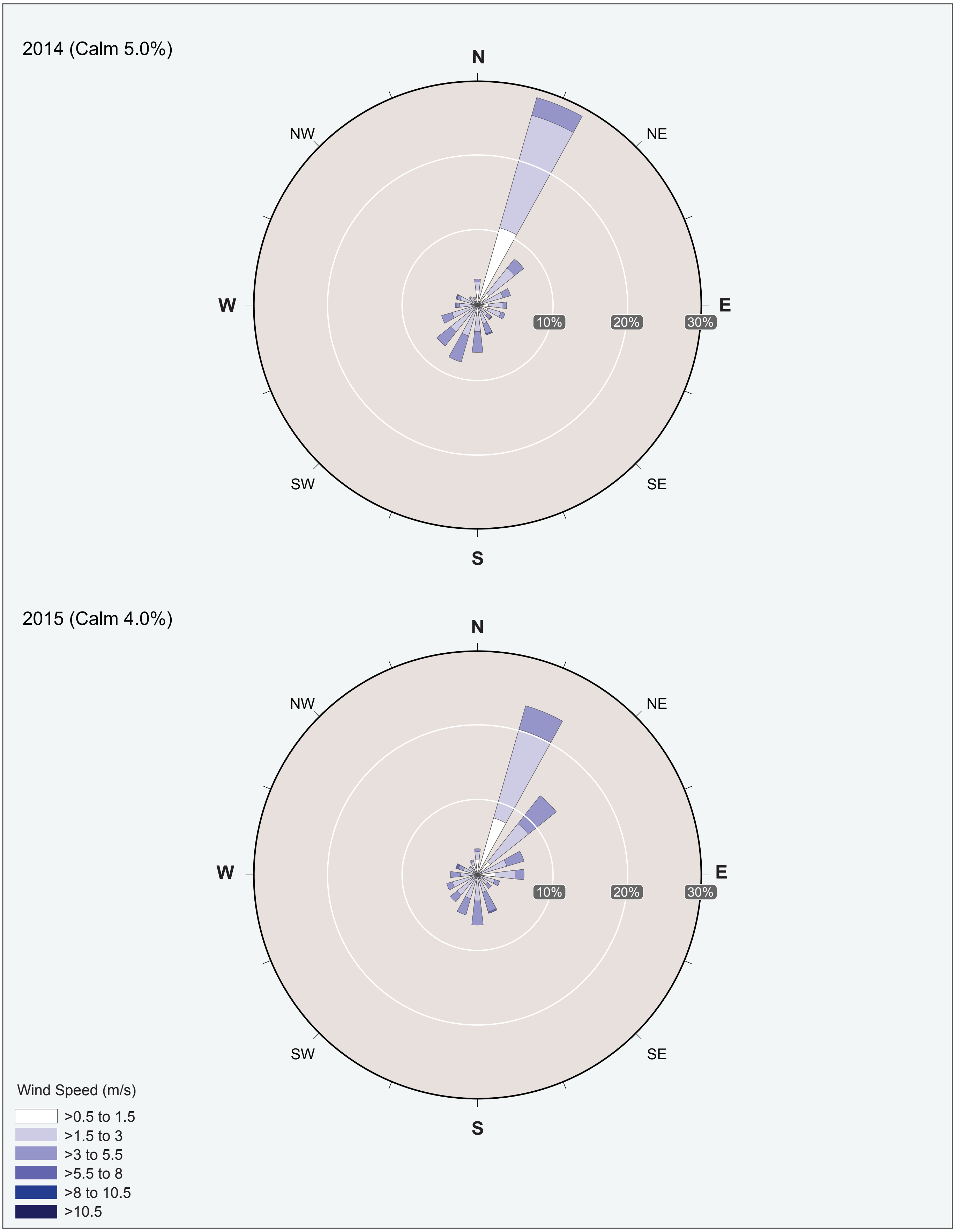
FIGURE 10.2



CPF SITE PREDICTED STABILITY CLASS FREQUENCY DISTRIBUTIONS

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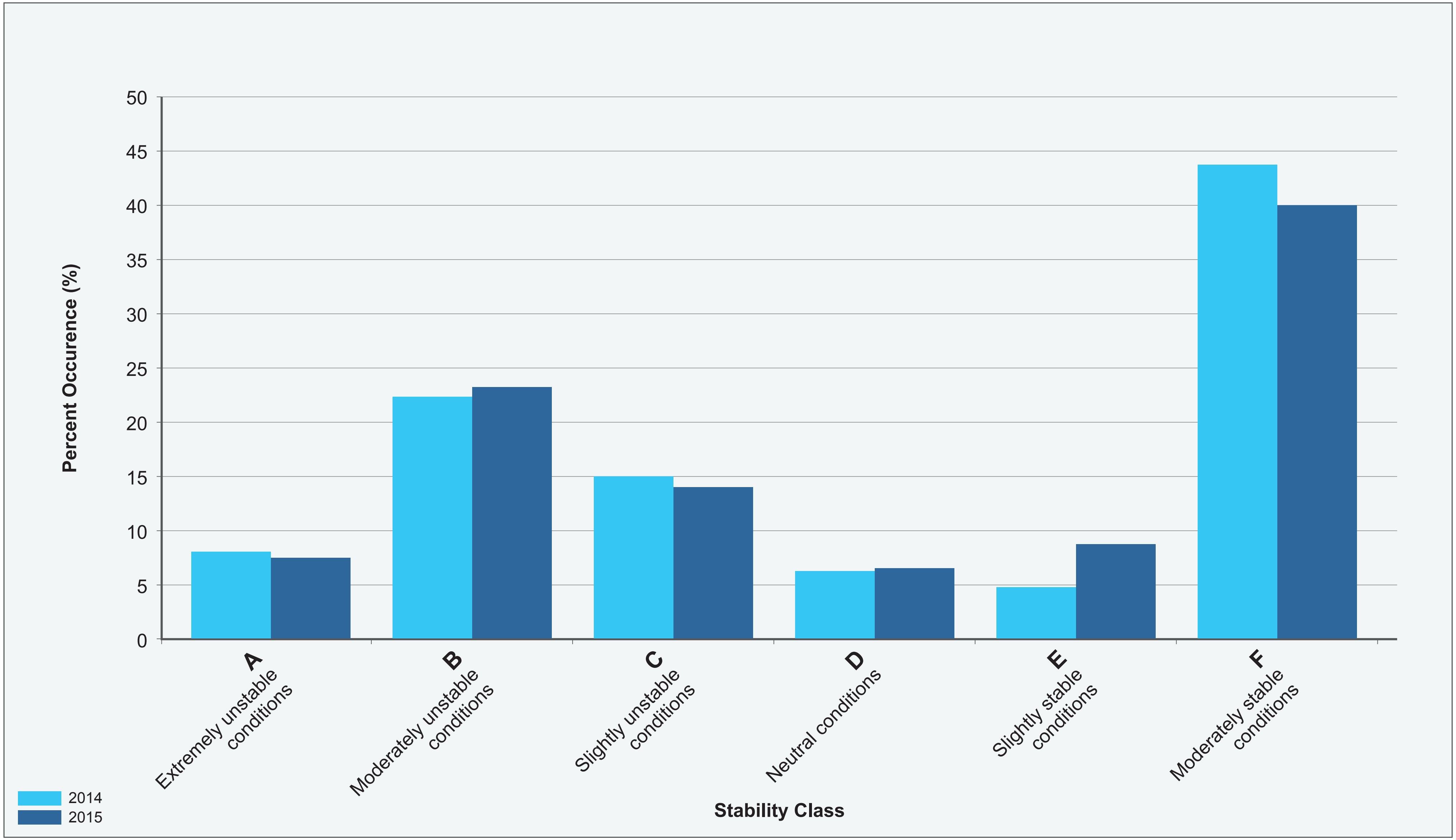
FIGURE 10.3



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CPF SITE PREDICTED DIURNAL VARIATION IN MIXING HEIGHT (CALMET)

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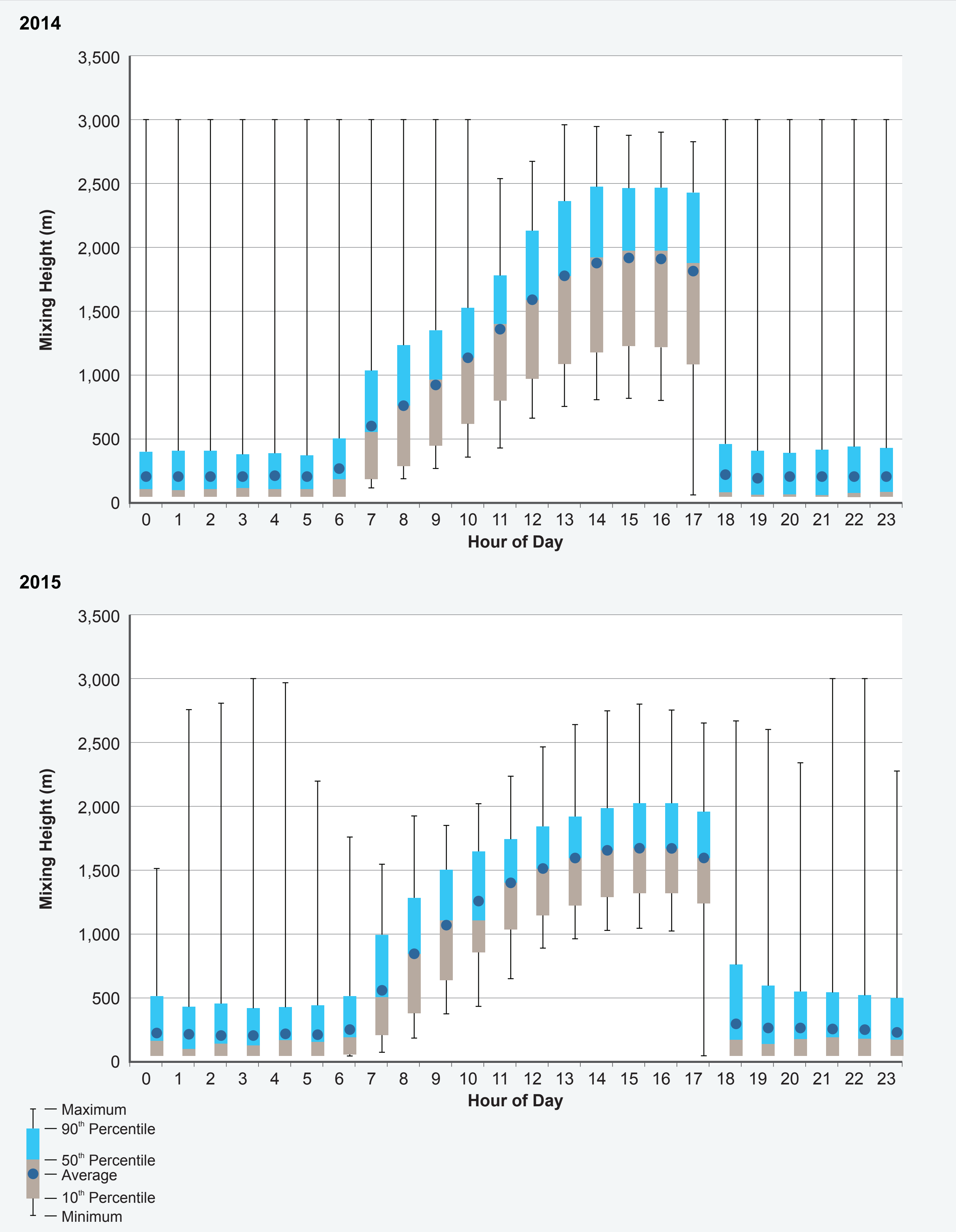
FIGURE 10.4



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The existing air quality for the CPF site would be expected to reflect the virtual absence of industrial pollution sources, and the ambient air quality can be assumed to be generally good. Gaseous pollutant concentrations would be negligible (i.e., 0 µg/m^3) compared to relevant international guidelines for ambient air quality (Part 19 of Volume 2) and the study area would be regarded as a 'non-degraded' airshed in relation to IFC assessment requirements.

Table 10.1 shows the estimated baseline particulate concentrations for the CPF site.

Table 10.1 – CPF Site Estimated Baseline Particulate Concentrations

	Pollutant					
	TSP		PM_{10}		$PM_{2.5}$	
Averaging period	24-hours	Annual	24-hours	Annual	24-hours	Annual
Range of background particulate concentrations expected to occur in the CPF site (µg/m^3)	10 to 70	20 to 40	5 to 35	10 to 15	2 to 20	5 to 8
Background concentration assumed (µg/m^3)	50	40	25	15	15	8
WHO (2005) ambient air quality (µg/m^3)	–	–	50	20	25	10
EC (2016) ambient air quality for Europe (µg/m^3)			50	40	–	25
USEPA (2017) ambient air quality (µg/m^3)	150 (260)*	60 (75)*	150	–	35	12 (15)

Source: Part 19 of Volume 2.
* The USEPA primary standards are set to protect public health, including the health of 'sensitive' populations, such as asthmatics, children and the elderly. Secondary standards, shown in parentheses, which are set for some pollutants, were developed to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation and buildings. In all cases, the secondary standards are either equal to or higher than the primary standards.

Annual long-term average concentrations have been conservatively assumed to be at the maximum of the expected range, as short-term localized or regional events do not have any significant impact on the annual average concentrations. The 24-hour average concentrations have been assumed to be at the upper end of the range, but not at the maximum, to exclude monitoring data that may be significantly influenced by localized or regional events such as fires or burning crops. The particulate estimates are below the World Health Organization (WHO) air quality guidelines (WHO, 2005), the European Commission air quality limit values (EC, 2016) and the US Environmental Protection Agency national ambient air quality standards (USEPA, 2017) (see Table 10.1), which are used for comparison in the absence of PNG statutory air quality standards. The air quality guidelines in Table 10.1 are provided for comparison only and do not communicate commitment by the Project. The modeling detailed in Chapter 15 assesses the most appropriate standards for Project development.

10.2.3.2 Onshore Export Pipeline Corridor

Wind speed and wind direction will be the key meteorological parameters that will influence the dispersion of pollutants (e.g., dust emissions) during construction of the onshore export pipeline. Air emissions during the operational phase are expected to be negligible.

Wind direction predicted for the onshore export pipeline corridor area is more varied and slightly stronger than at the CPF site. The corridor was predicted to experience mainly light to moderate winds (i.e., less than 5 m/s), with winds predominantly from the northern and southeastern quadrants, while calm wind conditions (i.e., less than 0.5 m/s) were predicted to occur 2.6% to 3% of the time (Figure 10.5).

ONSHORE EXPORT PIPELINE CORRIDOR WIND ROSES

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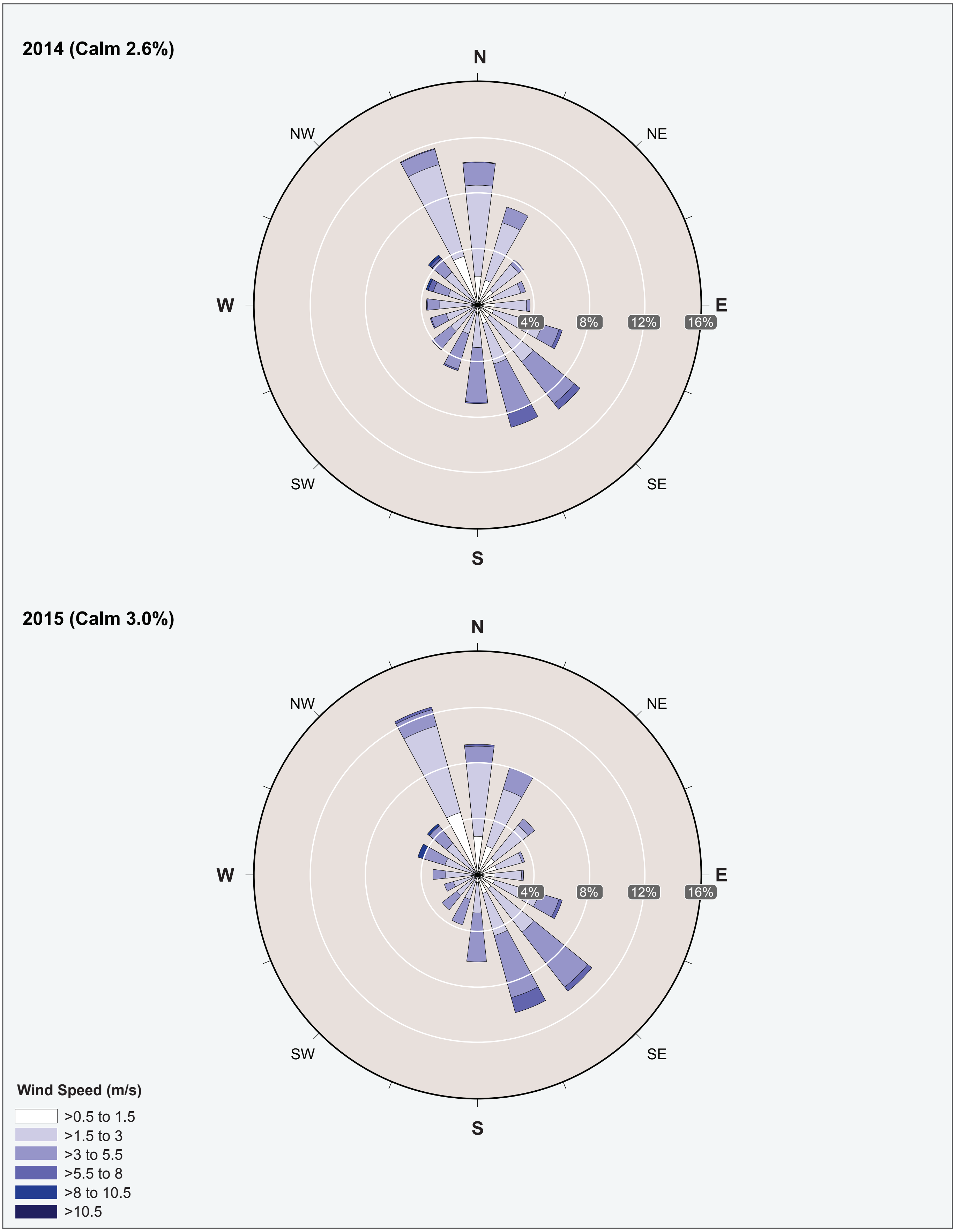
FIGURE 10.5



The ambient air quality for the export pipeline corridor can be assumed to be similar to the CPF and related facilities areas, i.e., generally good with negligible gaseous pollutant concentrations.

Baseline particulate levels are expected to be low along the onshore export pipeline corridor; however, levels may be higher near the coast where there is a greater concentration of villages than inland along the more remote sections of the corridor. The same background particulate concentrations assumed for the CPF and related facilities areas are considered appropriate for the onshore export pipeline corridor (see Table 10.1).

The gaseous pollutant values and particulate estimates for the onshore export pipeline corridor are below the air quality guidelines identified in Part 19 of Volume 2.

10.2.3.3 River Transport Corridor

As explained in Section 10.2.1, the meteorological information presented in Section 10.2.3.2 is also relevant for the river transport corridor.

Some existing air emissions from boat activities exist along the river corridors; however, these are likely to be isolated and short-lived in occurrence and are; therefore, not expected to be significant in the context of air quality. Consequently, baseline gaseous pollutant concentrations along the river corridors can be assumed to be negligible, and the same background particulate concentrations assumed for the CPF and related facilities areas are considered appropriate for the river transport corridor (see Table 10.1).

Both the gaseous pollutant values and the particulate estimates for the river transport corridor are below the air quality guidelines identified in Part 19 of Volume 2.

10.2.3.4 Offshore Export Pipeline

No significant potential for air quality impacts are expected during the construction or operational phases of the Project’s offshore export pipeline, as this Project-component area is primarily under water; therefore, no modeling or detailed analysis of the meteorology has been performed; however, the winds in this component area are discussed in Section 8.3.1.

The existing air quality in this part of the study area can be expected to be very good, with potential for low levels of particulate concentrations associated with salt spray and the transport of dust from the mainland by offshore winds. All other baseline pollutant concentrations can be expected to be negligible.

10.3 Noise

10.3.1 Study Overview

A baseline noise study was undertaken in the upstream Project area to characterize the existing ambient background noise levels and to allow the future prediction of potential impacts to be assessed.

Minimal information regarding the existing ambient baseline noise environment was available in the upstream Project area; therefore, a field survey was undertaken at potential sensitive receptors surrounding upstream Project infrastructure.

The baseline noise study area is defined as an area where noise impacts may be experienced due to Project activities, including the construction and operation of facilities and infrastructure. The upstream noise survey focused on gathering baseline information at key locations, i.e., sensitive receptors, such as existing villages, potential future in-migration locations and fauna-sensitive areas that will potentially be impacted by noise from the Project during both construction and operations.

The baseline survey was undertaken in November 2016 when weather conditions were predominantly calm and dry, and involved unattended noise monitoring at nine locations and attended noise monitoring at 10 locations (Figure 10.6):

- An unattended noise logger was deployed in a secure location at each identified site. The noise logger was set to continuously measure the ambient background noise levels over a minimum 48-hour monitoring period to quantify the day and night-time ambient noise levels for the area.
- Attended noise monitoring measurements were generally taken when the noise loggers were deployed and retrieved, using a hand-held sound level meter.[3] During the measurements, ambient noise sources were quantified, and surrounding noise sources with the potential to affect the noise impact assessment were identified. In addition, the landform surrounding the study sites was assessed, particularly around the proposed CPF site, for features that provide localized shielding, such as that provided by hills, which may have an impact on future noise emissions across the site.

Noise related to the offshore export pipeline corridor (i.e., underwater noise) is characterized in Section 8.7.

10.3.2 Factors Affecting Noise

Weather conditions can significantly affect the transmission of noise outdoors. Where background noise levels are measured in the absence of any mechanical plant noise, the effects of weather are limited to either sustained periods of heavy rainfall (i.e., noise from the impact of rain on the ground or building structures) or strong winds, which can cause either wind-induced microphone noise or can disturb the nearby foliage (i.e., the rustling of leaves in trees). As described in Section 7.3, weather conditions, including high rainfall and seasonally strong southeasterly winds, are expected to influence ambient noise levels in the study area.

An area's surrounding landform and topography can also significantly affect noise propagation due to the natural shielding provided by hills and mountain ranges, and the level of effect will depend on the proximity of the noise sources and receptors. If sound is propagating over ground, attenuation will occur due to acoustic energy losses on reflection depending on the surface; for example, smooth, hard surfaces, such as concrete or water, will provide little absorption, whereas thick grass may significantly reduce sound levels at higher frequencies. As described in Section 7.3 and shown in Figure 7.4, the complexity of the terrain, including complex ridges, escarpments and hills, in parts of the Project area, and in particular surrounding the proposed production, processing and related facilities in PRL-15 and along the onshore export pipeline corridor generally, may provide opportunities for shielding and attenuating noise emissions from Project activities. In general, the typically dense tropical forests described in Section 7.7.5 and occasional subsistence agricultural cover across most of the Project area will provide increased ground absorption relative to hardstand areas, roads and water surfaces, and will help attenuate noise propagation from the various works.

The anthropogenic setting of the area has been discussed previously in Chapter 9.

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3 Attended noise surveys conducted at ANT-7 and Herd Base collected data that will be used in the noise impact assessment to be undertaken at a later stage. The data from these attended noise surveys is not discussed in this chapter but is included in Part 20 of Volume 2 for completeness.

NOISE FIELD SURVEY SITES

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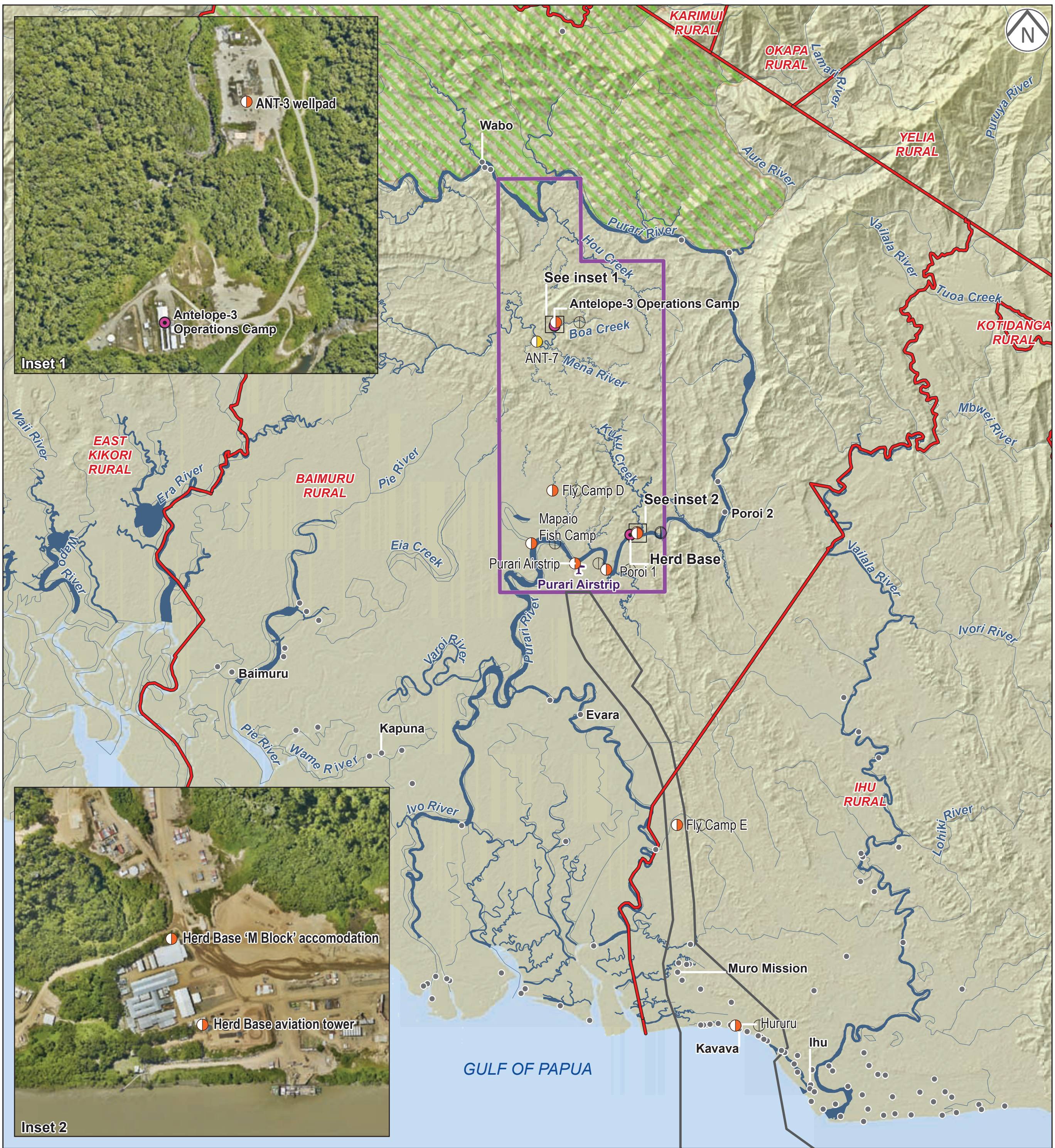
FIGURE 10.6



SCALE: 1:650,000 @ A4

0 5 10 15 20 25 km

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Town and village
- Base camp
- Airstrip
- Local level government boundary
- Waterway
- Waterbody
- PRL-15
- Export pipeline corridor
- Crater Mountain Wildlife Management Area

Noise Monitoring Locations

- Attended monitoring
- Attended and unattended monitoring

Communities outside of the Project area of influence have not been verified. Only government administrative centers and notable locations have been labeled for context.

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10.3.3 Noise Baseline Characterization

Average background noise levels from areas in the production, processing and related facilities of PRL-15, and the onshore export pipeline corridor are presented in Table 10.2, with ambient noise level guidelines for residential receptors provided in the Environmental, Health and Safety General Guidelines (IFC, 2007).

Table 10.2 – Measured (Unattended) Background and Residential Guideline Noise Levels

Study Area	General Description of Receptor Location	Receptor	Period	Average Background Noise Level dBA, L_{90}	IFC Noise Level Guidelines[#] dBA, $L_{eq(1h)}$
Production, processing and related facilities (PRL-15)	Remote uninhabited historic wellpad*	ANT-3 wellpad	Day, 7-22 hr	38	55
			Night, 22-7 hr	46	45
	Uninhabited forest	Fly Camp D[†]	Day, 7-22 hr	42	55
			Night, 22-7 hr	56	45
	Established villages	Poroi 1	Day, 7-22 hr	40	55
			Night, 22-7 hr	42	45
		Mapaio Fish Camp	Day, 7-22 hr	35	55
			Night, 22-7 hr	41	45
	Single dwelling near the operational airstrip	Purari Airstrip	Day, 7-22 hr	44	55
			Night, 22-7 hr	47	45
Onshore export pipeline	Uninhabited forest	Fly Camp E[†]	Day, 7-22 hr	46	55
			Night, 22-7 hr	56	45
	Established coastal village	Hururu	Day, 7-22 hr	42	55
			Night, 22-7 hr	38	45

* Remote, vegetation has been cleared from the edge of this wellpad.
[#] In accordance with Section 1.7 for off-site residential receptors (IFC, 2007).
[†] Remote and temporary camp locations used by the terrestrial biodiversity survey team.

The background noise levels recorded at three of the sites along the Purari River, i.e., Mapaio Fish Camp, Purari Airstrip and Poroi 1, are considered representative of other villages along the main river transport corridor. At each of these sites, monitoring was conducted close to the river, although it was set further back at Poroi 1, reflecting normal variation in the background noise environment. In addition, transient-noise emission sources were present, such as boats with outboard motors and passing barges, which would be typical of other locations along rivers in the corridor.

Observations from the field and analysis process suggest that the background noise environment is generally dominated by insect noise at all locations and shows a distinct increase at night at many locations due to the increase in insect activity.

At the established villages and settlements, where the surrounding undergrowth and forest has been cleared, the resultant night-time background noise levels were noticeably quieter (i.e., 38 to 42 dBA, L_{90}) than the remote undisturbed forest locations (i.e., fly camps), where night-time levels of around 55 to 56 dBA, L_{90} were recorded. This is attributed to the increased presence and close proximity of insects and, at night, other nocturnal fauna (e.g., frogs and bats) in the more remote and densely vegetated undisturbed locations. Correspondingly, the lower background noise levels at the villages and settlements are attributed to the clearing of vegetation resulting in lower levels of wildlife. Nearby turbulent river flows affected the background noise for some villages; however, the contribution of this noise was minimal when compared to that generated by fauna, particularly insects. The villages were also affected by intermittent noise associated with normal habitation, e.g., voices, domestic animals and equipment such as chainsaws and generators; however, these activities mostly occurred for short periods and were excluded from the analysis in accordance with standard procedure (Part 20 of Volume 2).

10.4 Landscape and Visual Amenity

10.4.1 Study Overview

The landscape and visual amenity baseline characterization has been developed considering the proposed approach that will be undertaken for the landscape and visual impact assessment, which comprises two components:

- Landscape effects assessment: Broader assessment that focuses on potential impacts on the landscape as a community resource; aesthetically driven assessment concerned with overall landscape change.
- Visual effects assessment: Concerned with potential changes to the general surrounds and views due to Project facilities, and therefore the effect on the visual amenity experienced by individuals and groups of people.

Part 21 of Volume 2 contains further information on the approach to the landscape and visual amenity baseline study.

10.4.2 National and Regional Setting

Papua New Guinea has a varied landscape. The rugged volcanic mountainscape of dense tropical forest in the New Guinea Highlands gives way to coastal lowlands, including wetlands. The coastline consists of coral and sand beaches, islands and offshore reef areas.

The Gulf Province landscape is typical of Papua New Guinea. Mountainscapes with elevations up to 1,673 m above sea level (asl) rapidly give way to coastal lowlands. Notable features are the Purari River, which is the third largest river in Papua New Guinea, and the Purari River delta. In addition, significant human disturbance is absent; population density is low, and human activity is primarily focused on subsistence farming and fishing (Sections 9.4 and 9.8). Anthropogenic disturbances, such as extensive commercial logging activities, and previous and contemporary commercial plantations (e.g., coconut) closer to coastal areas, are present; however, changes brought about by these disturbances are generally neither evident nor significant at a regional landscape scale due to the indiscernible changes at forest canopy level, which are described in Section 7.7.5.3.

10.4.3 Landscape Character Description

Tables 10.3 to 10.6 summarize the landscape character surrounding Project components (i.e., production, processing and related facilities in PRL-15; the onshore pipeline corridor outside PRL-15; the river transport corridor; and the offshore pipeline corridor). A brief description is also provided for Herd Base and the CPF area, the logistics base and the airstrip. The description of the ANT-3 wellpad and the surrounding area is considered representative of other wellpads in PRL-15.

10.4.3.1 Production, Processing and Related Facilities (PRL-15)

PRL-15 will contain most of the production, processing and related facilities components. Table 10.3 summarizes the landscape character of PRL-15.

Herd Base

The landscape at Herd Base is modified and not particularly unique. It is located along a fairly typical stretch of the Purari River and is geographically constrained by the river, the mountain foothills and the adjacent Kuku Creek. The base has been established on the northern river bank, which is elevated above the southern bank. Elevations at the base are from 6 m asl at the river's edge to 15 to 20 m asl where most infrastructure has been constructed. Steep foothills rise quickly to the north and west, to elevations of 75 to 95 m asl.

The base has been cleared of vegetation (Plate 10.1) for access and logistics purposes. The vegetation immediately surrounding the base is partially disturbed while further afield the vegetation is dense, undisturbed forest.

The vegetation clearance for operational purposes is evident, and this does generate an area of visual deviation from the surrounding undisturbed landscape, particularly from vantage points on or along the river.

Plate 10.1 – Herd Base (Southeastern Aspect)

Photo: SLR Consulting.

Table 10.3 – Production, Processing and Related Facilities (PRL-15) Landscape Character Description

Landscape Character	Landscape Description
Topography	♦ Mountain foothills and a dominant southeast to northwest trending range are located north of alluvial flats around the Purari River (see Figure 7.4) Elevations range from close to sea level near the Purari River up to 430 m asl in the foothills. ♦ Foothills are dominated by a rugged and steeply sloped ridge-and-ravine landform that is underlain by thickly bedded to massive sandstone, with significant cliffs forming prominent topographic features. Landform is recurrently scarred by slumps, landslides and gullying. ♦ Low-relief (i.e., 10 to 50 m) ridge-and-ravine country is typical of soft mudstone adjacent to Purari River. ♦ Alluvial flatlands and floodplain in the southern area adjoin the Purari River delta. ♦ Oxbow wetlands occur in the southwestern part of PRL-15 (see Figure 7.28; Plate 10.3).
Vegetation/ land cover	♦ Mountainscape is dominated by dense tropical forest with very limited access (Plate 10.2). ♦ Alluvial floodplains in southern and western areas are densely vegetated with tropical forest. ♦ Oxbow wetlands in PRL-15 include open lake and cut-off wetland areas with herbaceous and swamp forest species (Plate 10.4). Sago palm and aquatic vegetation feature throughout this area.

	Plate 10.2 – Dense Tropical Forest and Mountainscape of PRL-15	Plate 10.3 – PRL-15 Oxbow Wetlands	Plate 10.4 – Dense Tropical Forest and Purari River
	 Photo: SLR Consulting.	 Photo: SLR Consulting.	 Photo: SLR Consulting.

Table 10.3 – Production, Processing and Related Facilities (PRL-15) Landscape Character Description (cont'd)

Landscape Character	Landscape Description
Built forms/ structures	♦ Two small communities are located along the Purari River (Plate 10.5): Mapaio Fish Camp (Plate 10.6) and Poroi 1. Built forms are simple traditional dwellings comprising locally sourced timbers, with traditional thatch roofs and woven walls. ♦ The existing Project logistics base, Herd Base, is located immediately adjacent to the Purari River (Plate 10.7). Built forms include demountable buildings, sheds, storage facilities and aircraft hangers.
	Plate 10.5 – Mapaio Fish Camp Located on the Purari River  Photo: SLR Consulting. **Plate 10.6 – Traditional Dwelling at Mapaio Fish Camp**  Photo: SLR Consulting. **Plate 10.7 – Purari River and Dense Forest Surrounds**  Photo: SLR Consulting.
Land use	♦ Natural, largely undisturbed dense forest with very limited access. ♦ Small, subsistence-based settlements located adjacent to the Purari River. ♦ Discreet disturbances related to gas exploration, including isolated well pads, operations camps, access roads and an airstrip in PRL-15. ♦ No urban land uses and no evidence of forestry operations (during the survey).
Landscape value	♦ Landscape varies considerably, from foothills of the southern extension of the central ranges to low-lying intermittent swampy wetlands. ♦ Dense vegetation and restricted access are consistent across PRL-15. ♦ There is a very limited network of existing tracks and trails; therefore, the Purari River is the primary access point into the area. ♦ The PRL-15 oxbow wetlands consist of a freshwater lake and wetlands. It is an area of potentially high environmental and social sensitivity, as it is a regionally rare example of an isolated open-water lake ecosystem. ♦ The large size of PRL-15 and the dense vegetation masks the limited significant visual divergence from most vantage points.

Table 10.4 – Onshore Export Pipeline Corridor Landscape Character Description

Landscape Character	Landscape Description
Topography	♦ South of the Purari River, the corridor initially crosses ridge-and-ravine country that is typically steeply sloped. Further south, the landform gives way to low- to moderate-relief (i.e., 10 to 100 m asl) ridge-and-ravine country. ♦ The coastal lowlands in the south comprise beaches and plains with elevations from below sea level to 190 m asl. ♦ Toward the coast, the southern part of the corridor encompasses soft mudstone areas typical of the low-lying Purari River delta (Plate 10.8). ♦ Coastal villages are low-lying and occur adjacent to creek and channel networks that pass into tidal inlets, lagoons, swamps and inundation areas (Plates 10.9 to 10.11).
Vegetation/ land cover	♦ Dense forest on the ridges and ravines to the north gives way to dense scrub, marsh and mangroves in the far south (Plate 10.8). ♦ Small areas are cleared around villages for subsistence and plantation agriculture. ♦ Many areas are at or below sea level and are subject to inundation (Plate 10.9). ♦ Most of the area is undisturbed, with only partially cleared access tracks and trails between villages.
	Plate 10.8 – River, Lowlands and Dense Vegetation  Photo: SLR Consulting. **Plate 10.9 – Coastal Villages and Inundation Areas**  Photo: SLR Consulting. **Plate 10.10 – Coastal Village Flanked by Waterway**  Photo: SLR Consulting.
Built forms/ structures	♦ Non-coastal villages are small; and due to their relative isolation and remoteness, buildings tend to be small and to use traditional and locally sourced building materials. ♦ Away from the coastal and lowland villages, there is little to no built infrastructure. ♦ Simple traditional dwellings are typical in coastal villages (Plate 10.12).

Table 10.4 – Onshore Export Pipeline Corridor Landscape Character Description (cont'd)

<table>
<tr><th>Landscape Character</th><th colspan="3">Landscape Description</th></tr>
<tr><td>Land use</td><td colspan="3">♦ The area is predominantly densely vegetated with limited access.
♦ Village areas are mostly for housing and subsistence farming.
♦ A few small areas of agricultural activity occur. Crops are cultivated for consumption and trading (Plate 10.13).
♦ Substantial logging activity is evident throughout the upper sections of the onshore export pipeline corridor (Section 7.7.5.3 (including Plate 7.19) describes commercial logging activities in the study area).</td></tr>
<tr><td></td><td>Plate 10.11 – Coastal Villages

Photo: SLR Consulting.</td><td>Plate 10.12 – Coastal Village Buildings

Photo: SLR Consulting.</td><td>Plate 10.13 – Coconut Grove

Photo: SLR Consulting.</td></tr>
<tr><td>Landscape value</td><td colspan="3">♦ Landscapes vary considerably across onshore pipeline corridor areas, from the foothills of the ranges to low-lying intermittent swampy wetlands and coastal plains.
♦ Dense vegetation and limited accessibility is consistent across the whole area.
♦ Notwithstanding disturbance from logging activities, large expanses of the 70-km onshore export pipeline corridor and the dense vegetation shows limited visual divergence from most vantage points.</td></tr>
</table>

Table 10.5 – River Transport Corridor Landscape Character Description

<table>
<tr><th>Landscape Character</th><th colspan="3">Landscape Description</th></tr>
<tr><td>Topography</td><td colspan="3">♦ Varying topography as the corridor extends from the mountain foothills, beginning near the southern boundary of PRL-15 to the coast. Elevations range from below sea level to approximately 20 m asl.
♦ The Purari River’s main channel varies in width, from approximately 300 m at Herd Base (Plate 10.16) to nearly 1 km at the coastal inlet, while the Varoi-Warne and Ivo-Urika rivers provide consistent corridors of 200 to 300 m wide.
♦ Known as the Purari River delta, the areas adjacent to the Purari River consist of low-lying creek and channel networks that pass into tidal inlets, lagoons, swamps and inundation areas.</td></tr>
<tr><td>Vegetation/ land cover</td><td colspan="3">♦ Dominated by wetland communities and forest on ridges and ravines to the north with dense scrub, marsh and mangroves in the far south.
♦ Riparian vegetation (Plate 10.15) is thick.
♦ Many minor tributaries close to the coast have areas that are close to or below sea level and are subject to inundation, consequently, many lowland and swamp forest vegetation species are present, notably nipa palm and mangrove (Plate 10.14).</td></tr>
<tr><td></td><td>Plate 10.14 – Aerial View of Nipa Palm Expanse

Photo: SLR Consulting.</td><td>Plate 10.15 – Typical Dense Riparian Vegetation

Photo: SLR Consulting.</td><td>Plate 10.16 – Purari River at Herd Base

Photo: SLR Consulting.</td></tr>
</table>

Table 10.5 – River Transport Corridor Landscape Character Description (cont'd)

Landscape Character	Landscape Description
Built forms/ structures	♦ The few villages located along the river corridor (e.g., Aivai) consist mainly of simple traditional dwellings. ♦ Riverside villages are small, and buildings tend to be small, and to use traditional and locally sourced building materials. Some non-traditional building materials can be found due to the villages' close proximity to the river, which is used for transport. ♦ Little to no built infrastructure exists away from the river.
Land use	♦ The rivers are used for transportation, both for Project and non-Project activities. Multiple routes from the coast to Herd Base (Plate 10.16) and further upstream facilitate movement of people, supplies and equipment. The rivers are used for fishing and access to hunting grounds away from the villages. ♦ Clearing for gardens and plantations is evident in and around the villages. ♦ River village areas are mostly for housing, fishing and subsistence farming; beyond this the area is mainly undisturbed vegetation.
Landscape value	♦ Vegetation, including the riparian zone close to the river edges, is dense and limits accessibility. ♦ The rivers and other waterways are significant in their function as transport corridors, providing access to villages and natural resources inland. ♦ Riverine traffic may impact on the landscape character of rivers in terms of the presence of community and commercial vessels, water form (e.g., wave action and wakes) and riparian quality (e.g., disturbance from access to river banks; erosion and foam in riparian zones).

Table 10.6 – Offshore Export Pipeline Corridor Landscape Character Description

<table>
<tr><th>Landscape Character</th><th colspan="3">Landscape Description</th></tr>
<tr><td>Topography</td><td colspan="3">Irrelevant to this part of the study area.</td></tr>
<tr><td>Vegetation/ land cover</td><td colspan="3">Irrelevant to this part of the study area.</td></tr>
<tr><td>Built forms/ structures</td><td colspan="3">Irrelevant to this part of the study area.</td></tr>
<tr><td>Land use</td><td colspan="3">♦ Commercial prawning and fishing occur offshore in designated fishing zones while villagers use the entire coastline for transportation, fishing and other subsistence uses (Plate 10.17).
♦ Fishing and other commercial vessels, including LNG carriers, commonly navigate the waters of the Gulf of Papua farther off the coast.</td></tr>
<tr><td>Landscape value</td><td colspan="3">♦ Low-lying intermittent wetland, coastal plains and coastal foothills landscape (Plate 10.18) tend to be heavily vegetated along the coastline traversed by the offshore pipeline corridor, and views of densely vegetated coastal plains and northern foothills are common (Plate 10.19).
♦ Shipping traffic and other sea craft are intermittently present offshore and visible from various vantage locations along the coast.</td></tr>
<tr><td></td><td>Plate 10.17 – Prawn Netting (Gulf of Papua Coast)

Photo: SLR Consulting.</td><td>Plate 10.18 – Onshore View (Aerial) of Orokolo Bay Coast

Photo: SLR Consulting.</td><td>Plate 10.19 – Onshore View (Sea Level) of Orokolo Bay Coast

Photo: SLR Consulting.</td></tr>
</table>

CPF, Logistics Base and Airstrip Area

Although the precise location of the CPF, logistics base and airstrip has not been determined, the landscape of the wider area in which these components are proposed (see Figure 7.19) varies considerably, from low-lying intermittent swampy wetlands to mountain foothills (Plate 10.20). The landscape is densely vegetated and predominantly undisturbed, and the vegetation provides limited visual diversity from the river transport corridor, which contains most of the currently traversed vantage points into this area.

Plate 10.20 – Densely Vegetated Mountain Foothills

Photo: SLR Consulting.

ANT-3 Wellpad Landscape Character Description

The ANT-3 wellpad is located in mountainous terrain, typical of PRL-15 (see Figure 7.19). Vegetation has been cleared for gas exploration drilling and for the associated operations camp (Plate 10.21). Disturbance associated with existing drilling activities has generated an area visually divergent from the immediate surrounds; however, the cleared area of ANT-3 wellpad and the associated operations camp is surrounded by dense vegetation and steep topography.

Plate 10.21 – ANT-3 Wellpad from the Air

Photo: SLR Consulting. Note: The cleared area in the center is for the operations camp; the cleared area to the right is for the wellpad.

10.4.3.2 Onshore Pipeline Corridor

The onshore pipeline corridor component of the Project area is south of PRL-15 and stretches from the southern boundary of PRL-15 to the Gulf of Papua coastline. Table 10.4 summarizes the onshore pipeline corridor landscape character.

The onshore pipeline corridor encompasses existing villages along the Gulf of Papua coast (see Figure 9.2). These villages support most of the communities in the study area.

Sand and mud or silt beaches backed to the north by beach ridge complexes and beach plains comprise the Orokolo Bay area. Beach ridge systems and beach plains comprise recent sediments shaped as long parallel ridges and swales (Löffler et al., 1977).

Elevations range from below sea level to the coastal ridges at 100 m asl (see Figure 7.4). Creek and channel networks pass into tidal inlets, lagoons, swamps and inundation areas.

The visual environment in this coastal area varies; however, the low-lying and partially disturbed landscape is typical across the different villages in the study area.

10.4.3.3 River Transport Corridor

The river transport corridor lies west of the onshore export pipeline corridor and includes the Purari, Urika-Ivo and Warne-Varoi rivers (see Figure 7.10). Table 10.5 summarizes the landscape character of these riverways.

10.4.3.4 Offshore Export Pipeline Corridor

The offshore export pipeline corridor stretches from Orokolo Bay to an LNG plant proposed in Caution Bay in Central Province (see Figure 3.2). Table 10.6 summarizes the landscape character of the offshore export pipeline corridor.

10.5 Commercial Marine and River Transport

10.5.1 Study Overview

A baseline marine and river traffic and transport study (Part 22 of Volume 2) was undertaken in the upstream Project area to characterize commercial shipping, fishing vessels and village watercraft in the area. This section presents the findings of the commercial aspects of the marine and river traffic and transport study. The characterization of community traffic and transport is presented in Section 9.10.

The primary means of assessment for characterizing the commercial traffic and transport baseline included:

- A bibliographic review of existing published and unpublished literature.
- Examination of internet databases (i.e., marinetraffic.com and fleetmon.com) to obtain information on vessel type, size and frequency; existing international shipping lanes; coastal shipping routes; and key river transport corridors.
- A review of the Gulf of Papua Prawn Fishery (GOPPF) areas and trawler routes in the Gulf of Papua.

The study area for this study corresponds with the Project area of influence (PAOI), with a key focus on the offshore export pipeline corridor in the eastern Gulf of Papua and on the Purari River and its distributaries, the Urika-Ivo and Wame-Varoi rivers.

10.5.2 International and Coastal Shipping

No international shipping lanes traverse the Gulf of Papua near the offshore export pipeline corridor, although tankers arrive and depart from the PNG LNG Facilities in Caution Bay.

Shipping routes in the Gulf of Papua mainly center on commercial vessels sailing to and from Port Moresby and the inland river ports in Western Province (e.g., Kiunga) and Gulf Province (e.g., Kikori, Kopi, Baimuru and Herd Base) (Table 10.7 and Figure 10.7).

Table 10.7 – Main Coastal Shipping Routes in the Gulf of Papua and Inland Waterways

Route No.	Details	Typical Vessels or Purpose	Return Trips Per Year
1	Port Moresby to Daru	Cargo vessels and fuel tankers supplying Daru township	15*
2	Port Moresby to Kiunga[#]	Ok Tedi Mining Limited (OTML) copper concentrate bulk carriers	102
		OTML cargo (barges and containers)	25*
		Horizon Oil's Elevala Gas Condensate Project	15*
		Talisman Energy's Stanley Gas Condensate Project	15*
		P'nyang Gas Project	10*
		Shallow-draft container ships and towed barges serving Kiunga township	45*
		Subtotal	**212**
3	Port Moresby to Bamu River	Panakawa timber processing (veneer) and Kamusie Sawmill in the Wawoi and Guavi tributaries of the Bamu River	15*
4	Port Moresby to Kikori and Kopi	Supplies to oil and gas exploration activities and operating facilities owned by ExxonMobil and Oil Search and other businesses using Kikori township	120*
5	Port Moresby to Baimuru	Supplies to Baimuru township	15*
6	Port Moresby to Purari River	Supplies to TEP PNG's gas exploration in PRL-15	190[†]
		Log ships to Evara logging camp on the Purari River	24
7	Port Moresby to Ihu	Supplies to Ihu township	26*
8	Port Moresby to Kumul Marine Terminal	Svitzer's tugs or offshore supply vessels servicing the Kumul Marine Terminal	35
9	Port Moresby to PNG LNG marine terminal[**]	Four tugs and a pilot boat servicing the PNG LNG marine terminal in Caution Bay	200*
10	Port Moresby to PNG ports	Coastal shipping to PNG's eastern and northern ports	550*

* Estimates.
[#] The number of copper concentrate bulk carrier trips was based on the 381,075 t/yr of bulk dried concentrate exported from the Ok Tedi mine during 2014 via Kiunga River port (OTML, 2014) and OTML's two dedicated bulk carriers, which have a dried concentrate carrying capacity of 3,700 t each. Other shallow-draft general cargo and container ships, barge landing craft and tug-towed barges serve other hydrocarbon exploration activities, including the P'nyang Gas Development Project, the Horizon Oil and Repsol Elevala Gas/Condensate Project, and the Stanley Gas Field Development Project.
[†] Information provided by TEP PNG.
** Located in the PNG LNG Facilities.
Note: Shading denotes a coastal or river shipping route that overlaps with the PAOI.

COASTAL AND RIVER SHIPPING ROUTES

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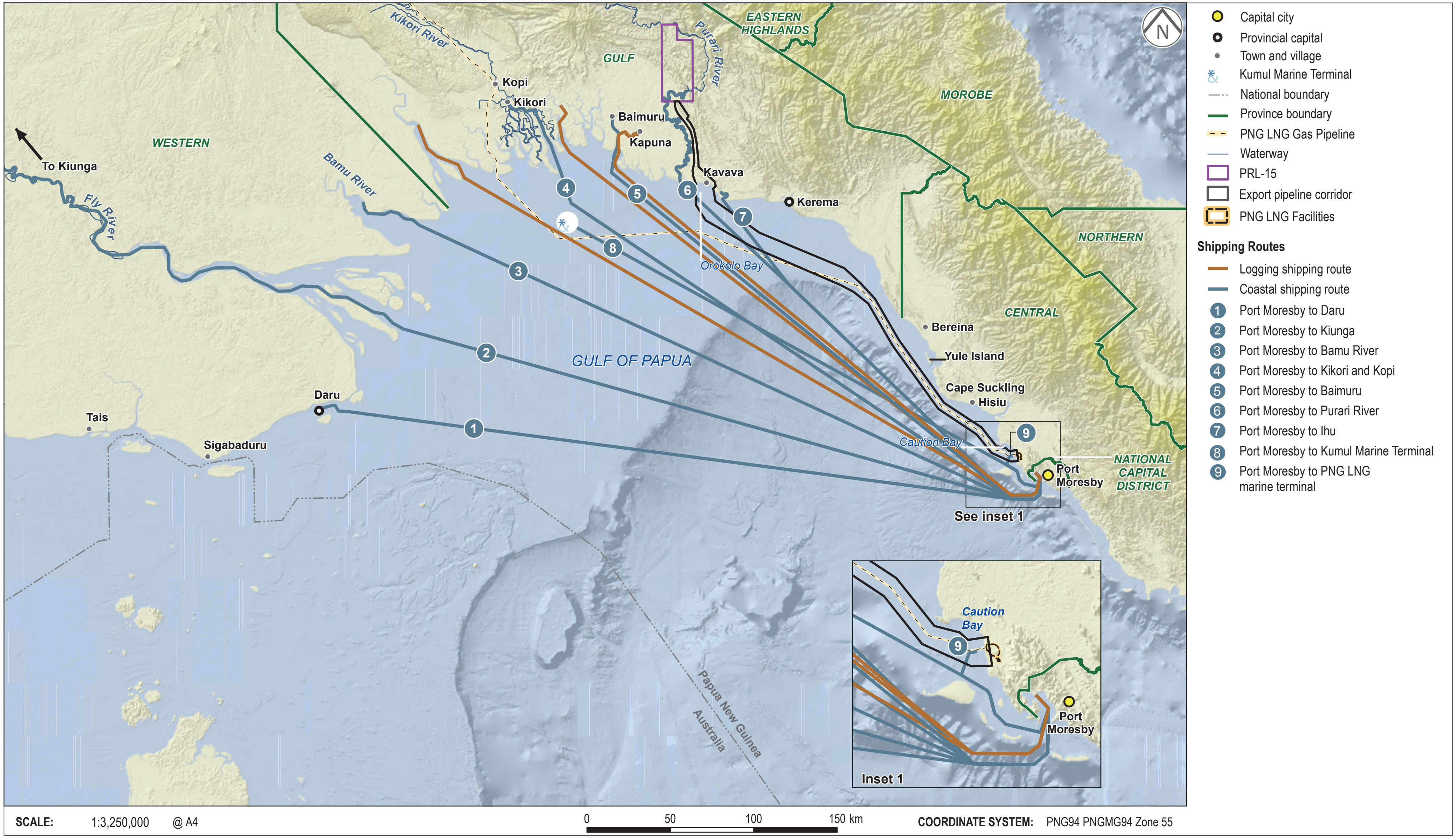
FIGURE 10.7



The busiest route is the Port Moresby to Kiunga route (i.e., 212 return trips/year), which is also the key route for shallow-draft copper concentrate bulk carriers (i.e., 102 return trips/year) transshipping copper concentrate from the Ok Tedi copper mine to a silo ship moored in Port Moresby harbor.

The shipping routes in the PAOI are:

- Route 6 – Port Moresby to Purari River. Herd Base is the river port and destination for TEP PNG's two contracted barge landing craft, which supply goods and equipment to the Project's current exploration activities. Log ships travel to and from Evara logging camp on the Purari River.
- Route 7 – Port Moresby to Ihu in Gulf Province. Gulf Province currently has three passenger vessels that service ports in the province, namely, the MV East/West Kikori, MV Baimuru and MV Ahi. One of these vessels is anticipated to serve Ihu part-time, although the frequency of the service to Ihu is currently unknown. The anticipated frequency is fortnightly visits (i.e., 26 return trips/year) to Ihu.
- Route 9 – Port Moresby to PNG LNG marine terminal. Besides the international LNG carriers visiting the PNG LNG marine terminal to load LNG, four tugs have been contracted to assist in towing and maneuvering LNG carriers in the shipping channel and turning basins and in berthing and unberthing LNG carriers at the PNG LNG marine terminal.

10.5.3 Commercial Fishing

The GOPPF has nine trawl-fishing grounds, three of which cross the Project's offshore export pipeline corridor (see Figure 8.26). These are the GOPPF reporting areas of Orokolo Bay, West Kerema and Iokea, which include the transit routes of trawlers accessing the trawling grounds in these areas. In addition, almost all trawlers to and from Port Moresby to the GOPPF reporting areas cross the export pipeline corridor near its approach to and in Caution Bay.

The GOPPF operates a current fleet of eight trawlers in the Gulf of Papua. The National Fisheries Authority currently licenses ten trawlers, but two are non-operational as they are either being overhauled or re-equipped. Due to prevailing weather and changeable sea states, the trawlers are generally large at 24 to 30 m long, although smaller vessels occasionally trawl in the more sheltered inshore waters. Trawling takes place 24 hours a day for approximately 250 days per year during the April to November open season.

In general, the fishing grounds extend seaward of the 3 nautical mile limit to approximately 40 m deep but typically the trawlers operate in the depth range of 10 m to 35 m. A small number of licensed trawlers have access to the 2 to 3 nautical mile zone based on joint venture agreements with the prawn resource owners, i.e., local Gulf Province communities that have customary rights to the marine biological resources out to the 3 nautical mile limit adjacent to their lands. This allows profit sharing on the value of the prawn catch by trawlers operating within the 3 nautical mile limit (Liviko, pers. com., 2015).

Section 8.6 provides baseline information on commercial marine fisheries resources.

10.5.4 Commercial River Traffic

Commercial river traffic on the Purari River or its delta distributaries includes vessels contracted by TEP PNG to supply goods and equipment services to exploration activities in PRL-15 via Herd Base (Plates 10.22 and 10.23) and log barges that travel along the Purari River to Evara logging camp (Plate 10.24).

In 2016, the two main TEP PNG barges made 190 return trips. In addition, TEP PNG uses two small, high-speed barge-punts from Herd Base to transfer local staff, goods and equipment to various locations across PRL-15 and to neighboring villages (Plate 10.25).

Frontier Holdings Limited, a subsidiary of Rimbunan Hijau (PNG) Limited[4] make approximately 24 log ship return trips a year to Evara logging camp. The logging barge, MV *Swift No. 5*, is 44.9 m long and has a mean draft of 3.1 m.

Plate 10.22 – TEP PNG's Contracted Barge Landing Craft MV *Balimo Chief*

Photo: EnviroGulf Consulting.

Plate 10.23 – TEP PNG's Contracted Barge Landing Craft MV *GFS Marine 01*

Photo: EnviroGulf Consulting.

Plate 10.24 – Log Barge MV *Swift No. 5* at Evara Logging Camp

Photo: ERIAS Group.

Plate 10.25 – TEP PNG's Exploration Barge-punt *Baimuru Bullet*

Photo: ERIAS Group.

10.6 Waste Characterization

10.6.1 Study Overview

A preliminary desktop study was undertaken to provide a high-level characterization of the receiving waste management environment in Papua New Guinea. This preliminary study has drawn on:

- Available public information, through internet searches, notably on waste classifications and regulatory requirements.
- Interviews with TEP PNG personnel about existing company waste management practices.
- Interviews with PNG's Conservation and Environment Protection Authority (CEPA) representatives and with current PNG waste facilities operators who were available.

4 Log barge routes were not confirmed during the study; however, log barges are likely to use all three distributaries and choose the route most suitable for navigation given the environmental conditions when traveling (similar to TEP PNG barges).

The focus of this section is to classify waste types and to outline the current practices of waste management facilities that the Project may consider using.

10.6.2 Waste Classifications

In the absence of specific definitions for hazardous and non-hazardous waste types and characteristics for Papua New Guinea, definitions from the following international conventions and guidelines have been considered:

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 1989).
- The Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region (Waigani Convention) (SPFS, 1995).
- The Stockholm Convention on Persistent Organic Pollutants (SESC, 2001).
- IFC/World Bank Group's Environmental, Health and Safety General Guidelines, Section 1.6 Waste Management (IFC, 2007).
- TOTAL General Specification: Environment: Environmental requirements for project design and E&P activities (GS EP ENV 001).
- A report from the International Association of Oil and Gas Producers regarding naturally occurring radioactive material (NORM) (IOGP, 2016).[5]

10.6.3 Waste Management Facilities – Receiving Environment

The existing receiving environment, i.e., the waste management facilities that are currently available in Papua New Guinea and confirmed by CEPA, are outlined in Table 10.8.

Table 10.8 – Existing Waste Management Facilities in Papua New Guinea

Facility	Operator	Capacity	Comments
Baruni Landfill – Port Moresby	Division of Waste Management - National Capital District Commission	More than 300 tonnes/ day	The facility receives municipal solid waste generated from households, settlements, institutions, and commercial facilities.
PNG Recycling – Port Moresby	Sims Metal Management	Unknown	PNG Recycling is a subsidiary of the international Sims Metal Management. It is one of Papua New Guinea's leading metal recyclers, with operations in Port Moresby, Lae and Tabubil. The facility provides customer-specific metal, tire, plastic and battery recycling solutions. It accepts used batteries, which are on-sold to PEC Trade in Lae. The company holds permits to export wastes, as required under the Waigani Convention.

5 'The Project is not expecting naturally occurring radioactive material (NORM) to be generated.

Table 10.8 – Existing Waste Management Facilities in Papua New Guinea (cont'd)

Facility	Operator	Capacity	Comments
Napa Napa refinery - Port Moresby	Puma Energy	Unknown	Limited information is available on this facility; however, it includes an oil recycling facility.
AES Waste and Resource Management Facility - Ruvuvu and TWM waste storage and transfer facility, Badili, Port Moresby	Total Waste Management (TWM PNG)	Waste oil treatment facility: 1 million m^3/yr. TWM PNG advised that waste management capacity is not constrained if a potential client and TWM PNG preplan how waste is collected, transferred and stored. TWM PNG can ramp up, as required to accommodate any contracted service.	The initial waste collection location and the waste oil treatment facility is located at Ruvuvu. TWM PNG offers a range of waste management services including solid general wastes, construction wastes, liquid wastes (industrial, grease trap and septic), security and contraband wastes and hazardous wastes. In Port Moresby, TWM PNG also offers recycling services for a range of products including waste oils and greases, ferrous metals, paper and cardboard, aluminum cans, tires, timber and some plastics.
ECE	Eco Care Engineering Ltd	Not applicable	An engineering firm based in Port Moresby. It currently has no infrastructure in place for waste management, but is investigating a commercial project southeast of Port Moresby.
Branis Recycling	Branis Recycling Ltd	Unknown	Based in Port Moresby, this company specializes in exporting high-value, non-ferrous metals. They also collect ferrous metals to on-sell to PNG Recycling.
Toxfree	Toxfree Australia	Unknown	An Australia-based company currently offering waste management services in Papua New Guinea. Wastes collected by Toxfree are reportedly shipped offshore to Australia under the Waigani Convention. Limited information is available on this company.
PEC Trade	PEC Trade	Unknown	A PNG company specializing in battery recycling based in Lae. Limited information is available on this company.

These existing waste management facilities offer the following waste management options, which consider national and international legislation, and good international industry practice, described in Chapter 2:

- Recycling (beneficial reuse) of select hazardous and non-hazardous wastes.
- Burial or on-site disposal of select non-hazardous wastes.
- Incineration and disposal of ash at a landfill for select hazardous and non-hazardous wastes.
- Disposal at a landfill for hazardous and non-hazardous wastes that cannot be recycled, treated or incinerated.
- Export of select wastes.

10.6.3.1 Recycling

Table 10.9 summarizes the current recycling and reuse options in Papua New Guinea.

Table 10.9 – Recycling and Reuse Options

Waste Facility/ Operator	Waste Accepted							
	Ferrous	Non-ferrous	Plastic	Paper and Cardboard	Glass	Waste Oil	Batteries	Rubber Tires
TWM PNG*	✓	✓	✓	✓	✓	✓	✓[#]	✓
PNG Recycling*	✓	✓	-	-	-	-	✓	-
Puma Energy	Limited information available					✓	Limited information available	✓
Branis	✓	✓	-	-	-	-	-	-
Toxfree	Limited information available					✓[†]	Limited information available	✓
Pec Trade	Limited information available						✓	Limited information available

* TWM PNG and PNG Recycling export materials (e.g., glass, plastic, paper and cardboard) to Australia for beneficial reuse, if they cannot be recycled in Papua New Guinea.
[#] TWM PNG recycles batteries via PNG Recycling.
[†] Toxfree exports all waste for recycling.

In addition, the following reuse options are available for non-hazardous wastes:

- Whole glass drink bottles may be returned to the bottling plant.
- Wood may be recycled and distributed to local communities.
- Geotechnically suitable and uncontaminated drill cuttings may be used for forming hardstand areas or as road fill.
- Spoil material may be used as general fill or for landscaping depending on its properties.

10.6.3.2 Incineration

Incineration is used to reduce the waste volume that would otherwise need to be transported whole to a waste management facility for disposal in a landfill or for export. In Papua New Guinea, incineration is regulated by national legislation, international conventions and good international industry practice.

The following types of waste can be incinerated:

- Hazardous inert wastes:
  - Medical wastes.
  - Oily debris, including used lubricated oils.
  - Plastic materials.
  - Unused, spent, expired and contaminated solvents, chemicals and additives.
  - Combustible drums and containers.
- Non-hazardous wastes:
  - Paper and cardboard.
  - Food scraps.
  - Vegetation.
  - Scrap wood (untreated).

Ashes that meet acceptance criteria can be transported to a landfill for disposal. Medical waste disposal is via incineration at public hospitals; however, reports suggest many hospital incinerators are not operational due to old age and maintenance issues, resulting in the burial of medical waste in pits. TWM PNG accepts, incinerates and disposes of medical waste.

10.6.3.3 Disposal at a Landfill

The Baruni Landfill is the only remaining legally gazetted landfill servicing the Port Moresby area. It accepts more than 300 tonnes/day of municipal solid waste from households, settlements, institutions and commercial facilities and is expected to remain in service for the next 10 years. The landfill site has limited fencing, and waste is disposed of in unconfined and uncontrolled piles.

10.6.3.4 Export of Select Waste

Two commercial recycling operators (i.e., PNG Recycling and TWM PNG) collect, process and export non-ferrous metals and batteries from Port Moresby to Australia, Singapore and the Republic of Korea. Branis Recycling also exports non-ferrous metals. In addition to non-ferrous material and batteries, mercury may be recovered from adsorbent material and then transported for recovery and recycling, or mercury adsorbent may be exported for disposal in accordance with applicable international convention.

Toxfree exports a variety of hazardous wastes, including halogenated and non-halogenated solvents, oily water, acids and alkalis, catalysts, oxidants and resins for either recycling or disposal in Australia. TWM PNG also exports hazardous sludge from wastewater ponds and amine facilities.

Export of hazardous wastes requires permits under the Waigani Convention.

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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 11: Impacts - Terrestrial

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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11.1.1 Context

11.1.1.1 Landforms

Ridge and Ravine Landform

The northern section of PRL-15 is in the foothills of the frontal part of the Papuan Fold and Thrust Belt (see Figure 7.1). The relief in this area is pronounced, with landforms shaped by tectonic processes forming ridges and ravines with significant cliffs (Plate 11.1). The landforms are underlain by thickly bedded to massive sandstone and are scarred by numerous slumps, landslides and gullying. The maximum elevation of the ridge and ravine landform in PRL-15 is about 410 m asl. The ridge and ravine landform continues south at a lower relief (i.e., 10 to 50 m asl) along the eastern edge of the export pipeline route toward the coast.

Plate 11.1 – Ridge and Ravine Landform in Northern Area of PRL-15

Photo: SLR Consulting.

Composite Meander and Levee Alluvial Landform

South of PRL-15, the lower Purari River and delta are formed of a central meander, back plains and swamp landform (Plate 11.2). The back plains are subject to frequent flooding and are permanently swampy where drainage is impeded by levees or meander plains. The drainage status varies greatly, depending on local conditions, from poorly to well drained.

Plate 11.2 – Meandering River and Levee Alluvial Plains Landform

Photo: SLR Consulting.

Recent Littoral Landform

In the southern portion of the export pipeline route adjacent to Orokolo Bay, the littoral landform consists of beach, beach ridge complexes and beach plains. These beach terrain systems and plains are composed of recent sediments shaped as long parallel ridges and swales. Immediately west of this area, the landform is dominated by the main eastern river mouth distributary of the Purari River, which discharges into the Gulf of Papua. The drainage is tidal with a maze of channels that are mainly made up of swamps, marshes and estuaries. Mud banks along the channels support mangrove vegetation.

11.1.1.2 Soils

Soil units in the Project area are dominated by Entisol and Inceptisol soil orders. These are poorly formed soils with limited soil pedological development.

In the ridge and ravine areas in PRL-15, ongoing erosion prevents soil from developing over the bedrock parent material. These are denudational soils formed from weathering of the Earth's surface and are grouped into Soil Complex 1 (see Figure 7.5). In other areas of Project activities, soil complexes are aggradational soils that are formed from material deposition. On the alluvial plains in the southwestern parts of PRL-15 and along the export pipeline route (Soil Complex 2) and in beach landforms near the coast (Soil Complex 3), the soils are poorly formed because of ongoing deposition preventing the young soil from developing. The inundated tidal flats, swamps and saturated alluvial soils near the coast are dominated by Histosol soils (Soil Complex 4), which typically form under saturated conditions and have high organic matter in the upper layers.

The PAOI contains several soil units with acid sulfate soils potentially present. Such soils are prone to releasing acid leachate if disturbed or drained and exposed to the atmosphere. Except for one site in the southern extent of PRL-15 (located on a saturated drainage line of Kuku Creek), all sites that indicated potential acid sulfate soil (PASS) were located on alluvial flood plains, beach ridges, and plains in the lower Purari River delta, which experience frequent inundation. These soils are typically Psammaquents and Sulfaquents of Soil Complexes 2 and 3.

The coastal soils, represented by Histosols and Hydraquents of Soil Complex 4, are also considered likely to be PASS.

Soil complexes in the PAOI are categorized to be limited in their capability for conventional ‘western’ agriculture. Notwithstanding, local communities have managed to successfully grow tree crops of sago, coconut, papaya, betel nut, and mustard and other food crops for many generations. This is achieved with considerable intervention and shaping by villagers to provide drainage and compost mounding to assist plant growth.

Metal concentrations in soils are well below human health-based screening levels for contaminants; however, there are exceedances for cobalt, copper, lead, manganese, nickel, selenium, vanadium and zinc when compared to ecological screening levels for soils. Concentrations of chromium, selenium, vanadium and zinc that were high compared to other sites were recorded in samples from two sites inland from the coast in the southern part of the export pipeline route. It is not known if the source of these metals is related to anthropogenic activities or natural conditions. There is no evidence of hydrocarbon contamination of soil at any of the sampling sites. Levels of total petroleum hydrocarbons (TPHs) and benzene, toluene, ethylbenzene and xylene (BTEX) in all samples tested were below the limits of reporting and below ecological screening levels.

11.1.2 Discipline-specific Impact Assessment Method

The significance assessment method described in Chapter 3 was adopted to qualitatively assess the potential impact on landforms and soils from each phase of the Project.

The significance assessment method examines the degree to which the existing environment may potentially change because of Project-related activities. This assessment method is a function of the magnitude of impact on a resource or receptor and the sensitivity of that resource or receptor, as described in Chapter 3. Together, they determine the significance of the impact.

Sensitivity is defined as the susceptibility of a resource or receptor to change, including its capacity to adapt to or accommodate the kinds of changes that the Project may bring about. It also considers the intrinsic value of a resource, e.g., capacity to support natural vegetation and food crops in the case of soils.

Table 11.1 defines the categories for assessment of sensitivity for landforms and soils and considers:

- ♦ Landform stability and susceptibility to erosion.
- ♦ Soil capacity, considering pedological development, fertility and any adverse properties, such as the presence of PASS.

Table 11.1 – Landforms and Soils Sensitivity of Resource or Receptor

Category	Description
Very high	♦ Landform is very steep to precipitous, very highly unstable and very highly susceptible to erosion. ♦ Soil is very poorly developed, highly infertile with very low organic matter and is very highly erosion prone if exposed, or has very high adverse properties, e.g., PASS. Soil does not recover or recovers minimally from disturbance with very low natural vegetation recovery or by very extensive remedial measures. ♦ Soil is not contaminated, with concentrations of contaminants below human health and ecological screening levels and having undetectable levels of hydrocarbons.

Table 11.1 – Landforms and Soils Sensitivity of Resource or Receptor (cont'd)

Category	Description
High	♦ Landform is steep, highly unstable and highly susceptible to erosion. ♦ Soil is poorly developed, has low fertility and organic matter content and is highly erosion prone if exposed, or has high adverse properties, e.g., PASS. Soil recovers very slowly from disturbance with low natural vegetation recovery or by extensive remedial measures. ♦ Soil is minimally contaminated, with concentrations of contaminants below human health and ecological screening levels but having detectable levels of hydrocarbons.
Medium	♦ Landform is moderately undulating, moderately unstable and moderately susceptible to erosion. ♦ Soil is minimally developed, moderately fertile with moderate organic matter and is moderately erosion prone if exposed, or has moderate adverse properties, e.g., PASS. Soil recovers slowly from disturbance with moderate natural vegetation recovery or by moderate remedial measures. ♦ Soil has low levels of contamination, with no exceedances of human health screening levels but occasional exceedances of ecological screening levels.
Low	♦ Landform is gently undulating, slightly unstable and minimally susceptible to erosion. ♦ Soil is moderately well developed, highly fertile with high organic matter and is slightly erosion prone if exposed or has minimal adverse properties, e.g., PASS. Soil recovers moderately quickly from disturbance with relatively rapid natural vegetation recovery or by some active remedial measures. ♦ Soil is highly contaminated, with occasional exceedances of human health screening levels and ecological screening levels.
Minimal	♦ Landform is flat, highly stable and not susceptible to erosion. ♦ Soil is very well developed, very highly fertile with very high organic matter and is not erosion prone if exposed, or has no adverse properties, e.g., PASS. Soil recovers very quickly from disturbance with very rapid natural vegetation recovery and minimal active remedial measures. ♦ Soil is very highly contaminated, with numerous exceedances of human health screening levels and ecological screening levels.

Magnitude of impact is defined by the impact's severity, and spatial and temporal extents. Table 11.2 defines the categories adopted for assessing the magnitude of Project impacts on landforms and soils. Assessment of the magnitude of impact is undertaken assuming proposed mitigation measures have been successfully implemented, i.e., it provides a residual impact assessment.

Table 11.2 – Landforms and Soils Magnitude of Impact Criteria

Category	Factor	Description
Very High	Severity	Impact degrades soils or reduces landform stability with no potential for recovery to pre-disturbance condition. Spoil volumes are very high, and the propensity for slumping and erosion is very high. Active stabilization and regeneration that need very close monitoring are required at very high cost.
	Spatial extent	Impact to landform and soils from disturbance or displacement occurs more than 1,000 m from Project activity or component causing the impact.
	Temporal extent	Impact is very long-term, extending beyond 10 years.
High	Severity	Impact degrades soils or reduces landform stability with some potential for recovery to pre-disturbance condition. Spoil volumes are high, and the propensity for slumping and erosion is high. Active stabilization and regeneration that need close monitoring are required at high cost.
	Spatial extent	Impacts to landform and soils from disturbance or displacement occur more than 500 m but less than 1,000 m from Project activity or component causing the impact.
	Temporal extent	Impact is medium- to long-term, extending up to 10 years.

Table 11.2 – Landforms and Soils Magnitude of Impact Criteria (cont'd)

Category	Factor	Description
Medium	Severity	Impact degrades soils or reduces landform stability with reasonable potential for recovery to predisturbance condition. Spoil volumes are moderate, and the propensity for slumping and erosion is moderate. Active stabilization and regeneration with regular monitoring are required at moderate cost.
	Spatial extent	Impact to landform and soils from disturbance or displacement occurs more than 200 m but less than 500 m from Project activity or component causing the impact.
	Temporal extent	Impact is medium-term, extending up to five years.
Low	Severity	Impact degrades soils or reduces landform stability with moderate potential for recovery to predisturbance condition. Spoil volumes are low, and the propensity for slumping and erosion is low. Stabilization and regeneration with some monitoring are required at low cost.
	Spatial extent	Impact to landform and soils from disturbance or displacement occurs more than 50 m but less than 200 m from Project activity or component causing the impact.
	Temporal extent	Impact is short-term, extending up to one year.
Minimal	Severity	Impact causes no to minimal degradation to soils or effects to landform stability with full recovery expected. Spoil volumes are minimal, and the propensity for slumping and erosion is minimal. Minimal stabilization, regeneration or monitoring is required, at minimal cost.
	Spatial extent	Impact to landform and soils from disturbance or displacement is localized (within 50 m from Project activity or component causing the impact).
	Temporal extent	Impact is very short-term, less than three months.

A matrix combining the magnitude of impact category with the sensitivity category determines the significance of the impact due to the Project's activities. Table 11.3 presents the matrix used to establish the significance of Project impacts on landform and soils.

Table 11.3 – Landforms and Soils Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Resource/Receptor				
	Very High	High	Medium	Low	Minimal
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.1.3 Identification of Potential Impacts

Potential impacts to groundwater can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g. flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of Project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

11.1.3.1 Landform Destabilization

Impact to landform considers events associated with Project activities and normal climatic events. Potential impacts associated with major natural hazards and unplanned events, such as landslides due to seismic events, are considered in Chapter 18.

Project activities, particularly excavations and earthworks in PRL-15 and along the export pipeline route, may destabilize landforms, increasing the incidence of landslides or mass movements. These soil movements may contribute to the degradation of soil structure by burying structured and fertile topsoil and plant propagules, degrading soil aggregates and exposing more dispersive subsoils.

Other potential impacts include increased soil erosion during rain events. Sediment-laden water may enter streams, degrading water quality and smothering aquatic fauna due to increased turbidity and in-stream sedimentation, respectively. Such impacts are considered in Sections 11.3, 11.4 and 11.5.

Impacts on landforms are dependent upon site-specific landform conditions and climate factors in the area of Project activities. Specific landform conditions identified in the PAOI are described in Section 7.2.4 and Section 11.1.1. Table 11.4 identifies the various Project components and the landform type upon which they will be constructed. The susceptibility of these various landforms to Project activities is further discussed in the following sections.

Table 11.4 – Project Components and Landform Types

Project Component	Landform Type		
	Ridge and Ravine	Composite Meander and Levee Alluvial	Recent Littoral
Wellpads (including water supply dams)	✓	-	-
Roads, flowline/trunklines and water supply pipelines	✓	✓	-
Pipe yards and construction accommodation camps	-	✓	-
Spoil disposal sites	✓	✓	-
CPF, operations accommodation camp and Logistics Base	-	✓	-
Quarries and landfills	✓	✓	-
Purari Airstrip extension	-	✓	-
Onshore export pipelines (including valve stations)	-	✓	✓

Ridge and Ravine Landform

The wellpads, flowline/trunklines, water supply pipelines, roads and spoil disposal sites, quarries and landfills are located on ridge and ravine landforms in PRL-15 (see Figure 4.4, Figure 4.8 and Figure 4.9).

These landform locations experience very high rainfall and the landforms are prone to landslides or mass movements. Activities associated with construction, operations and decommissioning can increase this risk. The steepness of the landform and the scale of the Project infrastructure will necessitate localized excavation, filling or cut and fill of the ground surface during construction and then again during decommissioning to recontour and stabilize the modified landform. Minor works associated with maintaining infrastructure, particularly roads, may also occur during operations. These activities may destabilize slopes, particularly in steep to precipitous terrain.

Composite Meander and Levee Alluvial Landform

The CPF, operations accommodation camp, Logistics Base, water supply and discharge pipelines, Purari Airstrip, quarries and landfills are located on the alluvial plain of the Purari River at the foot of the ridge and ravine landform in PRL-15 (see Figure 4.4). The onshore export pipeline route and ROW access road also traverses the eastern alluvial plain of the Purari River from PRL-15 to the coast (see Figure 4.6). Pipe yards and associated construction accommodation camps will also be located on this landform during the construction phase.

The landform locations experience high rainfall and considerable flood events. Given the flat nature of these river plain landforms, they are quite stable and unlikely to experience landslides or mass movements; however, localized excavation, filling, or cut and fill of the ground surface associated with construction, operations and decommissioning may destabilize landforms, e.g., steep watercourse banks.

Recent Littoral Landform

The export pipeline route traverses beach ridge complexes and beach plains adjacent to the coast. This area experiences moderate rainfall and considerable flooding; however, the landform is very stable and unlikely to experience landslides or mass movements due to the flat terrain. Activities associated with construction, operations and decommissioning are unlikely to increase the potential for such landslides or mass movements. Localized excavations, e.g., on steep watercourse banks, will present the greatest risk to landform stability, especially during Project construction.

11.1.3.2 Degradation of Soil Capacity

Project activities may adversely impact soil characteristics, including soil structure; stability from sheet, rill and gully erosion; and land capability class.

Construction will initially involve removing vegetation, thereby exposing soils to rainfall, which may degrade soil pedological structure, making the soils considerably more susceptible to erosion. Erosion may also degrade soil structure by removing structured and fertile topsoil and plant propagules, breaking soil aggregates, and exposing more dispersive subsoils. Degrading soil structure may also reduce the quantity of good-quality topsoil available for reuse in site rehabilitation works.

Excavating, reshaping, transporting, stockpiling or windrowing, and dumping of spoil may also significantly mix the subsoil and topsoil profiles. This may reduce the soil’s capability to support vegetation communities and any agricultural or horticultural uses, thus reducing its land capability classification.

Earthworks may expose unoxidized acid sulfate soils to the atmosphere generating acid leachate and mobilizing metals, thereby affecting the chemical properties of the soil. Soil contamination may also occur due to accidental hydrocarbon or chemical spills, or leaks of reservoir fluids from flowline/trunklines or condensate from the onshore export pipeline. Soil contamination can degrade soil structure and reduce soil fertility, and may be toxic to soil-associated biota. Soil acidification due to disturbance of ASS soils may also corrode buried infrastructure made from concrete and steel.

Constructing the wellpads, pipe yards, flowline/trunklines and onshore export pipelines, roads, quarries, spoil sites, CPF, accommodation camp, Logistics Base, landfills and the Purari Airstrip extension will involve soil exposure, excavation and movement, and; therefore, has the potential to impact on soil structure and character.

Key risk areas for PASS are soils of Soil Complexes 2 and 3 on the alluvial flood plains, beach ridges, and plain in the lower Purari River delta, which experience frequent inundation (see Figure 7.5). The coastal soils of Soil Complex 4 are also considered likely to be PASS.

Key risk areas for accidental hydrocarbon and chemical spills are the CPF and Logistics Base where the largest volumes of fuels, oils and chemicals will be stored and handled; however, accidental spills and leaks, including leaks of reservoir fluids from flowline/trunklines or condensate leaks from the onshore export pipeline, may potentially occur in all areas of Project activities. Assessment of such incidental and small-scale spills or leaks is undertaken in Section 11.1.5.

11.1.3.3 Embedded Design Controls

The following embedded design controls will address impacts to the degradation of soil capacity resulting from accidental hydrocarbon or chemical release. These controls are also relevant to other sections throughout this chapter that deal with accidental or planned releases of contaminants such as wastewater, chemicals or hydrocarbons:

- Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as:
  - Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan.
  - Building infrastructure on impervious surfaces where required
  - Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials.
  - Installing interceptor pits or similar to collect contaminated surface water runoff and treat where required.
  - Installing tanks above ground with impermeable liners and bunds around tanks.
  - Regularly inspect and maintain the containers, storage and transfer infrastructure to prevent/control spills or leaks.
  - Installing readily accessible spill kits and training staff in their use.
  - Appropriately treating and disposing of any accidentally contaminated soils [ED003].
- The drilling will be performed using water-based mud [ED004].
- The landfill will be designed to comply with TOTAL's general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices [ED005].
- Minimize chemical use and select chemicals considering the following criteria:
  - Lowest toxicity, lowest bioaccumulation potential and highest biodegradation;
  - Chemicals subject to bans or phase-outs [ED006].
- Use low-pressure detection alarms to detect pipeline leaks [ED007].
- Use fiber optic cable laid in the same trench to monitor pipelines. This cable will detect intrusions and ground movements [ED008].

- Locate valve stations along the onshore pipeline route to isolate pipeline sections if a leak occurs [ED009].
- The gathering and reinjection system, wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational controls (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring) [ED011].
- Hydrotesting will be undertaken to confirm weld integrity [ED012].
- The CPF will have an open drain system to manage rainwater; the system will have three separate networks:
  - OD1 = permanently hydrocarbon-contaminated drains.
  - OD2 = accidentally hydrocarbon-contaminated drains.
  - OD3 = hydrocarbon-free drains.

  Water from each system will be treated separately and discharged to the environment according to applicable limits [ED015].
- All OD1 waters will undergo water treatment by a hydrocarbon/water separation system prior to discharge to the Purari River according to applicable standards. All OD2 waters and water from primary treatment will be sent to an observation basin and treated by the hydrocarbon/water separation system prior to release if required. The clean OD2 water will be discharged to the Purari River. Non-contaminated stormwater (OD3) will be disposed of by natural percolation and evaporation [ED016].
- All OD1 water from wellpads will be collected in a dedicated closed tank and transported to the CPF for treatment prior to being discharged [ED017].
- The produced water generated at the CPF will be injected back into the reservoir. Produced water will be retained in a tank with a capacity to contain five days of water production, as a backup if injection is unavailable [ED018].
- All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired [ED019].
- Rainwater infiltration into hazardous materials storage areas will be prevented [ED020].
- Requirements for hazardous material transfer, overfill protection, and alarms will be implemented, e.g.,
  - Using dedicated fittings, pipes, and hoses specific to materials in tanks.
  - Providing secondary containment, drip trays, etc. at connection points or other possible overflow points.
  - Using dripless hose connections for vehicle tank and fixed connections with storage tanks.
  - Providing automatic fill shutoff valves on storage tanks to prevent overfilling.
  - Using piping connections with automatic overfill protection (float valve).
  - Fitting tanks with high-level alarms with both audible and visible annunciation [ED021].
- Hydrotest water discharges will be managed according to applicable requirements [ED040].

Impacts associated with increased soil erosion causing potential declines in water quality and harm to aquatic fauna due to increased turbidity and in-stream sedimentation are considered in Sections 11.3, 11.4 and 11.5.

11.1.3.4 Summary of Potential Impacts to Landforms and Soils

Potential impacts to landforms and soils due to the Project that have been considered in the impact assessment are as follows:

- Destabilized landforms causing increased incidence of landslides or mass movements.
- Degraded soil capacity due to impacts on soil structure and developmental status, fertility or disturbance of soil profiles.
- Degraded soil capacity due to accidental soil contamination or adverse chemical properties, such as presence of PASS.

The consideration of spills or leaks is related to releases that are accidental (but controllable), as part of construction, operation and decommissioning of large projects. Potential impacts of large-scale accidental spills associated with major natural hazards and unplanned events are considered in Chapter 18.

11.1.4 Proposed Mitigation and Management Measures

Table 11.5 describes mitigation and management measures to further reduce impacts to landforms and soils.

Table 11.5 – Landforms and Soils Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Destabilized landforms causing increased incidence of landslides or mass movements.	♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Cut trees where practicable to retain the rootstock and maintain soil stability [EM003]. ♦ Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g., drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipators, sediment control ponds, mulch berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated [EM004]. ♦ Areas of higher risk of landslides e.g., steep gradients, previously disturbed land, likely to occur from the works, or likely to be exacerbated by the works, will be stabilized to reduce the landslide risk. [EM006]. ♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape. E.g., – Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g. rip the substrate, replace topsoil, apply mulch – Rehabilitate Pandanus habitats, e.g. recreate mounds, re-instate the intertidal surface between Pandanus mounds – Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion.	Soil Management Plan; Site Restoration and Rehabilitation Plan

Table 11.5 – Landforms and Soils Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Destabilized landforms causing increased incidence of landslides or mass movements (cont'd).	– Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration. – Use native vegetation to revegetate sites when active rehabilitation measures are required. [EM029]	See above.
Degraded soil capacity due to impacts on soil structure and developmental status, fertility or disturbance of soil profiles.	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Stabilize spoil stockpiles and areas of ground disturbance as soon as practicable after initial disturbance using, e.g., mulched vegetation, aggregates and soil binders [EM005]. ♦ Areas of higher risk of landslides e.g., steep gradients, previously disturbed land, likely to occur from the works, or likely to be exacerbated by the works, will be stabilized to reduce the landslide risk. [EM006]. ♦ Where possible, separate and stockpile cleared topsoil (with the inherent seed bank and any coarse woody debris) to use for future rehabilitation [EM036].	Soil Management Plan; Site Restoration and Rehabilitation Plan
Degraded soil capacity due to adverse chemical properties, caused by oxidation of PASS disturbed during earthworks.	♦ Avoid disturbing acid sulfate soils, potentially in Soil Complex 4 coastal soils, and Soil Complex 2 and 3 on alluvial flood plains, beach ridge and plains in the lower Purari River delta, wherever possible, otherwise handle, store, treat, manage and dispose of acid sulfate soils according to good practice guidelines [EM007].	Soil Management Plan
Degraded soil capacity due to soil contamination from accidental hydrocarbon or chemical spills or leaks.	♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site contingency plans, that will consider fire management measures – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018].	Emergency Response Plan

11.1.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to landform and soils subject to the embedded design controls in Section 11.1.3 and the successful implementation of the proposed mitigation and management measures in Section 11.1.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

11.1.5.1 Landform Destabilization

The potential for Project activities to destabilize landforms and cause landslides is assessed in the following sections for the various landform types in the PAOI.

Ridge and Ravine Landform

The ridge and ravine landform in PRL-15 is highly susceptible to change from construction activities, as evidenced by the existing scars from slumps, landslides and gullying. Several faults and fractures are expressed in the topography by linear scarps.

Slopes developed on coarse-grained sedimentary rocks of the ridge and ravine landform, such as sandstone, are regular, infrequently dissected and have few, large deep-seated slumps. Although apparently reasonably stable, they are highly sensitive to change because of their steep slopes. The slopes tend to have fewer drainage lines dissecting them, and instability events tend to be less frequent than on slopes on fine-grained sedimentary rocks but larger in scale and impact. Slopes on fine-grained sedimentary rocks, such as mudstone and siltstone, tend to be more irregular, are frequently dissected and have numerous, small deep-seated slumps. The slopes tend to have more drainage lines dissecting them, and instability events tend to be more frequent than on slopes on course-grained sedimentary rocks but smaller in scale and impact.

The ridge and ravine landform in PRL-15 includes areas that are very steep, highly unstable and susceptible to erosion. Given that the Project design has avoided locating infrastructure in areas with the greatest risk of destabilization, the sensitivity is categorized as ***High*** (see Table 11.1).

The extent of reducing impact magnitude depends on the size of the infrastructure site (spatial extent), the duration and nature of the activities to construct the infrastructure, and the duration of the impact; hence, magnitude of impact will vary for each Project component constructed on the ridge and ravine landform.

Mitigation will include stabilization of areas with a higher risk of landslides and implementation of erosion and sediment control measures, thus reducing the potential for landslide or mass movement events to occur due to Project activities; and will reduce the scale of impact of any such events.

The magnitude of impact associated with the various Project components located on the ridge and ravine landform, assuming successful implementation of mitigation measures, is assessed to range from ***Low*** to ***Minimal*** during construction and operations, based on the categories described in Table 11.2. The roads, flowline/trunklines and spoil sites have a higher destabilization risk due to their greater geographical extent. Potential impacts to landforms from any landslides are expected to be limited to within 200 m of the Project activity or component causing the impact and be short-term with active stabilization, and with moderate potential for recovery to the predisturbance condition. Section 11.1.5.3 provides the individual ranking for each Project component. Considering the high sensitivity of the terrain unit and the ***Low*** to ***Minimal*** magnitude of impact, the residual impact significance is ***Minor*** to ***Moderate***. Decommissioning would involve leaving infrastructure sites in a stable condition, with any problematic locations identified during operations; hence impacts during decommissioning are expected to be similar to, or less than, those during the construction and operations phases.

Composite Meander and Levee Alluvial Landform

This river plain landform is quite stable in regard to landslides or mass movements due to its gently undulating to flat topography. The landform is moderately resilient, with soil recovering relatively quickly from disturbance. Its sensitivity to destabilization is therefore categorized to be ***Medium*** in accordance with Table 11.1.

Most Project components and construction activities will occur on this terrain type, as discussed in Section 11.1.3.1 and shown in Table 11.4. Project design to locate infrastructure on this terrain type rather than ridge and ravine terrain has minimized the risk of impacts from landslides.

Considering other mitigation measures to be implemented, as described in Section 11.1.4, impacts of the various Project components and activities on landform stability during construction and operations are expected to be minimal. They would be located near the Project disturbance (within 50 m), require minimal stabilization and be short-term. The magnitude of impact is therefore assessed to be ***Minimal***. This provides an overall impact significance rating of ***Negligible*** for all Project components on this landform.

Impacts during decommissioning are expected to be similar, or lesser, to the construction and operations phases.

Recent Littoral Landform Stability

The recent littoral landform of beach ridge complexes and beach plains adjacent to the coast is stable in regard to landslides or mass movements due to the flat terrain but would be susceptible to ground movement and erosion adjacent to excavations due to the sandy profile. Its sensitivity to destabilization is therefore categorized to be ***Medium***.

The potential for ground movements would be restricted to trench walls collapsing during pipeline installation in sandy soils; however, this would be avoided by using appropriate land stabilization techniques (e.g., sheet piling) in areas susceptible to collapse. The magnitude of impacts due to such ground movements would be very localized (e.g. less than 50 m), require minimal stabilization and be short-term. The magnitude of impact is therefore assessed to be ***Minimal*** during construction (and insignificant during operations and post-closure). The overall impact significance rating is ***Negligible***.

11.1.5.2 Degradation of Soil Capacity

The Project may potentially degrade soil capacity due to:

- Impacts on soil structure and developmental status, fertility or disturbance of soil profiles.
- Development of adverse chemical properties due to acid sulfate soil disturbance or accidental soil contamination.

The potential for Project activities to have such impacts is assessed in the following sections.

Soil Structure and Developmental Status

Project components that will involve soil exposure, excavation and movement and; therefore, have the potential to degrade soil structure and developmental status include wellpads, roads, flowline/trunklines, spoil disposal sites, CPF, operations accommodation camp, Logistics Base, pipe yards and construction accommodation camps, quarries, landfills, the Purari Airstrip extension and the onshore export pipeline.

Soil units in the Project area are poorly formed soils with limited soil pedological development and fertility (as described in Section 11.1.1). This poor development makes them more susceptible to erosion. Given that the soils are minimally developed and have only moderate fertility, they would be expected to recover slowly from any disturbance if topsoil is not appropriately managed. The sensitivity of soils to change in soil capacity in the area of all Project activities is therefore categorized to be ***Medium***.

The most significant and largest areas of exposed soils where topsoil management will be important to achieve rehabilitation and vegetation growth are the flowline/trunklines, export pipeline route and spoil disposal sites. Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice where required, until the area has been effectively stabilized and/or rehabilitated. Spoil stockpiles and areas of ground disturbance will be stabilized as soon as practicable after disturbance.

The disturbance of soil profiles may degrade soil structure with moderate potential for recovery to the pre-disturbance condition, and some stabilization may be required in the short term. Impacts to soil structure would; however, be confined to the direct area of ground disturbance or spoil placement. The magnitude of impact is; therefore, categorized to be ***Low*** for flowline/trunklines, the export pipeline route and spoil sites. The magnitude of impact for other Project components is ***Negligible***, given their much smaller spatial extent. The final end use and site rehabilitation of these areas will be considered in decommissioning planning.

This provides an overall impact significance rating of ***Minor*** for flowline/trunklines, export pipeline route and spoil sites and ***Negligible*** for other Project components.

Development of Adverse Chemical Properties

Project activities may create adverse chemical properties in soils due to:

- Generation of acidic leachate and metal mobilization due to exposing acid sulfate soils to the atmosphere.
- Soil contamination due to accidental hydrocarbon or chemical spills or leaks.

Acid Sulfate Soils

The soil complexes in the area of Project components are shown in Figure 11.1. The PAOI contains several soil units with acid sulfate soils potentially present, including Soil Complexes 2, 3 and 4 (as described in Section 7.2.5.1). Such soils are prone to releasing acid leachate if disturbed or drained and exposed to the atmosphere. Sites, which laboratory tests indicated have potential acid sulfate soils (PASS), were located on the alluvial flood plains and beach ridges. Soils on the plains in the lower Purari River delta, which experience frequent inundation, are also highly likely to be PASS given their formation in decomposed plant matter and therefore high sulfide content, their low position in the landscape and their near continuous saturation. These soils have not yet been sampled due to access and safety constraints, as these soils are largely underwater, and the potential for crocodiles to be present, respectively.

The sensitivity of the various soil complexes considering adverse properties due to the presence of PASS is categorized as follows, based on ratings described in Table 11.1:

- Soil Complex 1 – ***Minimal***.
- Soil Complex 2 – ***Medium***.
- Soil Complex 3 – ***Medium***.
- Soil Complex 4 – ***Medium***.

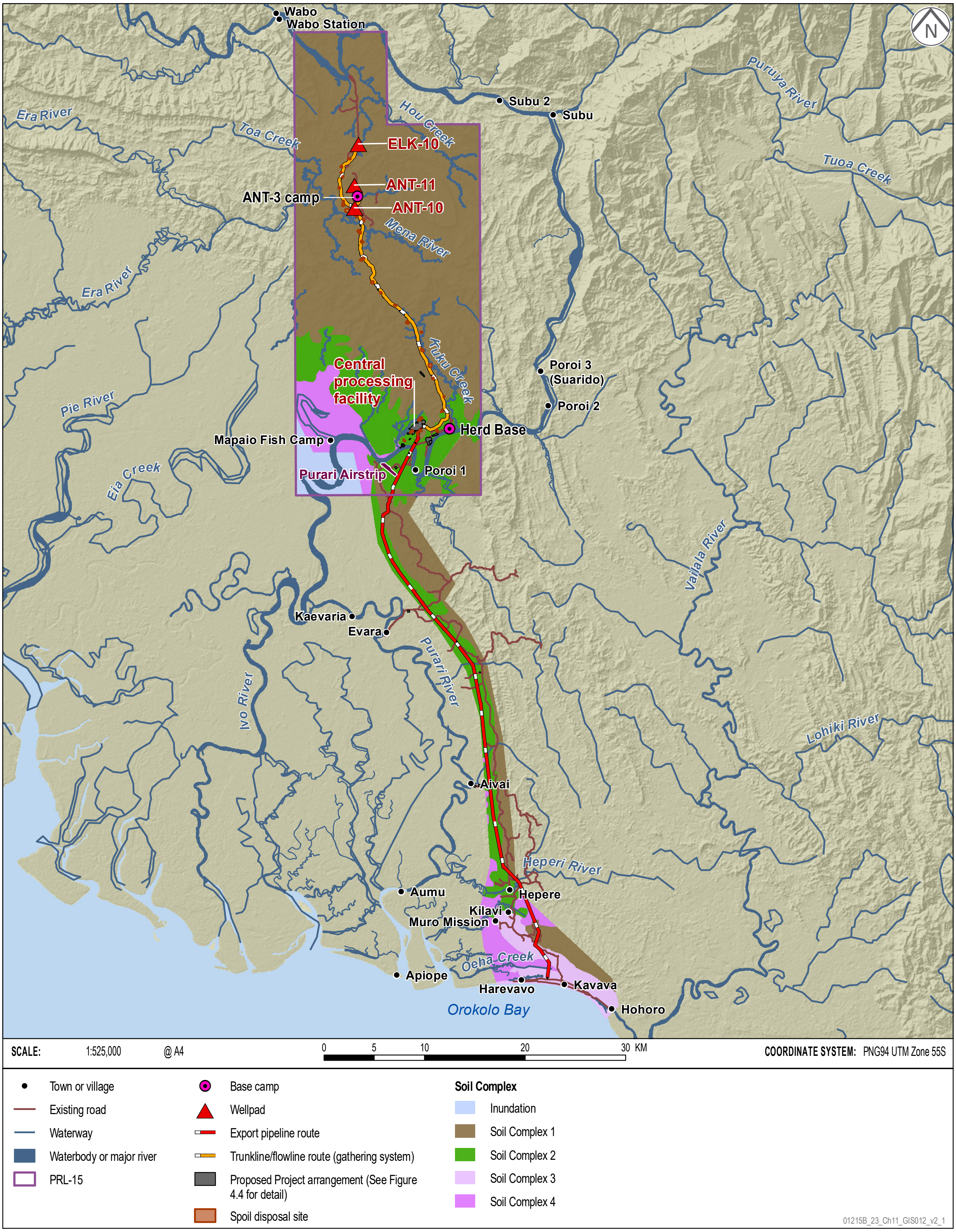
ASS/PASS will be mapped during preconstruction surveys. Disturbance to soils identified to be ASS/PASS will be avoided where practicable. Where disturbance of ASS is unavoidable, soils will be handled, stored, treated, managed and disposed of according to good practice guidelines, to mitigate any impacts.

With mitigation, minimal soil degradation is expected to occur due to acid generation and mobilization of metals. Any impacts to soils would be localized (within 50 m of the Project activity or component), and impacts would be short term with appropriate treatment of identified PASS.

SOIL COMPLEXES IN PRL-15 AND ALONG THE EXPORT PIPELINE ROUTE

Papua LNG Project | Environmental Impact Statement

FIGURE 11.1



Source: Figure theme data from BMT, 2019.

The magnitude of impact to soil capacity is therefore categorized to be ***Minimal***. This provides an overall significance rating of ***Negligible*** for activities in all soil complexes.

Soil Contamination

Accidental hydrocarbon or chemical spills or leaks may potentially occur at any area of Project activities within the PAOI where these are used or handled. Leaks of reservoir fluids from flowline/trunklines or condensate from the onshore export pipeline may also potentially occur.

Existing metal concentrations are well below health-based screening levels for contaminants (as described in Section 7.2.5); however, some metal concentrations exceed ecological soil screening levels. There is no evidence of hydrocarbon contamination of soil at any of the sampling sites. The soil within the PAOI is therefore categorized to have ***Medium*** sensitivity in accordance with Table 11.1.

Standard good industry practices will be adopted to prevent and protect against ground pollution due to accidental hydrocarbon and chemical spills or leaks during construction, operation and decommissioning activities, and to remediate where it occurs (as described in Sections 11.1.3 and 11.1.4). Hydrotesting, monitoring and maintenance of flowline/trunklines and the onshore export pipelines will either avoid or limit the occurrence and extent of any reservoir fluid or condensate leaks.

With the implementation of these measures, impacts to soil capacity would be expected to have moderate potential to recovery to the pre-disturbance condition and be limited to within 200 m of the Project component or activity causing the impact. The magnitude of impact for Project components in all locations is therefore categorized to be ***Low***, resulting in a significance rating of ***Minor***.

11.1.6 Summary of Assessment of Residual Impact Significance

Table 11.6 provides a summary of the assessment of residual impacts to landform and soils, including when and where (in which Project phase and location) these impacts are expected to occur. The table should be read in conjunction with the specific mitigation measures provided in Table 11.5.

All residual impacts are assessed to be ***Negligible*** to ***Minor***, except for impacts described below which are assessed to have a ***Moderate*** residual impact:

- Landslide or mass movement due to landform destabilization from road, flowline/trunklines and spoil site construction in the ridge and ravine landform.

Table 11.6 – Summary of Assessment of Residual Impact Significance for Landforms and Soils

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Land stability	Earthworks	Destabilization causing landslide/mass movement.	***Ridge and Ravine Landform***		♦ EM002 ♦ EM003 ♦ EM004 ♦ EM006 ♦ EM029		
			Wellpads	C, O, D		High/Minimal	Minor
			Roads and flowline/trunklines	C, O, D		High/Low	Moderate
			Spoil disposal sites	C, O, D		High/Low	Moderate
			Quarry	C, O, D		High/Minimal	Minor
			Composite Meander and Levee Alluvial Landform				
			Roads and flowline/trunklines	C, O, D		Medium/Minimal	Negligible
			Pipe yards and fly camps	C, O, D		Medium/Minimal	Negligible
			Spoil disposal sites	C, O, D		Medium/Minimal	Negligible
			CPF, Logistics Base and accommodation camp	C, O, D		Medium/Minimal	Negligible
			Quarries and landfills	C, O, D		Medium/Minimal	Negligible
			Airstrip extension	C, O, D		Medium/Minimal	Negligible
			Export pipelines	C, O, D		Medium/Minimal	Negligible
			Export pipeline route spoil disposal sites	C, O, D		Medium/Minimal	Negligible

Table 11.6 – Summary of Assessment of Residual Impact Significance for Landforms and Soils (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Land stability (cont'd)	Earthworks (cont'd)	Destabilization causing landslide/mass movement (cont'd)	***Recent Littoral Landform***		See above.		
			Export pipelines	C, O, D		Medium/Minimal	Negligible
Soil capacity	Earthworks	Adverse impacts on soil structure and developmental status, fertility or disturbance of soil profiles.	Flowline/trunklines, export pipelines and spoil disposal sites.	C	♦ EM001 ♦ EM002 ♦ EM005 ♦ EM006 ♦ EM036	Medium/Low	Minor
			Other Project components.	C, O		Medium/Minimal	Negligible
	Earthworks	Adverse effects on chemical properties, due to oxidation of PASS.	Soil Complex 1 (wellpads, roads, flowlines/ trunkline, spoil disposal sites, quarry).	C	♦ EM007	Minimal/Minimal	Negligible
			Soil Complex 2 (roads, spoil disposal sites, quarries, landfills, CPF, Logistics Base, accommodation camp, pipe yards, fly camps, airstrip extension, export pipelines).	C		Medium/Minimal	Negligible

Table 11.6 – Summary of Assessment of Residual Impact Significance for Landforms and Soils (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Soil capacity (cont'd)	Earthworks (cont'd)	Adverse effects on chemical properties, due to oxidation of PASS (cont'd).	Soil Complex 3 (export pipelines).	C	♦ EM007	Medium/Minimal	Negligible
			Soil Complex 4 (export pipelines).	C		Medium/Minimal	Negligible
	Use of hazardous materials.	Adverse effects on chemical properties, due to soil contamination from accidental hydrocarbon or chemical spills or leaks.	PRL-15 and export pipeline route**,** (all land-based Project activities and components).	C, O, D	♦ EM018	Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure

11.2 Groundwater

11.2.1 Context

Shallow, unconfined, perched groundwater occurs as localized bodies in surficial material in the area of the wellpads in the northern part of PRL-15. This perched groundwater is considered likely to exist within 10 m below ground surface (bgl) where present. The surficial material in this area is thought to have a high capacity to contain and transmit water, releasing it slowly from springs and seeps, and to act as a buffer that sustains stream baseflow for some time after rain. These shallow groundwater systems are thought to be localized (e.g., confined to single valleys) with recharge and discharge areas near each other.

Information regarding deeper groundwater in PRL-15 is limited; however, it is likely that permanent groundwater occurs in more extensive alluvial deposits in the valleys of major large streams (see Section 7.5). This groundwater is likely to be connected with surface water. The prevalence of low-permeability siltstones and mudstones is unlikely to support sufficient groundwater to classify aquifers as being present with the possible exception of sandstones in the Era Beds.

Small quantities of groundwater may occur in the geology of the gas resource target, the Kapau Limestone; however, exploration drilling to date has shown very little water is associated with gas and condensate. This geology is over 1,600 m deep, and the thickness of the low-permeability material overlying the hydrocarbon resource will effectively confine any water occurring in this unit.

Local, shallow perched groundwater occurs in superficial materials in the areas of the CPF and Logistics Base, as evidenced by seeps and spring-type erosion. Again, recharge and discharge areas for these minor systems are likely to be close together. Permanent shallow groundwater is also known to be present in alluvial sediments close to the confluence of Kuku Creek and the Purari River, where abstraction bores up to 50 m deep target groundwater from the alluvial material to supply water for use at Herd Base (see Figure 7.15). This alluvial material is thought to be connected to the surface waters of Kuku Creek and the Purari River. The depth to water-bearing material (i.e., greater than 15 m) and overlying low-permeability fine silts and clay materials helps protect this resource from potentially contaminating surface activities.

Weathered material overlying competent geology is likely to support perched groundwater following rains along the export pipeline route. Evidence of spring erosion is seen in this area. No information on deeper groundwater is known for this area; however, mudstones and siltstones that are not thought to represent aquifer materials dominate the geology of the ridgelines (Orubadi Formation). The groundwater present is unlikely to have been exposed to widespread contamination; although this area does include commercial logging camps and associated tracks that may be potential contamination sources.

The coastal and inland communities along the export pipeline route use shallow groundwater extensively (Plate 11.3). Groundwater is predominantly sourced from shallow wells and used for washing; but during dry periods, groundwater is relied on as a drinking water resource. The quality of the water encountered meets the relevant drinking water standards with respect to chemical properties. Widespread microbiological contamination is evident; however, and is likely to be due to domestic animals (e.g., pigs and dogs) and wildlife having open access to the wells and the closeness of the wells to latrines at some locations. The groundwater resource targeted by villagers is generally less than 1 m bgl; therefore, it is susceptible to contamination from surface activities and processes (Plate 11.4).

Plate 11.3 – Harevavo Coastal Village

Photo: Iain Woxvold.

Plate 11.4 – Groundwater Well at Harevavo

Photo: John Leyland.

11.2.2 Discipline-specific Impact Assessment Method

The significance assessment method described in Chapter 3 was adopted to qualitatively assess the potential impact on groundwater from Project construction and operation. This method considers the magnitude of impact on an environmental value and the sensitivity of that value.

Magnitude of impact is defined by the impact’s severity, and spatial and temporal extents. Table 11.7 defines the categories adopted for assessment of the magnitude of Project impacts on groundwater. Assessment of the magnitude of impact is undertaken assuming proposed mitigation measures have been successfully implemented, i.e., provides a residual impact assessment.

Table 11.7 – Groundwater Magnitude of Impact Criteria

Category	Description
Very High	♦ Impact likely to be severe on the groundwater quality or quantity at a scale comparable to the extent of the aquifer and over a long period of time (decades). ♦ Impact has the potential to substantially exceed water quality guidelines (where exceedances do not already exist). ♦ Impact is likely to cause the loss of water supply to all existing domestic users of the aquifer or other environmental values.
High	♦ Impact is likely to be major on the groundwater quality or quantity over the area of local use from that aquifer and over a period of 5 to 10 years. ♦ Impact has the potential to exceed water quality guidelines (where exceedances do not already exist). ♦ Impact is likely to significantly constrain the water supply to a large proportion of existing domestic users of the aquifer or other environmental values.
Medium	♦ Impact is likely to be moderate on the groundwater quality or quantity over the area of local use from that aquifer and for 1 to 5 years. ♦ Impact has the potential to cause only minor exceedance of water quality guidelines (where exceedances do not already exist). ♦ Impact constrains the water supply to some existing domestic users of the aquifer or other environmental values.
Low	♦ Impact is likely to be low on the groundwater quality or quantity, at a scale less than the extent of local use from that aquifer and less than a year. ♦ Impact does not exceed water quality guidelines (where exceedances do not already exist). ♦ Impact does not constrain water supply to existing domestic users or environmental values.
Minimal	♦ Impact is unlikely to be detectable.

Sensitivity considers the susceptibility of an environmental resource or receptor to change and its intrinsic importance considering factors such as:

- Capacity of the resource or receptor to adapt to change without adverse effects on the value's inherent attributes, i.e., its resilience.
- Rarity or uniqueness of the resource or receptor.
- Importance of the resource to the environment, e.g., support of groundwater-dependent ecosystems or stream baseflows.
- Domestic uses of the resource, e.g., for potable water supply, washing, bathing or food production.
- Importance to local communities, and/or the resource or receptor's iconic or symbolic importance to cultural value systems.

Table 11.8 defines the categories for assessment of sensitivity adopted in the groundwater assessment.

Table 11.8 – Groundwater Sensitivity of Resource or Receptor

Category	Description
Very High	♦ Surficial or shallow aquifers where water is used for local domestic supply (e.g., wells) or where water supports springs and provides the only available water supply for potable use.
High	♦ Surficial or shallow aquifers where water is used for local domestic purposes such as washing and bathing but is not the only water available for potable use. ♦ Areas adjacent to creeks and rivers where shallow aquifers rise to interact with surface waters and potentially therefore provide stream baseflow or support to groundwater-dependent ecosystems.
Medium	♦ Deeper aquifers that are less exposed to the surface and therefore are likely not used for local domestic purposes. ♦ Areas of lowland forest and swamplands that may rely on groundwater during the dry season (i.e., temporal groundwater-dependent ecosystems).
Low	♦ Environment where aquifers are deeper and therefore are likely not used for local domestic purposes.
Minimal	♦ Environment where aquifers are deep and confined and are not used for local domestic purposes or by groundwater-dependent ecosystems.

Significance of the impact from the Project's activities is determined by a matrix combining the magnitude of impact category on the groundwater resource or receptors with the sensitivity category of the groundwater resource or receptors. Table 11.9 presents the matrix used to establish the significance of Project impacts on groundwater resource/receptors.

Table 11.9 – Groundwater Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Resource/Receptor				
	Very High	**High**	**Medium**	**Low**	**Minimal**
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.2.3 Identification of Potential Impacts

Potential impacts to groundwater can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g. flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of Project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

11.2.3.1 Overview

Potential Project impacts on groundwater are discussed and assessed based on the infrastructure that will be constructed and activities that will be undertaken during different Project phases. The assessment of potential impacts also considers whether the activities have the potential for direct or indirect effects on individual groundwater values.

Project construction and operation will involve activities that may influence groundwater, including well drilling and construction and operation of flowlines, trunkline, export pipelines, CPF, Logistics Base and other supporting infrastructure. These activities and Project components are described in the following sections with the potential impacting processes to groundwater summarized in Section 11.2.3.6.

11.2.3.2 Gas and Condensate Production Wells

Gas and condensate production for the Project involves developing nine wells on three wellpads. Further description of these wells and the drilling campaign is provided in Section 4.3 with the overall upstream Project layout shown in Figure 4.4.

Drilling will use drilling mud that will contain chemical additives. The mud acts as a lubricant to keep the drill bit cool and clean, lifts cuttings from the drill holes and controls well pressure to prevent well blowout. Water to make up the muds will be sourced from temporary dam structures on nearby watercourses (i.e., Hou and Boa creeks). Groundwater is not proposed to be used.

Well drilling has the potential to introduce drilling muds and cuttings, and reservoir fluids, into aquifers if they are present.

The following embedded design controls address these impacts:

- The drilling will be performed using water-based mud [ED004].
- Wells are to be cased and cemented to insulate and protect any aquifers [ED010].
- The gathering and reinjection system, wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational controls (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring) [ED011].

11.2.3.3 Gas and Condensate Transfer Systems

The key components of the Project’s gas and condensate transfer systems, as shown in Figures 4.4 and 4.6, include:

- The gas gathering systems for each wellpad.
- Flowlines and a trunkline that transport the reservoir fluids from the wellpads to the CPF.
- Export pipelines from the CPF.

Groundwater is not proposed to be used in the construction or operations of this infrastructure.

A water injection pipeline will also convey produced water separated from the condensate in the condensate stabilization process from the CPF back to the ANT-11 produced water injection well.

Horizontal directional drilling is to be used for the export pipelines crossing of the Purari River. Similar to drilling of the wells, drill cuttings and muds associated with horizontal directional drilling have the potential to enter and degrade groundwater if inappropriately managed.

The accidental loss of reservoir fluids or condensate from the pipelines, e.g., from pipe weld failure, corrosion or pipeline damage during operations, may degrade the groundwater quality of shallow groundwater systems.

The reservoir fluids will contain chemical constituents in the gaseous and liquid phases (refer to Sections 4.2.2 and 4.2.3); including methane, the primary resource and main constituent, ethane, propane, butane, pentane and hexane and traces of aromatic organic compounds that are considered to be impurities (e.g., benzene, toluene, ethylbenzene and xylenes). Other constituents include sulfur compounds (e.g., hydrogen sulfide), carbon dioxide, nitrogen, mercury and arsenic compounds. The organic compounds are volatile, i.e., evaporate very easily into the air under ambient temperatures and pressures, and; therefore, are not considered a significant risk for groundwater contamination in the event of an accidental release. Of the non-organic compounds, only mercury and arsenic are potential groundwater contaminants, as carbon dioxide, nitrogen and hydrogen sulfide are all gases at ambient temperatures and pressures.

The onshore export pipelines will be laid in a trench that is typically 2.3 m deep and 4.1 m wide (as described in Section 4.10.5.2). Groundwater is therefore likely to be intercepted during trenching at the southern end of the onshore export pipeline corridor. This groundwater occurs at shallow depths, and inland village communities access groundwater from springs and wells excavated to approximately 2 m deep (see Section 7.5.3.2). Villagers on the coast also use shallow groundwater wells, which target shallow freshwater approximately 1 m bgl in marine, sandy beach and back beach deposits. This freshwater is likely to lie on top of more saline water in the deeper sediments below. Village groundwater use is predominantly for washing, but during dry periods groundwater is relied on as a drinking water resource.

Given the groundwater resource is very shallow, it is susceptible to contamination from surface activities and processes. The pipeline trenching may also cause shallow groundwater to discharge into the trench, potentially causing drawdown of water in nearby village wells.

The embedded design controls outlined in Section 11.1.3.3 are also relevant to addressing these impacts.

11.2.3.4 Central Processing Facility

Reservoir gas and fluids will be processed at the CPF to separate the gas from the condensate and to remove carbon dioxide, water and hydrogen sulfide, before being transported along the export pipelines to the liquefied natural gas (LNG) facilities. Further description of these facilities is provided in Section 4.5.3, including the layout of the CPF (see Figure 4.5).

No reservoir water is expected to be produced during Project gas production; however, relatively small quantities (3,000 barrels, or 475,000 L, of water per day) of condensation water will be produced during condensate stabilization. This produced water containing residual hydrocarbons will be injected back into the Antelope reservoir at the ANT-11 wellpad and therefore has the potential to degrade groundwater quality.

During the first years of production, prior to the Elk reservoir being depleted, acid gas will be treated using a thermal oxidizer and flue gas desulfurization process. The treatment process involves incineration of acid gas in the thermal oxidizer to convert sulfur compounds, including hydrogen sulfide, into sulfur dioxide (SO_2). The sulfur dioxide will then be removed from the flue gas by a flue gas desulfurization process that uses liquid caustic soda (NaOH) that is injected directly into the flue gas stream converting sulfur dioxide to sulfite salts. This desulfurization process will be based on a pH control system, maintained between pH 6 and 7, which selectively removes sulfur dioxide from the flue gas but leaves carbon dioxide. The liquid effluent containing the dissolved sulfite salts will be injected into the ANT-11 well, along with produced water from the condensate stabilization unit. Injection will occur into the gas zone of the reservoir in the dolomite carbonate formation at a depth of approximately 1,500 m. The liquid effluent from the desulfurization process will have a near neutral pH of 6 to 7 and be at a temperature of about 80ºC prior to mixing with the produced water. It will mostly comprise water (90%), with the remaining volume comprising dissolved sodium bisulfite ($NaHSO_3$) (6.4%) and sodium sulfite (Na_2SO_3) (3.6%).

Acid gas containing hydrogen sulfide and carbon dioxide that is removed from the raw gas by the AGRU will be injected into the Elk reservoir once it is depleted. The compressed acid gas will be transported to the ELK-10 wellpad via the Elk trunkline where it will be injected into the reservoir using the ELK-10 well, which will be converted to a gas injection well.

Injection of the desulfurization process liquid effluent into the Antelope reservoir and acid gas into the Elk reservoir has the potential to degrade groundwater quality.

Other chemicals and hazardous materials directly associated with and stored at the CPF that have the potential to contaminate groundwater resources include the following:

- Chemicals necessary in the CPF and required for chemical injection at the wellpads, comprising hydrate inhibitor (i.e., monoethylene glycol and triethylene glycol), corrosion inhibitor, biocide, oxygen scavenger and sodium hydroxide.
- Diesel (420-m^3 capacity) for diverse small equipment.
- Foam for the firewater system (21-m^3 capacity).
- Rainwater runoff from areas that have a permanent risk of hydrocarbon contamination in the open drain system and observation basin (2,340-m^3 capacity).

Accidental hydrocarbon and chemical leaks and spills from the various stores during CPF construction and operation may enter the shallow groundwater system and degrade groundwater quality. The embedded design controls outlined in Section 11.1.3.3 are also relevant to addressing these impacts.

No groundwater will be extracted for use as process water at the CPF.

11.2.3.5 Supporting Infrastructure

A variety of logistics infrastructure is required for Project construction, operation and decommissioning, including:

- Herd Base.
- Logistics Base.
- Operations accommodation camp.
- Access tracks and roads.
- Purari Airstrip extension.
- Pipeline construction pipe yards.
- Temporary construction accommodation camps.
- Fuel storage and refueling areas.
- Quarries.
- General waste landfills.

Construction, operation and decommissioning of this supporting infrastructure will involve storing and distributing fuels, oils, and other hazardous materials, which have the potential to contaminate shallow groundwater resources if accidental spills or leaks occur. Spills can percolate through soils resulting in groundwater contamination. Leachate from the general waste landfills also represents another potential source for contaminants to enter groundwater. The embedded design controls outlined in Section 11.1.3.3 are also relevant to addressing these impacts.

11.2.3.6 Summary of Potential Impacts

The following potential impacts to groundwater have been identified from the described Project activities and components:

- Groundwater contamination due to:
  - Introduction of drilling muds and cuttings during the drilling of wells.
  - Injection of produced water and liquid effluent from the flue gas desulfurization process prior to depletion of the Elk reservoir into ANT-11 well.
  - Acid gas injection into the ELK-10 well, following depletion of the Elk reservoir.
  - Accidental leaks of reservoir fluids from flowline/trunklines or condensate from the export pipeline.
  - Accidental hydrocarbon or chemical spills or leaks at Project facilities and various areas of activities.
  - Leachates from the general waste landfills.[1]
- Reduction in the quantity of shallow groundwater at inland and coastal villages due to drawdown in the pipeline trench.

The consideration of spills or leaks is related to releases that are accidental (but controllable), as part of construction, operation and decommissioning of large projects. Potential impacts of large-scale accidental spills associated with major natural hazards and unplanned events are considered in Chapter 18.

11.2.4 Proposed Mitigation and Management Measures

There are no additional mitigation or management measures required as the embedded design controls outlined in Section 11.2.3 address all of the impacts.

11.2.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to groundwater subject to the embedded design controls in Sections 11.1.3 and 11.2.3. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

11.2.5.1 Contamination of Groundwater

Introduction of Drilling Muds and Cuttings

Localized bodies of shallow, unconfined, perched groundwater occur in surficial material in the north of PRL-15 (as described in Section 11.2.1); however, given that the wellpads are located on the top of ridgelines, shallow groundwater occurrence is expected to be limited in the drilling areas. The deeper formations consist of siltstones and mudstones that are unlikely to support the occurrence of deeper aquifers in the area. The sensitivity of groundwater in the area of the wellpads is therefore assessed to be ***Minimal***.

1 Sludge generated by the sewage treatment plant will be disposed of in the general waste landfill; hence, potential sewage contamination of groundwater is considered in the landfill assessment.

The wells will be cased and cemented, which will insulate and protect any aquifers that may be present from the introduction of drilling muds, and reservoir fluids and drilling will be undertaken using water-based mud that has low toxicity and is biodegradable.

Adverse impacts on groundwater quality due to the introduction of drilling muds and cuttings in the groundwater during construction are therefore likely to be low. The magnitude of impacts to groundwater is therefore considered to be ***Low***, providing an overall significance rating of ***Negligible***.

Injection of Produced Water and Desulfurization Process Liquid Effluent

The sensitivity of groundwater in the area of the wellpads is assessed to be ***Minimal***.

Liquid effluent from the flue gas desulfurization process will be injected into the Antelope reservoir along with the produced water, prior to the depleted Elk reservoir becoming available for acid gas injection. The desulfurization process liquid effluent will represent between 60 to 70% of the volume injected into the reservoir during these first, approximately four years, with the remaining 30 to 40% being the treated produced water.

The desulfurization process liquid effluent will have a near neutral pH of 6 to 7 and will mostly comprise water (90%), with the remaining volume comprising dissolved sodium bisulfite ($NaHSO_3$) (6.4%) and sodium sulfite (Na_2SO_3) (3.6%). The USEPA has verified these chemicals to be of low human health concern based on experimental and modeled data (USEPA, 2019). They are used as food additives to prevent oxidation and inhibit bacterial growth, and are also used in drinking water treatment to remove residual chlorine. Industry also use them as oxygen scavengers in piping systems to avoid corrosion problems.

The produced water and desulfurization process liquid effluent will be injected into the Antelope reservoir at a depth of over 1,600 m below ground level, and therefore will be contained well below the depth of any usable groundwater. The magnitude of impact on groundwater resources from the injection of produced water and desulfurization process liquid effluent into the Antelope reservoir is assessed to be ***Low*** and the residual risk is assessed to be ***Negligible***.

Injection of Acid Gas

Shallow groundwater is expected to be of limited occurrence in the area of the Elk wellpad. Deeper formations consist of siltstones and mudstones that are unlikely to support aquifers being present in the area, hence the sensitivity of groundwater in the area of the acid gas injection is assessed to be ***Minimal***.

Disposal of acid gas into a deep formation allows the economic production of sour gas while minimizing hydrogen sulfide (H_2S) and carbon dioxide (CO_2) atmospheric emissions (BCOGC, 2018). Suitable disposal formations for injection are generally greater than 1,000 m below ground level and have containment from contact with usable water or the environment. Disposal into a depleted hydrocarbon reservoir is recognized to be an effective method of containing acid gas, provided that rigorous design and maintenance is undertaken of the acid gas disposal well and due consideration is given to the condition of any other existing or abandoned wells that subsurface acid gas plumes may contact (BCOGC, 2018).

The acid gas will be injected into the depleted Elk reservoir at a depth of over 1,600 m below ground level and; therefore, will be contained well below the depth of any usable groundwater resource. The proposed embedded design controls will maintain wellbore integrity and contain acid gas within the reservoir such that migration to any shallow groundwater aquifers is not expected to occur. The magnitude of impacts due to acid gas contaminating groundwater and effecting environmental values is therefore considered to be ***Low***. The residual risk is; therefore ***Negligible***.

Accidental Leaks from Flowlines, Trunkline or Export Pipelines

Groundwater occurrence and use varies along the length of the pipeline corridors (as described in Section 11.2.1). The resource sensitivity; therefore, varies in the PAOI. The sensitivity in PRL-15 and along the export pipeline route is ***Minimal*** in elevated areas where aquifers are deep and are not used for local domestic purposes or by groundwater-dependent ecosystems. In lower elevation areas in PRL-15 and along the export pipeline route where shallow aquifers potentially support areas of lowland alluvial forest and freshwater swamp vegetation during dry periods (see Figures 7.20 and 7.21), and are not used for local domestic purposes, sensitivity of groundwater is assessed to be ***Medium***. The groundwater sensitivity is assessed to be ***High*** near the coast, where coastal and inland villages use shallow groundwater aquifers for local domestic potable supply, but they are not the sole source of potable water.

Consideration of pipeline leaks in this section relates to minor accidental releases of reservoir fluids or condensates, such as might occur from pipeline weld failures. Leaks can percolate through soils resulting in groundwater contamination, particularly in loose sandy soils and where the groundwater is shallow, such as along the coastline. Potential impacts of large-scale accidental releases associated with major natural hazards and unplanned events are considered in Chapter 18. Design and mitigation measures to minimize impacts from such an event to as low as reasonably practicable are also described in Chapter 18.

Hydrotesting will be undertaken following pipelaying to test pipeline weld integrity. Valve stations will isolate pipeline sections in the event of leaks. Low-pressure detection alarms will detect accidental leaks from pipelines during operations and fiber optic cables will detect any ground movements near the pipelines.

The closest villages from the onshore export pipeline route are Iuku and Mareke and are approximately 400 m from the pipeline, however there are houses approximately 350 m away from the pipeline route. Impacts on the groundwater quality in village wells are not expected given this distance, the highly volatile nature of the condensate and the embedded design controls proposed. Based on these considerations, the magnitude of impacts due to pipeline leaks contaminating groundwater used by villagers or supporting groundwater-dependent ecosystems is assessed to be ***Minimal***.

Considering the various groundwater sensitivities in the PAOI, the residual significance of impacts is:

- ***Negligible*** for elevated areas of PRL-15 and along the export pipeline route.
- ***Negligible*** for areas adjacent to creeks and rivers in PRL-15.
- ***Minor*** near coastal and inland villages along the export pipeline route.

Accidental Hydrocarbon and Chemical Spills or Leaks

As discussed, the sensitivity elevated areas of PRL-15 and along the export pipeline route is ***Minimal***, and ***Medium*** in areas adjacent to creeks and rivers in PRL-15. The groundwater sensitivity is categorized to be ***High*** near the coast.

Accidental hydrocarbon or chemical spills or leaks may potentially occur at any area of Project activity in the PAOI. Standard good industry practices will be adopted to prevent and protect against pollution due to accidental hydrocarbon and chemical spills or leaks during preparatory works, construction, operation and decommissioning activities, and to remediate where it occurs (as described in Section 11.2.3). These measures will limit the potential for contaminants to enter and contaminate groundwater. Impacts on groundwater quality are unlikely to be detectable, and the magnitude of impact is assessed to be ***Minimal***.

The residual significance of impacts is:

- ***Negligible*** for elevated areas of PRL-15 and along the export pipeline route.
- ***Negligible*** for areas adjacent to creeks and rivers in PRL-15.
- ***Minor*** near coastal and inland villages along the export pipeline route.

Leachates from the General Waste Landfill

The general waste landfill will be located between the CPF and the Purari River (see Figure 4.4). Local, shallow, perched groundwater occurs in alluvial sediments in this area and is considered likely to be connected with the surface water of nearby streams (as described in Section 11.2.1); however, the groundwater near the landfill provides an insignificant contribution to stream baseflow within the catchment and does not support groundwater-dependent ecosystems. There are also no local domestic uses of the groundwater in this area. The groundwater sensitivity in this area is therefore categorized to be ***Medium***.

The landfill will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices, whichever is the more stringent. Given the design standard applied, impacts on groundwater quality are expected to be low, not affecting domestic water uses. The magnitude of impact is therefore categorized to be ***Low***, providing an overall significance rating of ***Minor***.

11.2.5.2 Reduction in the Quantity of Coastal and Inland Shallow Groundwater

The groundwater sensitivity in the coastal area is categorized to be ***High***, given it is periodically used for domestic water supply but is not the sole source of potable water (as described in Section 11.2.1).

This fresh groundwater occurs approximately 1 m bgl in marine, sandy beach and back beach deposits, and is likely to lie on top of more saline water in the deeper sediments below. Communities further inland also access groundwater from springs and wells excavated to approximately 2 m deep.

The pipeline will be laid in a trench that is approximately 2.3 m deep; therefore, groundwater may be intercepted during trenching at the southern end of the onshore export pipeline route. The trenching may cause groundwater to discharge into the trench potentially causing drawdown of fresh groundwater in shallow aquifers. Such impacts would occur until the trench is backfilled and the natural groundwater flow re-establishes.

The closest receptors to the pipeline are houses located about 350 m away (as described in Section 11.2.5.1). It is unknown what the extent of groundwater drawdown will be; however, the water supply to some existing domestic users of the aquifer may be constrained hence the magnitude of impact is categorized as ***Medium***, giving an overall significance rating of ***Moderate***.

11.2.6 Summary of Residual Impacts to Groundwater

Table 11.10 provides a summary of the assessment of residual impacts to groundwater, including in which Project phase and location these impacts are expected to occur.

Most residual impacts to groundwater are assessed to be ***Negligible*** to ***Minor***, with the exception of the potential for a reduction in the shallow groundwater quantity at inland and coastal villages due to the groundwater drawdown into the pipeline trench, which is assessed as ***Moderate***.

Table 11.10 – Summary of Assessment of Residual Impact Significance for Groundwater

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Groundwater quality	Drilling of wells.	Groundwater contamination due to the introduction of drilling muds and cuttings.	PRL-15 (wellpads)	C	None	Minimal/Low	Negligible
	Produced water and desulfurization process liquid effluent disposal.	Groundwater contamination due to produced water and desulfurization process liquid effluent injection into ANT-11.	Antelope gasfield	O	None	Minimal/Low	Negligible
	Acid gas injection.	Groundwater contamination due to acid gas injection into ELK-10.	Elk gasfield	O	None	Minimal/Low	Negligible
	Pipeline operations.	Groundwater contamination due to accidental leaks of reservoir fluids from flowline/trunklines or condensate from the export pipeline.	Elevated areas of PRL-15 and the export pipeline route.	O	None	Minimal/ Minimal	Negligible
			Adjacent to creeks and rivers in PRL-15 and along the export pipeline route.	O		Medium/ Minimal	Negligible
			Coastal and inland villages along the export pipeline route.	O		High/Minimal	Minor

Table 11.10 – Summary of Assessment of Residual Impact Significance for Groundwater (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Groundwater quality (cont'd)	Use of hazardous materials.	Groundwater contamination from accidental hydrocarbon or chemical spills or leaks at Project facilities and various areas of activities.	Elevated areas of PRL-15 and the export pipeline route.	C, O	None	Minimal/ Minimal	Negligible
			Areas adjacent to creeks and rivers in PRL-15 and along the export pipeline route.	C, O		Medium/ Minimal	Negligible
			Coastal and inland villages along the export pipeline route.	C, O		High/Minimal	Minor
	Landfill construction and operation.	Groundwater contamination due to leachates from the general waste landfill.	PRL-15	C, O, D	None	Medium/Low	Minor
Groundwater quantity	Onshore pipeline trenching.	Reduction in the shallow groundwater quantity at inland and coastal villages due to the groundwater drawdown into the pipeline trench.	Coastal villages along the export pipeline route.	C	None	High/Medium	Moderate

C = Construction, O = Operations, D = Decommissioning and closure

11.3 Hydrology, Fluvial Geomorphology and Sediment Processes

11.3.1 Context

The Project is located in the lower Purari River catchment and the upper reaches of the Era River catchment (see Figure 7.6). The Purari River catchment is the third largest catchment in Papua New Guinea, extending from Mount Wilhelm to Orokolo Bay in the Gulf of Papua. The Purari River is a large meandering river in the PAOI below Hathor Gorge, with deep channels on the outside of bends and shallow depositional environments on the inside of bends (Plate 11.5). The river splits into several distributaries and forms a delta, eventually discharging into the Gulf of Papua. Shallow bars are formed across the mouths of most distributaries due to the high sediment loads in the river and the processes operating at the delta.

Plate 11.5 – Purari River

Photo: Bruno de Vals.

The Aure River is the primary tributary of the Purari River downstream of Hathor Gorge. The tributary streams in PRL-15 provide a negligible contribution to the total annual flow of the Purari River. The Purari River has characteristically low interannual flow variability; however, at daily timescales river levels can rapid change in response to rainfall.

The Purari River lower catchment is prone to flooding and consists of a large floodplain. High rainfall occurs throughout the year, and flood events can occur in any month; however, there are seasonal differences in rainfall and associated flow patterns. The Era River experiences more frequent flood events and higher flow during the southeast winds season (May to October). The Purari River also has more frequent flooding during the southeast trade winds season but can also experience low flows during this season when rainfall in the upper catchment is low.

Table 11.11 presents the flow rates for several waterways in the PAOI. These are based on stream flow assessments associated with catchment modeling described in Section 7.3.2.3.

Table 11.11 – Mean Daily Baseflow for Selected PAOI Waterways

Waterway	Measurement Location	Catchment	Mean Daily Flow (ML/day)	Mean Annual Flow (ML/a)
Purari River	Near Wabo	Purari	17,500	6,325,430
Hou Creek	Confluence with Purari River	Purari	102	36,791
Kuku Creek	Confluence with Purari River	Purari	58	20,929
Purari River	Above Purari, Ivo-Urika and Wame-Varoi distributary rivers	Purari	22,400	8,106,615
Era River	Confluence with Toa Creek	Era	40	14,389
Boa Creek	Confluence with Mena River	Era	133	48,076

The soils of the Purari River catchment are highly erodible which, combined with high year-round rainfall, results in large sediment loads entering the catchment’s waterways. Up to 80% of the sediment load estimated for the Purari River downstream of PRL-15 is derived from catchment areas upstream of PRL-15. Approximately 20% is derived from the Aure River and approximately 0.2% is derived from the tributaries in PRL-15 (see Section 7.3).

The Purari River has higher turbidity than the tributary streams in PRL-15. Turbidity in tributary streams is both spatially and temporally variable. It is possible that commercial logging that has occurred south of PRL-15 (see Section 7.7.5.3) has degraded local waterways, especially from sediment runoff from cleared areas. Degradation in PRL-15 is more limited at present, without a history of extensive logging or other broad-scale disturbance activities.

11.3.2 Discipline-specific Impact Assessment Method

11.3.2.1 Impact Assessment Approach

The significance assessment method described in Chapter 3 was used to characterize impacts relevant to hydrology, fluvial geomorphology and sediment processes. Tables 11.12 to 11.15 describe the magnitude and sensitivity matrices used. Magnitude is assessed considering combinations of (1) geographic extent and (2) the higher of severity and duration.

Table 11.12 – Impact Magnitude Descriptors Relevant to Hydrology, Fluvial Geomorphology and Sediment Processes

<table>
<tr><th colspan="2" rowspan="2">Geographic Extent of Impact*</th><th colspan="3">Severity and Duration of Impact</th></tr>
<tr><th colspan="2">Severity</th><th>Duration</th></tr>
<tr><td>5</td><td>Impact to any environmental feature that extends significantly beyond the subregion (close to regional) scale</td><td>5</td><td>Extreme impact to hydrology, fluvial geomorphology or sediment transport such that:
♦ Intensity, frequency and duration of the impact is well outside the range of natural variability; or
♦ One or more environmental values (social and biodiversity) are no longer supported.</td><td>Impact lasts >30 years.</td></tr>
<tr><td>4</td><td>Impact to any environmental feature that extends beyond the subregion (but not close to regional) scale</td><td>4</td><td>Severe impact to hydrology, fluvial geomorphology or sediment transport such that:
♦ Intensity, frequency and duration of the impact is slightly outside the range of natural variability; or
♦ One or more environmental values (social and biodiversity) are adversely affected but are supported in a highly modified condition.</td><td>Impact lasts 5 to 30 years.</td></tr>
</table>

Table 11.12 – Impact Magnitude Descriptors Relevant to Hydrology, Fluvial Geomorphology and Sediment Processes (cont'd)

Geographic Extent of Impact*		Severity and Duration of Impact		
		Severity		Duration
3	Impact to any environmental feature that extends beyond the *localized* area but does not extend beyond the *subregion*	3	Moderate impact to hydrology, fluvial geomorphology or sediment transport such that: ♦ Intensity, frequency and duration of the impact is within the range of natural variability, similar to levels experienced during extreme events such as major landslides, extreme droughts, severe storms or tropical cyclones; or ♦ One or more environmental values (i.e., social and biodiversity) are adversely affected but are still supported in a slightly to moderately modified condition.	Impact lasts <5 years.
2	Impact to any environmental feature in a *localized* area	2	Minor impact to hydrology, fluvial geomorphology or sediment transport such that: ♦ Intensity, frequency and duration of the impact is within the upper range of natural variability but below levels experienced during extreme events such as major landslides, extreme droughts, severe storms or tropical cyclones; and ♦ All environmental values (i.e., social and biodiversity) are maintained.	Impact lasts <1 year.
1	Impact to any environmental feature in a *highly localized* area	1	Very minor to no impact to hydrology, fluvial geomorphology or sediment transport such that: ♦ Intensity, frequency and duration of the impact is within the average range of natural variability; and ♦ All environmental values (i.e., social and biodiversity) are maintained.	Impact lasts days to weeks.

**Region* = Area greater than 15,000 km^2 (25% of the Kikori-Purari river basin).
Subregion = Area more than 2 km from the Project footprint but less than 15,000 km^2.
Localized = Area up to 2 km from the Project footprint.
Highly localized = Area up to 0.5 km from the Project footprint.

Table 11.13 – Impact Magnitude Matrix Relevant to Hydrology, Fluvial Geomorphology and Sediment Processes

Severity/ Duration	Geographic Extent				
	1	**2**	**3**	**4**	**5**
1	Minimal	Low	Medium	Medium	High
2	Low	Low	Medium	High	High
3	Low	Medium	High	Very high	Very high
4	Medium	Medium	High	Very high	Very high
5	Medium	Medium	Very high	Very high	Very high

Table 11.14 – Hydrology, Fluvial Geomorphology and Sediment Processes Sensitivity of Resource or Receptor

Rating	Descriptor
Very High	♦ Environment is in a natural condition with no evidence of modification. ♦ Environment supports physical properties or processes that are considered rare or exceptional at the regional scale.
High	♦ Environment is in a near-natural condition with minimal human-induced modification. ♦ Environment supports physical properties that are considered rare or exceptional at the local scale but are well represented regionally.
Medium	♦ Environment is in a near-natural condition with some human-induced modification. ♦ Environment supports physical properties or processes that are well represented at the local scale and experience low inter-decadal variability from extreme events (e.g., cyclones and floods).
Low	♦ Environment is moderately degraded compared to equivalent areas. ♦ Environment supports physical properties or processes that have very high natural variability due to extreme events (e.g., cyclones and floods) that have a frequency of <1 per year. ♦ Environment supports physical properties or processes that are resilient to change, experiencing extreme natural events (e.g., cyclones and floods) every few years.
Minimal	♦ Environment is highly degraded compared to equivalent areas. ♦ Environment supports physical properties or processes that are very resilient to change, experiencing extreme natural events (e.g., cyclones and floods) every year.

Table 11.15 – Hydrology, Fluvial Geomorphology and Sediment Processes Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Receptor				
	Very High	**High**	**Medium**	**Low**	**Minimal**
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.3.2.2 Information Used in Assessment

The impact assessment was informed by numerical modeling and other analyses, as follows:

- Analysis of sediment generation, which was based on generic erosion rates.
- Hydraulic (flood) modeling, which was undertaken in subcatchments where significant Project works will occur to identify areas most at risk of flooding.
- Scour risk assessment, which was derived from the hydraulic modeling to assess potential scour risks at pipeline crossings of representative waterways.

Catchment modeling was also undertaken for the Purari and Era rivers to estimate baseline flow volumes and sediment loads from various subcatchments in the PAOI. The results were used to calculate the order of magnitude contribution of subcatchments to flow volumes and sediment loads in the overall catchments. The absolute sediment loads derived from this modeling are considered indicative only since flow records for subcatchments are unavailable to enable model calibration.

Hydraulic modeling activities are described in Part 2 of Volume 2. Other assessment approaches are described further below.

Sediment Generation from Erosion

For the impact assessment, Project-generated sediment loads have been estimated based on standard erosion equations using the following erosion rates:[2]

- Undisturbed areas – 2 mm/a. This is a conservative estimate based on previous monitoring of denudation rates in the Ok Tedi catchment, reported in Alluvium (2015).
- Disturbed areas – 50 mm/a. This is the rate adopted for the PNG LNG Project (Hydrobiology, 2008) and the P'nyang Development Project (Alluvium, 2015).
- Roads (once stabilized) – 20 mm/a. This is the rate adopted for the P'nyang Development Project (Alluvium, 2015).

Erosion rates are multiplied by the area over which the disturbance occurs to estimate the sediment load (cubic meters) generated from disturbed areas. The difference between the sediment load derived from the disturbed area rate compared with the undisturbed area rate provides the net sediment load due to the Project. The sediment generated per annum changes based on the Project development stage. For simplicity; however, only two scenarios were considered:

- Maximum construction phase disturbance, which is the total disturbed area at the disturbed erosion rate compared to the total disturbed area at the undisturbed rate.
- Operations phase disturbance, which is the total road area at the road erosion rate compared to the total road area at the undisturbed rate.

Scour Risk Assessment

The scour risk assessment involved applying the hydraulic modeling outputs to empirical formulae developed for scour assessments. These formulae account for the following factors that affect general scour:

- Change in cross-sectional area of flow.
- Change in discharge.
- Sediment grading.
- Upstream sediment supply.
- Duration of flow.

The assessment also included evaluating the critical velocity at which scour occurs, based on the United States National Engineering Handbook Technical Supplement 14B (NRCS, 2007). All relevant formulae for the assessment (both scour and critical velocity) are presented in Table 11.16. The assessments were undertaken at the locations assessed by hydraulic modeling during baseline studies, described in Part 2 of Volume 2.

2 These rates are not based on site-specific soil data but are adopted from studies in similar catchments in Papua New Guinea.

Table 11.16 – Formulae for Scour Depth and Critical Velocity Assessments

Source	Formula*	
Blench (1969)	$z_t = y_{ms} - y_0$	Where: z_t = Scour depth (m) $y_{ms} = 1.20[\frac{q^{\left(\frac{2}{3}\right)}}{D_{50}{}^{\frac{1}{6}}}]$ for sand-bed of 0.06<D_{50}≤2mm $y_{ms} = 1.23[\frac{q^{\left(\frac{2}{3}\right)}}{D_{50}{}^{\frac{1}{12}}}]$ for gravel-bed of D_{50} >2 mm
Blench (1970) and Lacey (1931)	$z_t = KQ_d^a W_f^b D_{50}^c$	Where: z_t = scour depth (m) K = 0.03 (Blench) or 0.162 (Lacey) a = 1/3 (Blench) or 2/3 (Lacey) b = 0 (Blench) or -2/3 (Lacey) c = -1/6 (Blench) or -0.1092 (Lacey)
Blodgett (1986)	$z_{t(mean)}=KD_{50}^{-0.1}$ $z_{t(max)}=KD_{50}^{-0.11}$	Where: z_t = scour depth (m) K = 0.84 (mean) or 3.8 (max)
Pemberton and Lara (1984)	$d_S = K(q)^{0.24}$	Where: d_S = depth of scour below streambed (m) K = 1.32 q = unit water discharge (m^3/s per m of width)
Technical Supplement 14B (NRCS, 2007)	$V_c = Ky^{\frac{1}{6}}D_{50}^{\frac{1}{3}}$	Where: V_c = critical velocity (m/s) y = average flow depth in the reach in question (m) K = 6.19

* D_{50} in all equations represents the particle diameter that represents 50% of the mass of the sample.

All scour assessment equations rely on the sediment size at the pipeline crossings of representative waterways. In lieu of detailed data on the sediment for each crossing site, the assessment was based on three sediment sizes: 0.1 mm (very fine sand), 1.0 mm (coarse sand) and 10 mm (gravel). These are considered representative of the range of sediment sizes that would likely occur in the relevant waterways.

As scour assessments have been based on hydraulic modeling outputs, which were developed during baseline assessments, not all pipeline waterway crossings have been captured; however, representative waterway locations have been assessed to cover a range of conditions such that waterways not assessed would be expected to experience scour that is equal to or lesser than scour at assessed locations.

11.3.3 Identification of Potential Impacts

Potential impacts to hydraulic processes and sediment transport can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges). [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

11.3.3.1 Changes to Hydraulic Processes and Sediment Transport

11.3.3.1.1 Earthworks and Physical Infrastructure

Figures 11.2 to 11.4 show the location of various Project infrastructure and associated earthworks in relation to soil types in the PAOI. Pipeline and road waterway crossing locations are shown in Figure 11.5. Table 11.17 describes the areas of disturbance and infrastructure that will be located throughout the various PAOI catchments and subcatchments.

Table 11.17 – Waterways Potentially Affected by Changes in Surface Drainage Patterns

Infrastructure Element	Disturbance to Waterways and Physical Processes	Affected Subcatchments	
Access roads	The right of way (ROW) will be cleared where new roads are required. Part of the ROW will be stabilized as a road structure (e.g., with crushed aggregate) while the remainder will be retained as a grassed verge. Drains will adjoin roads to divert flow from the road and surrounding areas. These drains will discharge into local waterways at road crossing locations. Access roads will cross waterways where required over culverts or bridges (to maintain flow).	Hou Creek Kuku Creek Oyomo Creek	Purari River
		Boa Creek Mena River Purari River banks in PRL-15	Era River
Flowlines, trunklines, injection lines and export pipelines	Pipelines and roads will share a ROW. The pipelines will be placed in a trench and then buried. The buried area will be retained free of vegetation except grass. Pipelines will be buried under waterways where required using trenches, except the Purari River which will be bored under using horizontal directional drilling (HDD).	Hou Creek Kuku Creek Oyomo Creek Purari River tributaries along the export pipeline route	Purari River
		Boa Creek Mena River	Era River
Wellpads	A new wellpad will be established at ANT-10. Other wells will be located at existing wellpads.	Boa Creek Mena River	Era River
Impoundments	Dams will be used to impound water to provide supply for drilling during construction. The dams will allow overflow during normal flow conditions.	Hou Creek	Purari River
		Boa Creek	Era River
Quarries	Quarries will require clearing and earthworks and will create depressions in the landscape that could capture water, depending on topography. Quarries will use perimeter channels to divert overland flow to minimize ponding.	Kuku Creek Banks of Purari River	Purari River
Spoil disposal sites	Spoil from excavations will be placed in natural depressions. These stockpiles will be stabilized and left in place. Dump locations will include perimeter drains to divert overland flow to prevent soil erosion.	Hou Creek Kuku Creek Oyomo Creek Purari River tributaries along the export pipeline route	Purari River
		Boa Creek Mena River	Era River
CPF	The CPF will require clearing and earthworks, and filling and diversion of several tributary streams. Once completed, a perimeter drain will surround the CPF to divert clean water from overland flow.	Oyomo Creek	Purari River

Table 11.17 – Waterways Potentially Affected by Changes in Surface Drainage Patterns (cont'd)

Infrastructure Element	Disturbance to Waterways and Physical Processes	Affected Subcatchments	
Logistics Base	The Logistics Base will require clearing and earthworks.	Purari River banks in PRL-15	Purari River
Purari Airstrip	The Purari Airstrip expansion will require clearing and earthworks.	Purari River banks in PRL-15	Purari River
Camps, landfills, check valve stations and pipe yards	These elements will require clearing and earthworks and will likely be bunded to contain spills and to divert overland flow.	Oyomo Creek Purari River banks in PRL-15 Purari River tributaries along the export pipeline route	Purari River

Earthworks are required throughout the PAOI, particularly for wellpads, quarries, spoil disposal sites, roads, pipelaying and the construction of the CPF, Logistics Base and Purari Airstrip extension. For this assessment, earthworks include site clearing, scrubbing and grubbing, topsoil stripping, spoil (subsoil) excavation, stockpiling and disposal, spoil or rock cut and fill, transportation of soil/spoil and rock materials in the work areas, drainage, and disposal of excess, stripped and unusable spoil material. Project physical infrastructure to be constructed that will intersect with waterways includes water supply dams for drilling of wells, pipelines, roads and the CPF. These earthworks and infrastructure are described in further detail in Chapter 4.

Earthworks and Project infrastructure have the potential to cause the following impacts:

- Changes to hydraulic processes (e.g., water flow direction, velocity and volume), caused by:
  - Changes in topography (i.e., cut and fill).
  - Development of site drainage networks.
  - Construction of infrastructure and spoil disposal sites in drainage depressions, floodplains and waterways.
  - Decreased vegetation and increased impervious surfaces.
- Increased suspended sediment and sedimentation levels in waterways due to:
  - Increased soil erosion and sediment loads.
  - Increased scour potential from changes in drainage patterns.

Changes to Hydraulic Processes

The main Project activities affecting hydraulic processes are:

- Diversion of overland flows (and associated operation of stormwater infrastructure) and defined stream channels.
- Vegetation clearance.
- Installation of pipelines across waterways.
- Installation of culverts to maintain flows.

Details on the potential impacts on these process changes are provided in the following sections. Further design of drainage, waterway crossings and infrastructure alignments will be undertaken during the FEED and detailed design phases of the Project. These design activities will provide an inherent level of mitigation or avoidance of impacts, as described in the following sections.

PROJECT INFRASTRUCTURE AND SOIL TYPES IN HOU CREEK AND ERA RIVER CATCHMENTS

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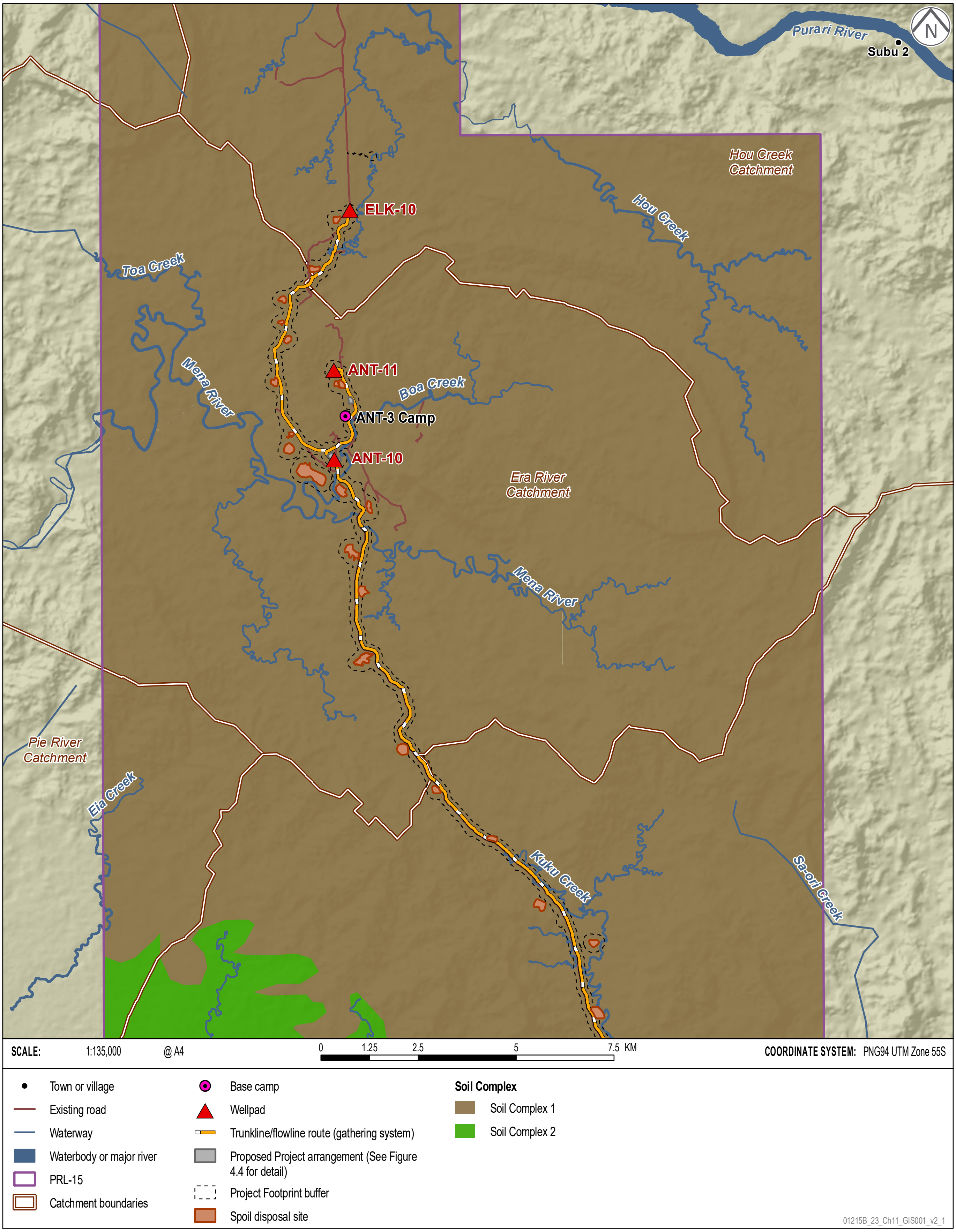
FIGURE 11.2



Source: Figure theme data from BMT, 2019.

PROJECT INFRASTRUCTURE AND SOIL TYPES IN KUKU CREEK AND OYOMO CREEK CATCHMENTS

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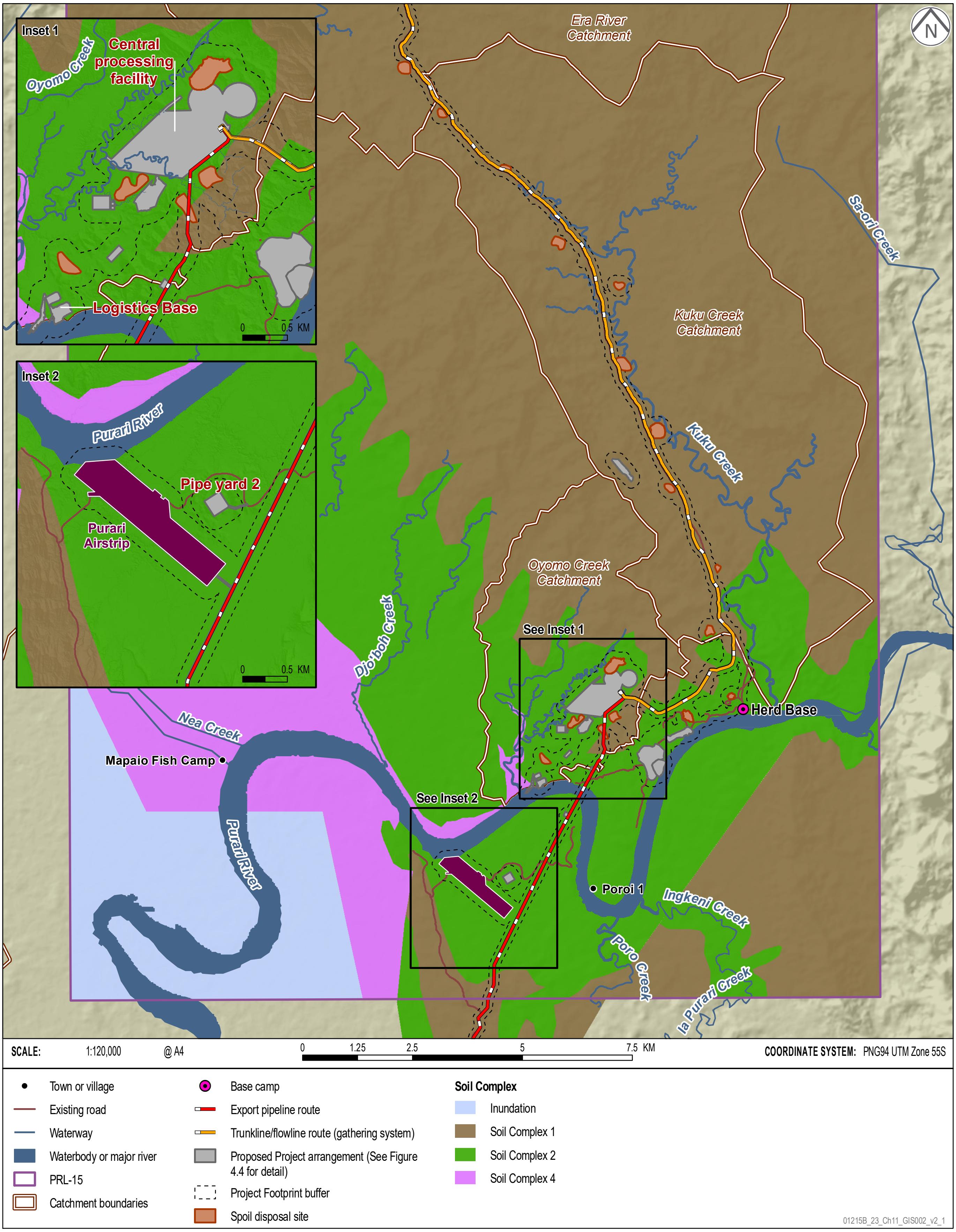
FIGURE 11.3



Source: Figure theme data from BMT, 2019.

SOIL TYPES ALONG THE EXPORT PIPELINE ROUTE

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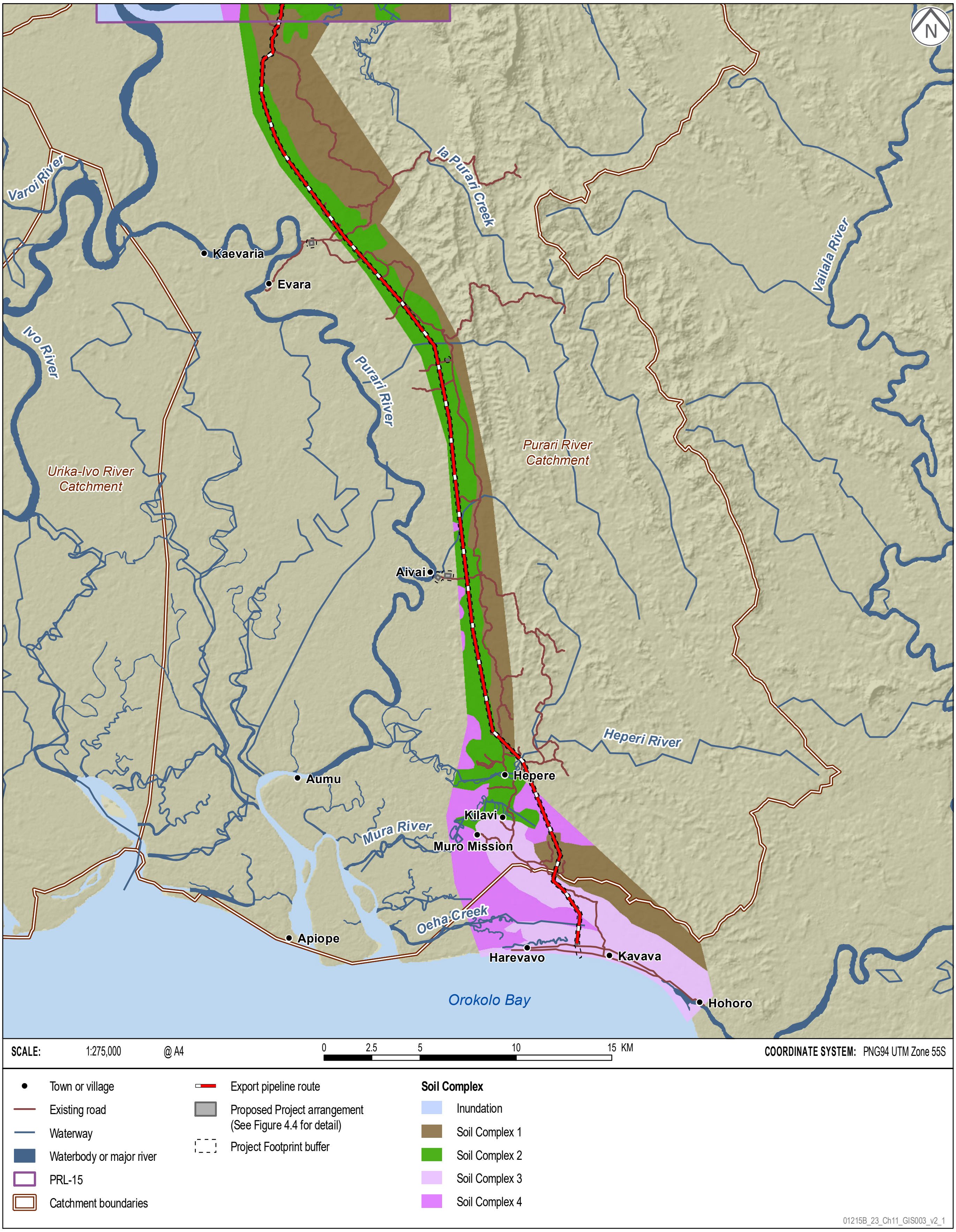
FIGURE 11.4



Source: Figure theme data from BMT, 2019.

WATERWAY CROSSING LOCATIONS

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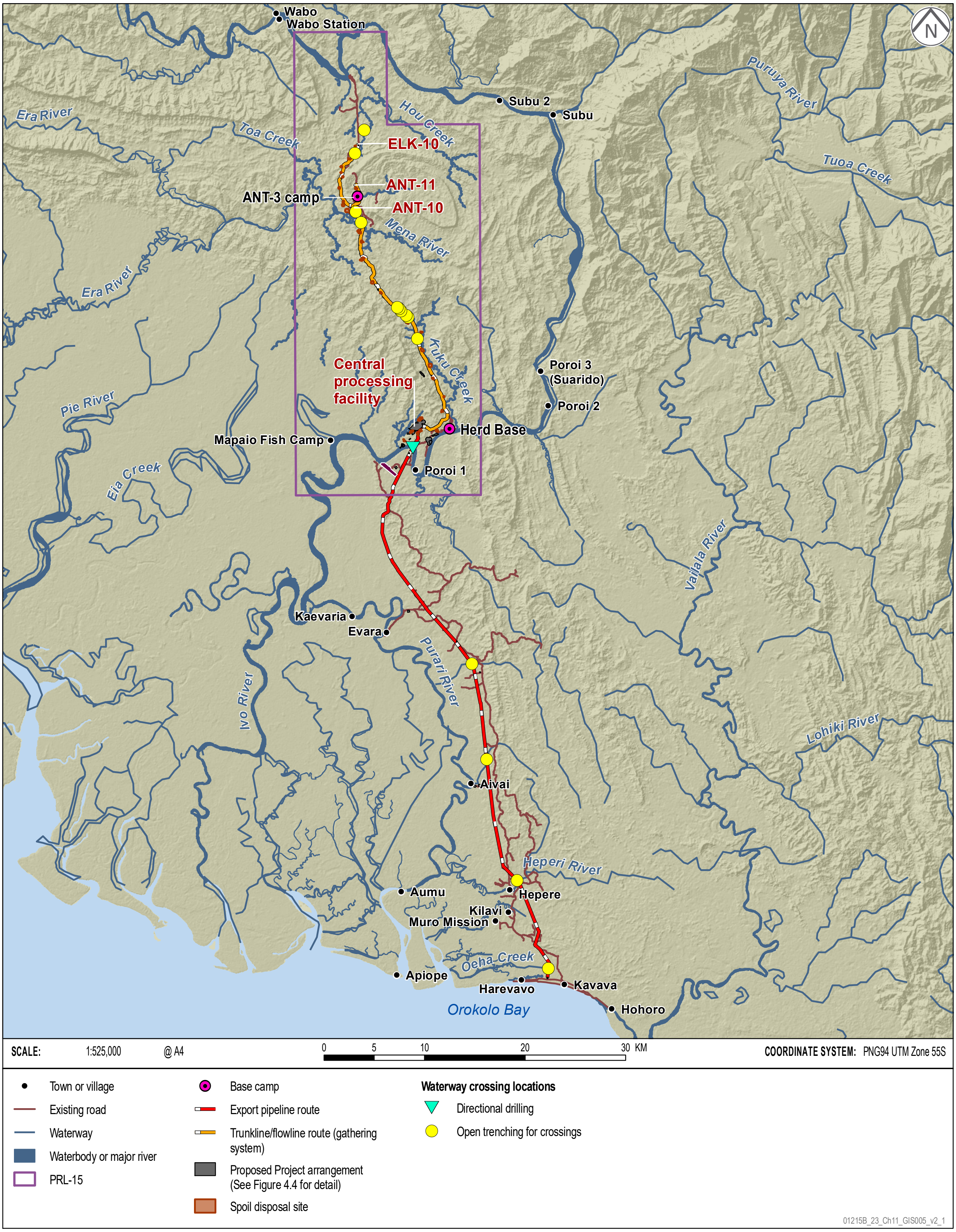
FIGURE 11.5



Source: Figure theme data from BMT, 2019.

Diversion of Overland Flows

Overland flows (i.e., outside defined channels) will be diverted around Project infrastructure (including new quarries). This could cause highly localized changes to overland drainage patterns in and adjacent to the disturbance footprint; however, defined waterways will typically be retained in their present form and will not be diverted. The exceptions are streams in the proposed CPF footprint, which will be diverted around the CPF. This will disturb approximately 92 ha of the 2,250 ha (i.e., less than 5%) of the Oyomo Creek catchment, as shown in Figure 11.6. Importantly, the diversion of flows into different subcatchments is not proposed.

Vegetation Clearance

Vegetation clearing and earthworks will increase the volume of runoff by replacing previously vegetated areas with surfaces with an increased runoff potential (e.g., roads and grassed areas). Increased runoff can cause localized scour, especially where runoff is channeled through drainage networks to a single discharge point.

Installation of Pipelines Across Waterways

The crossing of the Purari River will use horizontal directional drilling (HDD) beneath the river and therefore has no implications for earthworks or surface level changes.

Pipelines will be installed under other waterways using open trenching, which will be backfilled immediately to a depth equivalent to the original conditions. Pipelines will; therefore, not interfere with stream flows when first constructed; however, natural channel scour at crossing locations may occur during periods of high flows.

Based on the scour assessment using formulae from the United States National Engineering Handbook Technical Supplement 14B (NRCS, 2007), the critical velocity for scour (i.e., the stream velocity at which scour will occur if exceeded) is not exceeded at any modeled waterway crossing; however, as this assessment has not been based on detailed site soil data, a risk of scour remains at all waterway crossings with highly dispersive soils. Table 11.18 presents the potential scour depths for each of the modeled waterways (i.e., Boa Creek, Mena River and unnamed streams along the export pipeline route). Scour assessment of crossings at Hou and Kuku creeks and the Heperi River were not conducted, as these areas were excluded from hydraulic models as part of baseline assessments; however, a comparison of these crossings to modeled crossings indicated scour at these creek crossings would be less than or equivalent to scour at other crossings.

The results presented in Table 11.18 are the mean results derived from the scour formulae described in Table 11.16, with individual results for the separate formulae presented in Table 11.19.

The results indicate a scour depth of at least 1 m at each crossing, which is expected to partly or fully expose the pipeline. The exposed pipeline is expected to cause highly localized changes to stream flows and morphological processes (e.g., sediment accretion and further scour). Sediment deposition will occur during periods of low flows, potentially leading to full or partial pipeline reburial.

CHANGES TO OYOMO CREEK DRAINAGE

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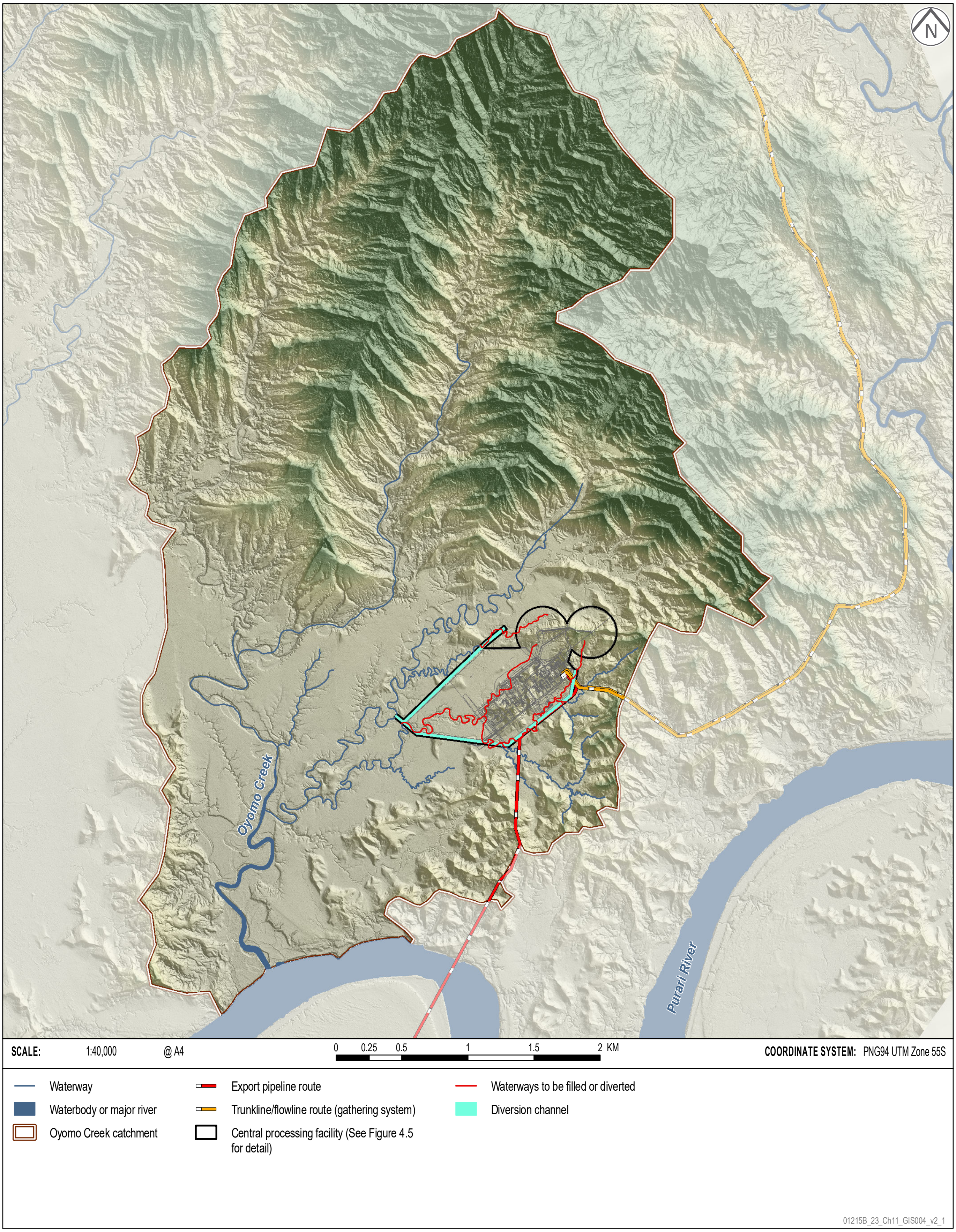
FIGURE 11.6



Source: Figure theme data from BMT, 2019.

Installation of Culverts to Maintain Flows

Culverts will be installed to maintain flows; however, inappropriately designed culverts can interfere with stream flows and associated morphological processes. Upstream flooding can occur during high flow events when the culvert flow capacity is exceeded causing scour.

Increased Levels of Suspended Sediment and Sedimentation

Construction works will remove vegetation and disturb soils, with approximately 930 ha of ground disturbance proposed to occur in the PAOI (Section 4.10.7). Table 11.20 provides an indicative breakdown of ground disturbance areas in the main PAOI catchments.

Figures 11.2 to 11.4 show that the disturbance occurs across all four mapped soil complexes for the PAOI. Each of these complexes is highly erodible soil. Additionally, ROWs in PRL-15 are aligned close to areas of steep topography, including Kuku Ridge and the Mena plateau. Clearing and ground disturbance in or downslope of these features can cause a heightened risk of landslides.

Disturbed soils will; therefore, be prone to erosion, which will increase sediment yield in the affected catchments. This will be particularly pronounced where disturbance occurs in areas of steeper gradients, such as around Boa and Kuku creeks. Furthermore, gullying on roads will represent a significant sediment source, especially in areas where road drains flow along unstable slopes. Fugitive sediment from disturbed areas and roads may potentially be transported in runoff to the streams that drain the construction areas.

Additionally, excess spoil is intended to be stockpiled permanently in low-lying depressions at various locations (see Figure 11.2 and Figure 11.3). Rain could mobilize soil from these stockpiles. Sediment mobilization may also degrade water quality and harm freshwater and estuarine biodiversity, with such impacts considered in Sections 11.4 and 11.5.

The following embedded design control addresses potential impacts to hydraulic processes and sediment transport:

- All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is to:
  - Account for local rainfall conditions and catchment size of works areas.
  - Allow avoiding unseasonal waterlogging.
  - Allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable [ED014].

Table 11.18 – Mean Critical Stream Velocities and Scour Depths for Pipeline Waterway Crossings

Waterway*	Scour Assessment Reporting Location*	Modeled Velocity (m/s)	Critical Velocity† (m/s)			Mean Scour Depth† (m)		
			D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm
Boa Creek	S1-11	1.99	3.66	7.89	17.00	0.59	0.18	-0.01
Mena River	S2-5	0.42	3.31	7.12	15.34	0.63	0.28	0.13
Unnamed rivers and minor tributaries along the export pipeline route	S14-19	0.32	2.50	5.39	12.67	0.24	0.16	0.11
	S17-9	0.67	2.53	5.46	11.76	0.30	0.20	0.14

* Reporting locations are shown in the hydraulic modeling results in Part 2 of Volume 2. Scour assessment of crossings at Hou and Kuku creeks and the Heperi River were not conducted, as these areas were excluded from hydraulic models as part of baseline assessments; however, a comparison of these crossings to modeled crossings indicated scour at these creek crossings would be less than or equivalent to scour at other crossings.

† As described in Section 11.3.2.2, assessment was undertaken considering three different sediment sizes (i.e., 0.1 mm (very fine sand), 1.0 mm (coarse sand) and 10 mm (gravel) considered representative of the range of sediment sizes that would likely occur in the relevant waterways. The mean was determined using the average of results presented in Table 11.20, excluding Blodgett maximum scour depth.

Table 11.19 – All Scour Depth Results for Relevant Waterway Crossings

Crossing Point ID	Peak Flow (m^3/s)	Flow Width (m)	Velocity (m/s)	Mean Flow depth (m)	Blodgett Mean Scour Depth (m)			Blodgett Maximum Scour Depth (m)			Lacey Scour Depth (m)			Blench (1969) Scour Depth (m)			Blench (1970) Scour Depth (m)			Pemberton and Lara Scour Depth (m)		
					D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm	D_{50} 0.1 mm	D_{50} 1.0 mm	D_{50} 10 mm
S1-11	143.16	31.77	1.99	4.27	1.06	0.84	0.67	4.9	3.8	2.95	0.23	0.16	0.11	0.53	-1.0	-1.5	0.57	0.44	0.34	0.57	0.44	0.34
S2-5	212.38	66.3	1.63	2.91	1.06	0.84	0.67	4.9	3.8	2.95	0.26	0.18	0.12	0.92	-0.30	-0.70	0.45	0.35	0.27	0.45	0.35	0.27
S14-19	25.98	375.2	0.32	0.44	1.06	0.84	0.67	4.9	3.8	2.95	0.13	0.09	0.06	-0.14	-0.23	-0.26	0.04	0.03	0.02	0.13	0.09	0.06
S17-9	64.31	417.2	0.67	0.47	1.06	0.84	0.67	4.9	3.8	2.95	0.18	0.12	0.08	0.04	-0.13	-0.18	0.06	0.05	0.04	0.18	0.12	0.08

Table 11.20 – Ground Disturbance Profile for PAOI Catchments

Subcatchment	Size (ha)	Construction Phase Disturbance		Operations Phase Disturbance		
		Disturbance Area (ha)	Percentage of Subcatchment (%)	Non-road Infrastructure (ha)	Road Infrastructure (ha)	Percentage of Subcatchment (%)
Era River Catchment						
Boa Creek	4,615	64	1.39	38	39	1.67
Mena River	7,185	56	0.78	10	53	0.88
Era River (downstream of Mena River and Boa Creek confluence)	163,000	69	0.04	24	49	0.04
Total	**174,800**	**189**	**0.11**	**72**	**141**	**0.12**
Purari River Catchment						
Hou Creek	74,970	26	0.03	7	34	0.05
Kuku Creek	8,208	133	1.62	31	117	1.80
Oyomo Creek	2,250	146	6.49	127	23	6.67
Purari River and subcatchments downstream of the Purari River export pipeline crossing (excludes Ivo-Urika and Wame-Varoi distributaries)	84,190	402	0.48	146	424	0.68
Total	**169,618**	**707**	**8.62**	**311**	**598**	**0.54**

11.3.3.1.2 Wastewater, Stormwater and Hydrotesting Releases

Controlled wastewater and stormwater discharges from various Project areas will occur to the Purari River via one or more outlets at the Logistics Base. These discharges will consist of treated sewage effluent and treated contaminated stormwater runoff from the CPF. Hydrotest water will be discharged to a site in accordance with the environmental permit, which may be the Purari River, however the exact location(s) will be determined during FEED. Discharges to the river have the potential to cause erosion and scour.

The following embedded design control addresses this potential impact:

- Hydrotest water discharges will be managed according to applicable requirements [ED040].

Impacts of Project discharges on water quality are considered in Section 11.4.

11.3.3.1.3 Dredging

Construction of the Logistics Base along the Purari River will require dredging of a berth pocket and installation of in-stream structures as part of the quay line and jetty.

The dredging will be required to provide underkeel clearance for berthing vessels. This dredged area is likely to be maintained for the life of the Project, with the expected frequency of dredging and dredge volumes to be determined during FEED.

Detailed design of the area to be dredged has not yet been undertaken; however, up to 6,000 m^3 may be excavated from the riverbed. The area to be dredged has been estimated based on river bathymetry and the likely dredge depth that will be required for vessels (i.e., 3 to 3.5 m based on a draught of 2.5 m for a fully loaded barge). The likely dredge area is shown in Figure 11.7 and has a surface area of approximately 1.5 ha.

For the impact assessment, dredging is assumed to be undertaken using a backhoe dredge or similar excavation-based dredger, with material placed directly in a barge for onshore or in-river disposal. This technique is most likely based on the volume and location of dredging. A backhoe dredge operates by directly removing riverbed sediment using an excavation arm and bucket.

The logistics base quay line and jetty will likely use sheet piles and similar structures rather than freestanding piles. This provides for a more stable environment for the docking, loading, unloading and departing of vessels. As shown in Figure 11.7, there are two locations where the sheet piles would be used: the southwest corner of the logistics base, immediately downstream of a natural outcrop, upstream of the dredging footprint; and immediately downstream of the dredging footprint.

Dredging of the berth and installation of sheet piles have the potential to cause the following impacts:

- Changes to hydraulic processes (i.e., hydrology, flow characteristics and scouring) associated with changes to the riverbed and introduction of physical barriers.
- Increased levels of suspended sediment and sedimentation from sediment mobilized during dredging (capital and maintenance) and disposal (if in-river disposal is undertaken).

Changes to Hydraulic Processes

A net removal of material from the Purari River from dredging can change overall morphology due to a change in the amount of sediment available in the river for natural fluvial processes (e.g., scour and deposition). These downstream changes may persist where the dredged basin is a long-term feature.

LIKELY AREA OF DREDGING FOR LOGISTICS BASE

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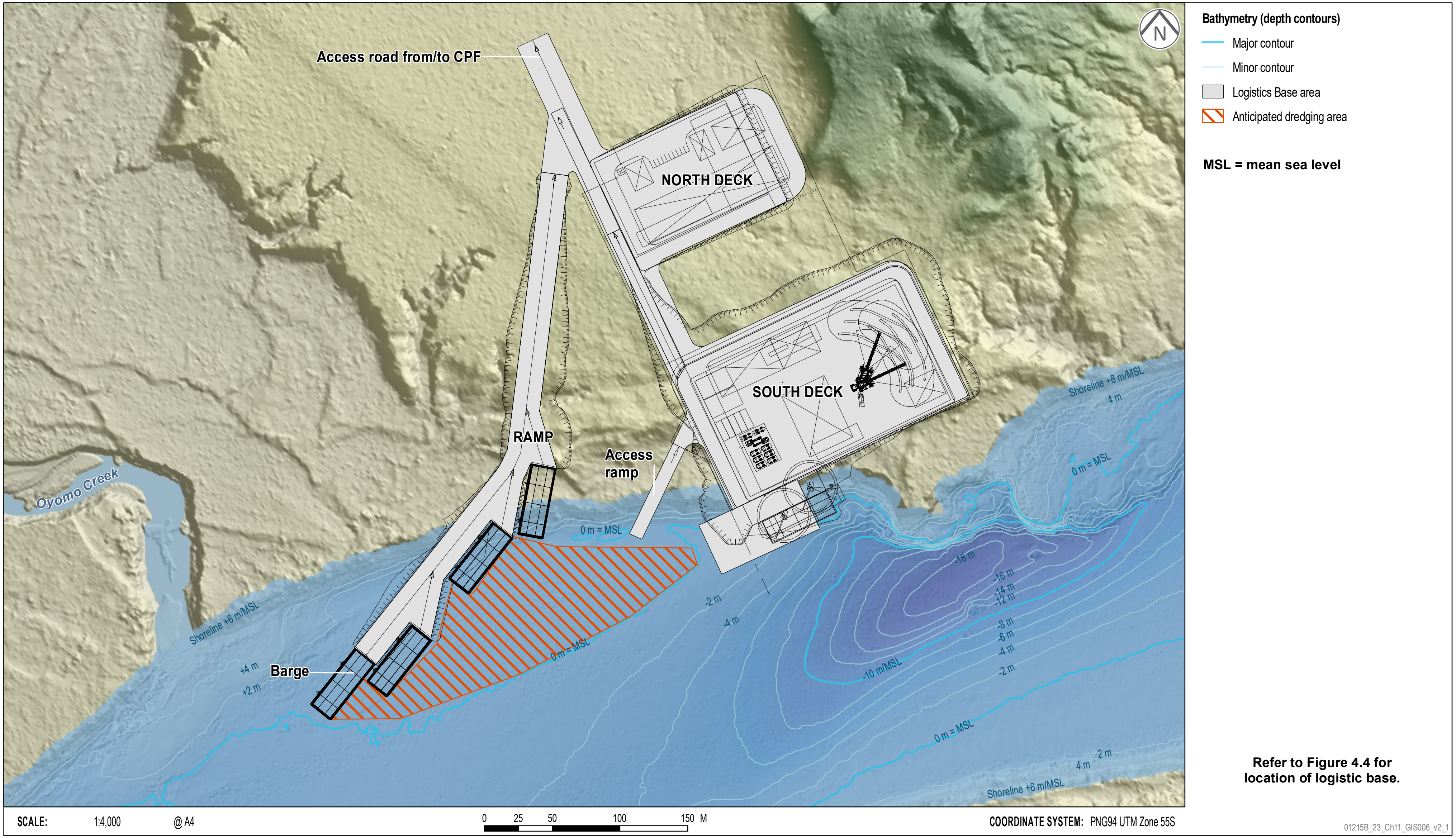
FIGURE 11.7



Source: Figure theme data from BMT, 2019.

Additionally, scour and slumping may occur adjacent to the dredging footprint due to the change in local hydrodynamics from the deepening. This could cause the loss of riparian habitat and the release of additional sediment into the river.

Installation of sheet piles will cause a localized change in fluvial processes due to the diversion of water naturally flowing downstream. Depending on the prevailing hydrodynamic forces at the sheet pile locations, this would likely cause some deposition upstream and scour downstream, due to the 'blocking' of sediment transport.

Additionally, scour and slumping may occur adjacent to the dredging footprint due to the change in local hydrodynamics. This could cause the loss of riparian habitat and the release of additional sediment into the river.

Increased Suspended Sediment and Sedimentation Levels

Dredging of the riverbed will suspend sediments in the water column and increase water turbidity. The suspended sediment behavior will depend on particle size and hydrodynamic processes. Sediment sampling undertaken near the proposed dredge pocket indicates that riverbed sediment consists of a mixture of sand (particle size diameter 0.06 to 2 mm; 44%) and silt (particle size diameter 2 to 60 µm; 40%), with some clay (particle size diameter less than 2 µm; 16%). Sand-sized particles are expected to settle on the riverbed close to the dredging footprint. The more buoyant fine sediment fractions (i.e., silts and clays) will remain suspended and be transported further downstream.

This will increase total suspended solid (TSS) concentrations in and downstream of the dredge area, which will be transported downstream by river flows. The extent of the TSS changes will depend on a range of factors, including river flows, dredge location, type of dredge, working methods, duration of dredging and dredging rates.

The Purari River is known to cause reverse flow into Oyomo Creek during periods of high river flow. As Oyomo Creek, which is a clear water stream, is immediately downstream of the dredge pocket, turbid plumes from the dredging could extend into Oyomo Creek during periods of high flow in the Purari River, potentially increasing the sediment loads delivered to this system during high flows.

11.3.3.1.4 Vessel Traffic

Vessel traffic in the Purari River will increase during all Project phases. The most traffic will occur in the construction period during months 1 to 18 when barges bring aggregate materials for earthworks to the site. During the peak period (months 8 to 18), between four and five barge deliveries per day will be made to the Logistics Base, resulting in nine to ten barges on the river system at a given time.

River traffic can cause scour of the riverbed and banks due to propeller wash and vessel wake. An increase in vessel movements may increase scouring, especially where traffic is regular and at high densities. Long-term scour, if unaddressed, can cause river banks to slump and introduce sediment into the river.

Scour risk is expected to be highest on the outer bends of large meanders where natural erosion is occurring and in areas where riparian vegetation has been removed, such as commercial logging areas.

11.3.3.2 Reduction in Stream Flows from Water Extraction

Water will be required for the following Project activities:

- Creation of drilling mud for production drilling.

- Pressurizing of drilling mud for well control purposes.
- Pipeline cleaning and hydrotesting.
- Processing of reservoir fluids and gas at the CPF.
- Potable water supply for the CPF, Logistics Base and accommodation camps.

Approximately 200 m^3/day of water will be required at each well to create drilling muds, with occasional peaks of up to 1,300 m^3/day. Water is also needed to pressurize the drilling mud for well control purposes, and a flow rate of 100 m^3/day will be required. The total water demand during drilling is expected to be between 300 and 1,400 m^3/day at each well (see Section 4.10.3.6).

Water for the ANT-10 and ELK-10 drilling and wellpads is expected to be extracted from Boa Creek and Hou Creek, respectively. So that enough water is available during periods of low river flow, temporary dam structures 5-m high will be constructed on the creeks, which will create a water storage volume of 2,000 m^3. Preliminary locations of water extraction points for drilling and operations are shown in Figure 11.8. The final water extraction points and dam structure locations will be defined during FEED.

Water to clean and hydrotest the onshore pipelines is expected to be drawn from the Purari River at the Logistics Base. The volume of water required will be defined during FEED; however, it can be expected to be approximately equivalent to the total volume of the onshore pipelines, i.e., approximately 19,000 m^3 for flowlines and trunkline and 50,000 m^3 for export pipelines. The total volume of water required for hydrotesting is therefore estimated to be approximately 69,000 m^3; however, water extraction requirements will be less than this volume since hydrotest water will be recycled from one section of pipe to another.

The average minimum flow rate of the Purari River measured at Wabo is 1,920 m^3/s (see Section 7.3.2.3), which is equivalent to 165,000,000 m^3/day. At the extraction point at the Logistics Base, the flow rate is greater due to the additional inflows from the Aure River. The total water extraction requirements for hydrotesting (69,000 m^3); therefore, represents less than 0.05% of the total daily flow under minimum flow conditions.

Approximately 2,500 m^3/day of water will also be extracted from the Purari River for use at the CPF; 2,400 m^3/day is required for acid gas removal during the first years prior to acid gas injection into the depleted Elk reservoir and 100 m^3/day is required for domestic water supply for the accommodation camp. This volume represents less than 0.002% of the average minimum flow of the Purari River. The CPF water requirements will decrease to approximately 200 m^3/day when acid gas injection commences.

Reductions in water flows may potentially reduce impact environmental flows that sustain human livelihoods and aquatic ecosystems. Impacts on aquatic biodiversity are assessed in Section 11.5.

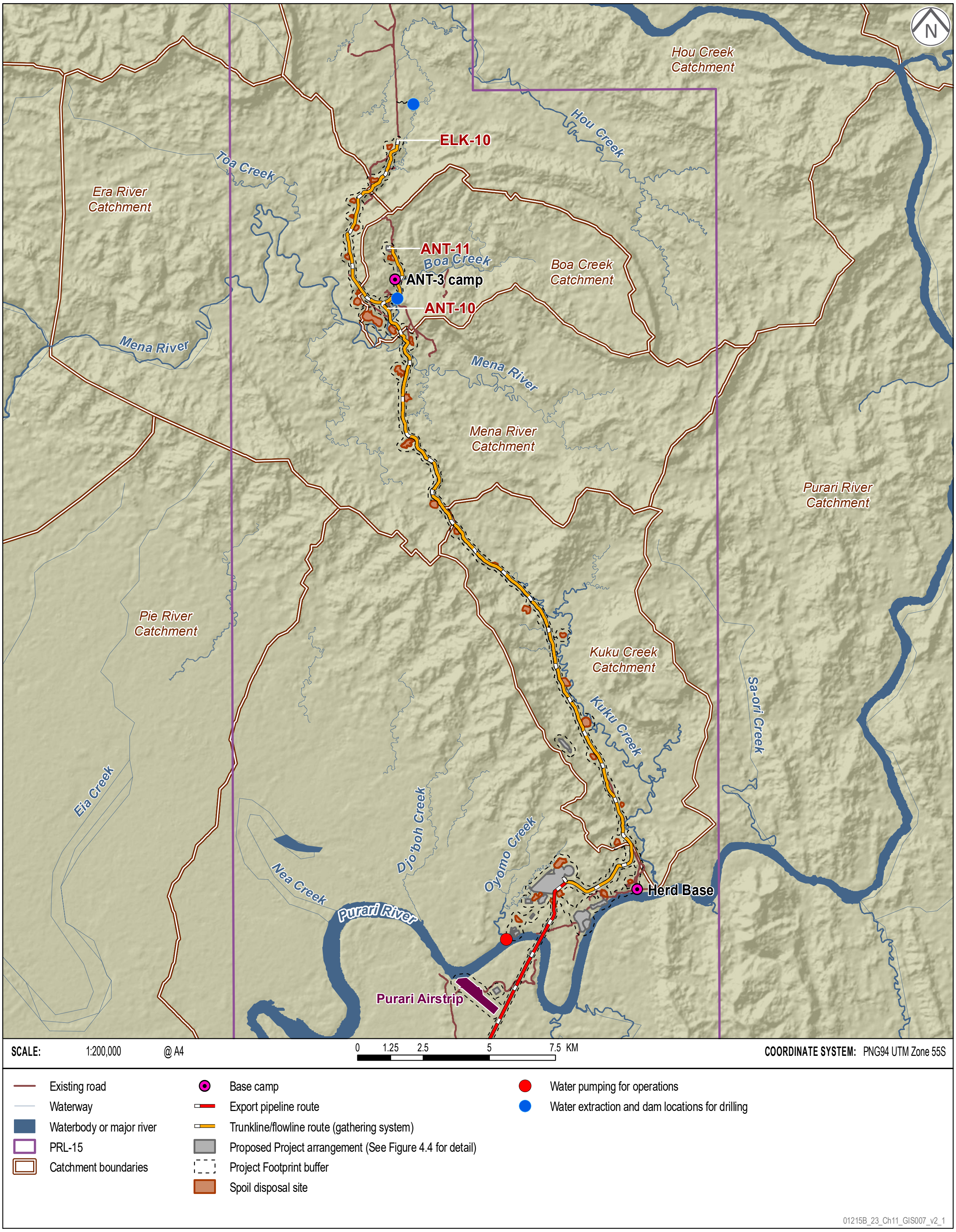
11.3.4 Proposed Mitigation and Management Measures

Table 11.21 describes mitigation and management measures to further reduce impacts to hydrology, fluvial geomorphology and sediment processes.

WATER EXTRACTION LOCATIONS

Papua LNG Project | Environmental Impact Statement

FIGURE 11.8



Source: Figure theme data from BMT, 2019.

Table 11.21 – Hydrology, Fluvial Geomorphology and Sediment Processes Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Alterations to hydrology, flow characteristics and scouring (due to earthworks and physical infrastructure)	♦ Backfill trenches as soon as practicable after disturbance, using material originally excavated from the trench as much as possible. The backfilled trenches should not exceed the preconstruction levels after the material has settled [EM009]. ♦ Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g., drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipaters, sediment control ponds, mulch berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated [EM004].	Site Restoration and Rehabilitation Plan; Water Management Plan
Soil erosion causing increased TSS, turbidity and sedimentation of streams (due to earthworks and physical infrastructure)	♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Cut trees where practicable to retain the rootstock and maintain soil stability [EM003]. ♦ Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g. drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipaters, sediment control ponds, mulch berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated [EM004]. ♦ Stabilize spoil stockpiles and areas of ground disturbance as soon as practicable after initial disturbance using, e.g., mulched vegetation, aggregates and soil binders [EM005]. ♦ Areas of higher risk of landslides e.g., steep gradients, previously disturbed land, likely to occur from the works, or likely to be exacerbated by the works, will be stabilized to reduce the landslide risk. [EM006]. ♦ Minimize or avoid sidecasting during construction (e.g. for road, pipeline, wellpad and CPF works). Any sidecasting that does occur will avoid defined stream channels [EM010]. ♦ Water from trenches will be discharged in accordance with applicable water quality standards with erosion and sediment controls where relevant [EM011]. ♦ Maintain buffer zones between permanent surface water and project infrastructure, except to carry out works associated with the construction of watercourse crossing or where facilities are proposed to be located within that buffer [EM012]. ♦ Minimize in-stream and stream bank disturbance during high rainfall [EM013].	Soil Management Plan; Site Restoration and Rehabilitation Plan; Water Management Plan

Table 11.21 – Hydrology, Fluvial Geomorphology and Sediment Processes Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Sediment mobilization causing increased TSS, turbidity and sedimentation of streams (due to dredging)	♦ Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species [EM037].	Water Management Plan
Sediment mobilization causing increased TSS, turbidity and sedimentation of streams (due to riverbed scouring from vessel movements)	♦ Implement low speed limits through areas sensitive to vessel wash impacts [EM014].	Traffic and Transport Management Plan
Reduction in streamflow from water abstraction	♦ Hydrotest water management will consider: – The definition of volume and discharge rates and discharge locations. – Chemicals additives selection, according to requirements defined in embedded design controls – Reusing hydrotest water to minimize the discharge volume. – Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. – Monitoring hydrotest water discharges to the environment against applicable limits [EM015]. ♦ Maintain hydraulic and biological connectivity during construction and operations in natural flow lines across linear infrastructure, such as pipelines and roads, and in relation to water extraction, e.g., dams, including: – Install appropriately sized culverts, drains and structures to allow fish passage, according to good international industry practice standards. – Rehabilitate waterways after construction and decommissioning to a sustainable, stable state, that reflects the original character, and maintains waterway flows and connectivity [EM020].	Water Management Plan

11.3.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to hydrology, fluvial geomorphology and sediment processes subject to the embedded design controls in Section 11.3.3 and the successful implementation of the proposed mitigation and management measures in Section 11.3.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

11.3.5.1 Changes to Hydraulic Processes and Sediment Transport

11.3.5.1.1 Earthworks and Physical Infrastructure

Construction in Oyomo Creek catchment will occur over 92 ha and cause the loss and diversion of approximately 5,600 m of waterway, comprising 3,100 m of moderate gradient tributary and 2,500 m of low gradient tributary (see Figure 11.6). While the loss and diversion of waterways in the Oyomo Creek catchment will be long-term (beyond the life of the Project), this change is unlikely to have a material significance on overall drainage patterns and hydraulic processes in the PAOI. Impacts on hydrology and fluvial geomorphology will be localized around the area of the earthworks at the CPF; hence, the magnitude of impacts will be ***Low***. The sensitivity of the waterways is ***Medium*** as they are in near-natural condition***.*** This provides an overall impact significance rating of ***Minor****.*

While there is a risk of scour at pipeline waterway crossings, especially in Boa Creek (see Section 11.3.3.1), considering that crossings will be monitored and stabilized or remediated when scour occurs, impacts are expected to be highly localized and short-term and therefore of ***Minimal*** magnitude. Waterways in the PAOI are in near-natural condition with regards to hydrology and fluvial geomorphology, and therefore of ***Medium*** sensitivity, and the impact significance from scouring is assessed to be ***Negligible***.

Where culverts are appropriately designed at road crossings, changes in flow regimes and fluvial geomorphology of waterways in the PAOI compared to pre-existing conditions will be insignificant and of ***Minimal*** magnitude. Given the stream sensitivity of ***Medium***, the residual impacts significance is ***Negligible***.

Table 11.22 presents the potential sediment loads generated in PAOI waterway catchments during the Project construction phase, adopting the erosion rates described in Section 11.3.2 before mitigation is implemented. The overall sediment transport loads contributed by the Project are likely to be significantly less than the volumes indicated in the table given the application of proposed erosion and sediment control measures.

Sediment impacts in waterways are expected to be highly localized to localized (depending on the catchment size and the area of ground disturbance), with the overall magnitude of impact differing between waterways, as follows:

- Boa Creek and Mena River – ***Medium*** magnitude impact.
- Era River – ***Minimal*** magnitude impact.
- Hou Creek – ***Minimal*** magnitude impact.
- Kuku Creek – ***Medium*** magnitude impact.
- Oyomo Creek – ***High*** magnitude impact.
- Purari River (excluding Hou, Kuku and Oyomo creeks) – ***Low*** magnitude impact.

Table 11.22 – Anticipated Sediment Generation per PAOI Catchment During the Construction Phase Before Mitigation

Subcatchment	Catchment Area (ha)	Disturbance Area (ha)	Sediment Generated during Construction Disturbance* (m^3)	Sediment Generated under Existing Undisturbed Conditions* (m^3)	Sediment Generated by the Project* (m^3)	Total Sediment Generated in the Catchment with the Project* (m^3)	Project Contribution to the Total Sediment Generated* (%)
Era River Catchment							
Boa Creek	4,615	64	32,000	1,280	30,720	123,020	25%
Mena River	7,185	56	28,000	1,120	26,880	170,580	16%
Era River (downstream of the Mena River and Boa Creek confluence)	163,000	69	34,500	1,380	33,120	3,293,120	1%
Total:		**189**	**94,500**	**3,780**	**90,720**	**3,586,720**	**-**
Purari River Catchment							
Hou Creek	74,970	26	13,000	520	12,480	1,511,880	1%
Kuku Creek	8,208	133	66,500	2,660	63,840	228,000	28%
Oyomo Creek	2,250	146	73,000	2,920	70,080	115,080	61%
Purari River and subcatchments downstream of the Purari River export pipeline crossing (excludes the Ivo-Urika and Wame-Varoi distributaries)	84,190	402	201,000	8,040	192,960	1,876,760	10%
Total:		**707**	**353,500**	**14,140**	**339,360**	**3,731,720**	**-**

* Disturbance calculations:
Sediment Generated during Construction Disturbance (m^3) = Disturbance Area (ha) x 50 mm/a.
Sediment Generated under Undisturbed Conditions (m^3) = Disturbance Area (ha) x 2 mm/a.
Sediment Generated by the Project (m^3) = Sediment Generated during Construction Disturbance (m^3) – Sediment Generated under Existing Undisturbed Conditions (m^3).
Total Sediment Generated in the Catchment with the Project (m^3) = (Catchment Area (ha) – Disturbance Area (ha)) x 2 mm/a plus Disturbance Area (ha) x 50 mm/a.
Project Contribution to the Total Sediment Generated (%) = Sediment Generated by the Project (m^3)/Total Sediment Generated in the Catchment with the Project (m^3) (x100).

The sediment loads predicted during the operations phase are shown in Table 11.23, based on ongoing sediment generation from roads. The magnitude of these sedimentation impacts are all ***Low*** except that for the Era River and Hou Creek, which is ***Minimal*** for both.

All waterways listed have a ***Medium*** sensitivity with regards to sediment processes (i.e., near-natural condition with some human-induced modification), except the Purari River and adjoining subcatchments downstream of the export pipeline crossing. These waterways have a ***Low*** sensitivity due to the extensive ground disturbance in the catchment from logging operations.

Based on these ratings, the overall impact significance for sediment transport is as follows:

Construction Phase

- Mena River and Oyomo, Boa and Kuku creeks – ***Moderate***.
- Era River and Hou Creek – ***Negligible***.
- Purari River and adjoining subcatchments downstream of the export pipeline crossing – ***Minor***.

Operations Phase

- Mena River, Boa, Kuku and Oyomo creeks and Purari River and adjoining subcatchments downstream of the export pipeline crossing – ***Minor***.
- Era River and Hou Creek – ***Negligible***.

11.3.5.1.2 Wastewater, Stormwater and Hydrotesting Releases

No scour impacts are expected from point source discharges to the Purari River where the discharges occur over protective rip rap or other energy dissipator devices. The magnitude of impact is therefore ***Minimal*** and, given the waterway sensitivity is ***Medium***, the residual impact significance is ***Negligible***.

11.3.5.1.3 Dredging and In-stream Structures

Backhoe dredging involves the physical extraction of bed sediments using a crane bucket. While removing 6,000 m^3 of sediment from the Purari River represents a minor proportion of the overall volume of material in the shoals near the Logistics Base, regular removal of this volume, as part of maintenance dredging, could cause a net change in fluvial geomorphology in a localized area. Additionally, the installation of sheet piles for the jetty and quay line could cause changes in deposition and scour either side of the structures.

These changes would be highly localized to the dredging and sheet pile areas, less than that likely to be experienced during extreme flow events but may be detectable above natural variability; therefore, the magnitude of impacts on hydraulic processes due to dredging would be ***Low***. Dredging and sheet piles are not expected to cause scouring of the river bank. As the Purari River is highly dynamic with regards to hydrology and morphological changes, it is considered to have ***Low*** sensitivity in terms of hydraulic processes. This provides an overall significance rating of ***Minor*** for this impact.

Only small volumes of material are released into the water column using a backhoe dredge (PIANC, 2010), creating far less turbidity than other dredging methods where material is fluidized (e.g., cutter-suction dredging) (Envisan, 2013); therefore, any sediment plumes created by dredging at the new jetty in the Purari River are expected to be highly localized and, due to strong river flows and sediment advection and dispersion, of a short-term nature restricted to the dredging period (i.e., weeks).

Table 11.23 – Anticipated Sediment Generation per PAOI Catchment During the Operations Phase Before Mitigation

Subcatchment	Catchment Area (ha)	Road Area* (ha)	Sediment Generated during Operations Disturbance† (m^3)	Sediment Generated under Existing Undisturbed Conditions† (m^3)	Sediment Generated by the Project† (m^3)	Total Sediment Generated in the Catchment with the Project† (m^3)	Project Contribution to the Total Sediment Generated (%)
Era River Catchment							
Boa Creek	4,615	39	7,800	780	7,020	99,320	7.1%
Mena River	7,185	53	10,600	1,060	9,540	153,240	6.2%
Era River (downstream of the Mena River and Boa Creek confluence)	163,000	49	9,800	980	8,820	3,268,820	0.3%
Total:		**141**	**28,200**	**2,820**	**25,380**	**3,521,380**	**-**
Purari River Catchment							
Hou Creek	74,970	34	6,800	680	6,120	1,505,520	0.4%
Kuku Creek	8,208	117	23,400	2,340	21,060	185,220	11.4%
Oyomo Creek	2,250	23	4,600	460	4,140	49,140	8.4%
Purari River and subcatchments downstream of the Purari River export pipeline crossing (excludes the Ivo-Urika and Wame-Varoi distributaries)	84,190	424	84,800	8,480	76,230	1,760,120	4.3%
Total:		**598**	**119,600**	**11,960**	**107,640**	**3,500,000**	**-**

* The operations phase disturbance area includes both existing and newly constructed roads but excludes the area of the road right-of-way that is outside of the actual road footprint.
† Disturbance calculations:
Sediment Generated during Operations Disturbance (m^3) = Road Area (ha) x 20 mm/a.
Sediment Generated under Undisturbed Conditions (m^3) = Road Area (ha) x 2 mm/a.
Sediment Generated by the Project (m^3) = Sediment Generated during Operations Disturbance (m^3) – Sediment Generated under Existing Undisturbed Conditions (m^3).
Total Sediment Generated in the Catchment with the Project (m^3) = (Catchment Area (ha) – Road Area (ha)) x 2 mm/a + Road Area (ha) x 20 mm/a.
Project Contribution to the Total Sediment Generated = Sediment Generated by the Project (m^3)/Total Sediment Generated in the Catchment with the Project (m^3).

Field turbidity measurements near the proposed dredging area show high turbidity (150 to 250 NTU) and high TSS levels (100 to 150 mg/L), with much higher spikes during periods of high rainfall and runoff. Turbidity is also expected to be high in Oyomo Creek during the southeast trade winds season (previously measured to be 300 NTU near the confluence with the Purari River) but is lower during the northwest monsoon season (measured at 91 NTU). These existing high turbidity and TSS levels indicate that dredging disturbance is unlikely to significantly exceed natural variability. While temporary spikes may occur during the works, especially if pockets of silts and clay are encountered, these will not significantly change existing water quality conditions in the Purari River or Oyomo Creek. Given the high ambient turbidity, it is expected that the plume will be difficult to visually detect more than 0.5 km downstream of the dredge site; hence, the magnitude of impact is assessed to be ***Minimal***. The Purari River and Oyomo Creek are considered to have a sensitivity of ***Low*** and ***Medium***, respectively, as described in Section 11.3.5.1.1. This provides an overall impact significance rating of ***Negligible*** for both waterways.

11.3.5.1.4 Vessel Traffic

The highest risk of scour from Project-induced river traffic, causing increased TSS and turbidity levels, will be naturally eroding areas (e.g., outer bends of rivers); however, in the context of the highly mobile and turbid nature of the Purari River, the low density of planned vessel movements are considered unlikely to cause changes outside the bounds of natural variability and to be highly localized. Increases in TSS levels and turbidity due to vessel movements are therefore considered to be of ***Minimal*** magnitude.

The Purari River has a ***Low*** sensitivity in terms of hydraulic processes due to its highly dynamic nature. These magnitude and sensitivity rankings provide a ***Negligible*** impact significance.

11.3.5.2 Reduction in Stream Flows from Water Extraction

Table 11.11 highlights that the estimated mean annual flow of the Hou and Boa creeks is 36,791 ML and 48,076 ML respectively. Extracting water from Hou and Boa creeks to drill wells will reduce downstream flow which may have implications for aquatic and terrestrial biodiversity, especially during periods of low rainfall; however, where sufficient environmental flows are maintained by appropriately designed water supply dams and water extraction management procedures, these flow reductions are unlikely to exceed that experienced during extreme weather events. Additionally, impacts will be temporary and occur only during periods of low flow, which may last a period of several months, and only during drilling of wells in the construction phase (estimated at around 25 months). This provides an overall magnitude rating of ***Low***. These waterways are in near-natural condition and have a ***Medium*** sensitivity, providing an overall significance rating of ***Minor*** for this impact.

Water extraction will not adversely affect the Purari River due to the low volumes of extraction compared to flow. The total water extraction requirements for hydrotesting represent less than 0.05% of the total daily flow of the Purari River under minimum flow conditions, as described in Section 11.3.3.2. Water extracted from the Purari River for use at the CPF and for potable water supply for the accommodation camps also represents a very small proportion of the total flow of the Purari River (less than 0.002%). The magnitude of impact of extracting water from the Purari River on the maintenance of environmental flows is therefore ***Minimal.*** The sensitivity of the Purari River is ***Low***, considering the very high natural variability in flow. This provides an overall impact significance rating of ***Negligible***.

11.3.6 Summary of Residual Impacts to Hydrology, Fluvial Geomorphology and Sediment Processes

Table 11.24 provides a summary of the assessment of residual impacts to hydrology, fluvial geomorphology and sediment processes, including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the specific mitigation measures provided in Table 11.21.

All residual impacts are assessed to be ***Negligible*** to ***Minor***, except sediment impacts on several waterways due to earthworks in the construction phase. ***Moderate*** residual impacts are expected to occur on Oyomo Creek, associated with earthworks at the CPF site, and on Mena River, Kuku Creek and Boa Creek, due to earthworks associated with pipeline laying and road construction.

Table 11.24 – Summary of Assessment of Residual Impacts for Hydrology, Fluvial Geomorphology and Sediment Processes

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Impact	
						Sensitivity/ Magnitude	Significance
Changes to hydraulic processes and sediment transport	Earthworks and physical infrastructure	Diversion and filling of waterways in Oyomo Creek catchment.	PRL-15	C	♦ EM004 ♦ EM009	Medium/Low	Minor
		Scour of waterways at pipeline crossings.	Onshore pipeline routes	O		Medium/ Minimal	Negligible
		Change in drainage patterns at waterway road crossings.	Onshore pipeline routes	O		Medium/ Minimal	Negligible
		Soil erosion due to ground disturbance causing increased TSS, turbidity and sedimentation of Oyomo Creek.	PRL-15	C	♦ EM002 ♦ EM003 ♦ EM004 ♦ EM005 ♦ EM006 ♦ EM010 ♦ EM011 ♦ EM012 ♦ EM013	Medium/High	Moderate
		Soil erosion due to ground disturbance causing increased TSS, turbidity and sedimentation of the Mena River, Kuku Creek and Boa Creek.	PRL-15	C		Medium/ Medium	Moderate
		Soil erosion due to ground disturbance causing increased TSS, turbidity and sedimentation of the Era River and Hou Creek.	PRL-15	C		Medium/ Minimal	Negligible
		Soil erosion due to ground disturbance causing increased TSS, turbidity and sedimentation of the Purari River and adjoining subcatchments downstream of the export pipeline crossing.	PRL-15 Onshore pipeline routes	C		Low/Low	Minor
		Soil erosion from roads causing increased TSS, turbidity and sedimentation of Boa Creek, Mena River, Kuku Creek and Oyomo Creek.	PRL-15	O		Medium/Low	Minor
		Soil erosion from roads causing increased TSS, turbidity and sedimentation of Hou Creek and Era River.	PRL-15	O		Medium/ Minimal	Negligible

Table 11.24 – Summary of Assessment of Residual Impacts for Hydrology, Fluvial Geomorphology and Sediment Processes (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Impact	
						Sensitivity/ Magnitude	Significance
Changes to hydraulic processes and sediment transport (cont'd)	Earthworks and physical infrastructure (cont'd)	Soil erosion from roads causing increased TSS, turbidity and sedimentation of the Purari River and adjoining subcatchments downstream of the export pipeline crossing.	PRL-15 Export pipeline route	O	See above	Low/Low	Minor
	Discharge of wastewater, stormwater and hydrotest water	Scour at point source discharge locations.	River transport corridor	C, O		Medium/ Minimal	Negligible
	Dredging at the Logistics Base	Changes in fluvial geomorphology of the Purari River.	River transport corridor	C, O	♦ EM037	Low/Low	Minor
		Increased TSS or turbidity in the Purari River.	River transport corridor	C, O		Low/Minimal	Negligible
		Increased TSS or turbidity in Oyomo Creek.	River transport corridor	C, O		Medium/ Minimal	Negligible
	Logistics and transport (barging along the waterways)	Scour of high-risk areas, with consequent sediment mobilization.	River transport corridor	C, O	♦ EM014	Low/Minimal	Negligible
Reduction in stream flow	Water extraction	Reduced flows in Hou and Boa creeks (due to water extraction for drilling).	PRL-15	C, O	♦ EM015 ♦ EM020	Medium/Low	Minor
		Reduced flows in the Purari River (due to water extraction for the CPF, hydrotesting and potable water supply).	PRL-15	C, O		Low/Minimal	Negligible

C = Construction, O = Operations.

11.4 Surface Water Quality

11.4.1 Context

The PAOI includes a range of high-, moderate- and low-gradient tributary streams and the main Purari River. The Purari River, including the three main delta distributaries (i.e., the Purari, Urika-Ivo and Wame-Varoi rivers), consists of both freshwater and estuarine components, with the estuarine boundary delineated by the inland extent of mangrove vegetation.

The tributary streams of the Era and Purari rivers in PRL-15 are characterized by low electrical conductivity with minimal seasonal variability. These streams are slightly to moderately alkaline and contain high bicarbonate levels, reflecting the widespread presence of calcareous rocks in the catchment. Turbidity levels in these streams are generally lower than the main channel of the Purari River but increase near the confluences with the river. All the waterways have high levels of oxygenation except Nea Creek (which is a tie channel to the PRL-15 oxbow wetlands) where waters are tannin-stained and are likely to be influenced by wetland outflows.

The Purari River has elevated turbidity and suspended sediments levels year-round; although, these reach a peak during the northwest monsoon when river flow is highest flow due to higher rainfall in the upper catchment. Freshwater flows heavily dominate the river, with an underlying saltwater wedge present near the river mouth.

All waters in the PAOI have low levels of nutrients and metals; however, microbiological quality is poor, with coliform bacteria present at levels exceeding drinking water standards.

Baseline characterization has shown no sediment contamination in the Purari River or in other streams in PRL-15 by metals, total petroleum hydrocarbons or other organic contaminants.

11.4.2 Discipline-specific Impact Assessment Method

The significance assessment approach described in Chapter 3 was used to characterize impacts relevant to surface water quality and contamination. Tables 11.25 to 11.28 present magnitude and sensitivity descriptors and impact matrices. Magnitude is assessed considering combinations of (1) geographic extent and (2) the higher of severity and duration.

Compliance standard assessment was also undertaken where appropriate, with reference made to the following standards and guidelines for water quality:

- Papua New Guinea *Environment (Water Quality Criteria) Regulation 2002 (Water Quality Regulation)* for the protection of aquatic ecosystems.
- Papua New Guinea *Public Health (Drinking Water) Regulation 1984 (Drinking Water Regulation)*.
- Other examples of good international industry practice guidelines for ambient water quality, such as the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) and the World Health Organization Guidelines for Drinking-water Quality (WHO, 2017).
- Emission limit values for discharge water quality provided by TOTAL General Specifications (TOTAL, 2015), International Finance Corporation Environmental, Health and Safety guidelines (IFC, 2007a, 2007b) and other examples of good international industry practice.

No numerical modeling studies were undertaken for the impact assessment given the Project's commitment that planned water discharges will meet relevant emission limit values and considering the large assimilative capacity of the Purari River, which is the third largest river in Papua New Guinea (see Section 7.3.1).

Table 11.25 – Impact Magnitude Descriptors Relevant to Surface Water and Contamination

Geographic Extent of Impact*		Severity and Duration of Impact		
		Severity		Duration
5	Impact to any environmental feature that extends significantly beyond the *subregion* (close to *regional*) scale.	5	Extreme impact to surface water or sediment such that: ♦ Intensity, frequency and duration of impact is well outside the range of natural variability; or ♦ One or more environmental values of waters (i.e., social and biodiversity) are no longer supported.	Impact lasts >30 years.
4	Impact to any environmental feature that extends beyond the *subregion* (but not close to *regional*) scale.	4	Severe impact to surface water or sediment such that: ♦ Intensity, frequency and duration of impact is slightly outside the range of natural variability; or ♦ One or more environmental values of waters (i.e., social and biodiversity) are adversely affected but supported in a highly modified condition.	Impact lasts 5 to 30 years.
3	Impact to any environmental feature that extends beyond the *localized* area but does not extend beyond *subregion*.	3	Moderate impact to surface water or sediment such that: ♦ Intensity, frequency and duration of impact is within the range of natural variability, similar to levels experienced during extreme events such as major landslides, extreme droughts, severe storms or tropical cyclones; or ♦ One or more environmental values of waters (i.e., social and biodiversity) are adversely affected but still supported in a slightly to moderately modified condition.	Impact lasts <5 years.
2	Impact to any environmental feature in a *localized* area.	2	Minor impact to surface water or sediment such that: ♦ Intensity, frequency and duration of impact is within the upper range of natural variability but below levels experienced during extreme events such as major landslides, extreme droughts, severe storms or tropical cyclones; and ♦ All environmental values of waters (i.e., social and biodiversity) are maintained.	Impact lasts <1 year.
1	Impact to any environmental feature in a *highly localized* area.	1	Very minor to no impact to surface water or sediment such that: ♦ Intensity, frequency and duration of impact is within the average range of natural variability; and ♦ All environmental values of waters (i.e., social and biodiversity) are maintained.	Impact lasts days to weeks.

**Region* = Area greater than 15,000 km^2 (25% of the Kikori-Purari river basin).
Subregion = Area more than 2 km from the Project footprint but less than 15,000 km^2.
Localized = Area up to 2 km from the Project footprint.
Highly localized = Area up to 0.5 km from the Project footprint.

Table 11.26 – Impact Magnitude Matrix Relevant to Surface Water Quality

Severity/ Duration	Geographic Extent				
	1	**2**	**3**	**4**	**5**
1	Minimal	Low	Medium	Medium	High
2	Low	Low	Medium	High	High
3	Low	Medium	High	Very high	Very high
4	Medium	Medium	High	Very high	Very high
5	Medium	Medium	Very high	Very high	Very high

Table 11.27 – Surface Water Quality Sensitivity of Resource or Receptor

Rating	Descriptor
Very High	♦ Environment is in a natural condition with no evidence of modification; all environmental benchmarks, i.e., water quality criteria, are met. ♦ Environment supports physical properties or processes that are considered rare or exceptional at the regional scale.
High	♦ Environment is in a near-natural condition with minimal human-induced modification; most environmental benchmarks i.e., water quality criteria, are met. ♦ Environment supports physical properties that are considered rare or exceptional at the local scale but are well represented regionally.
Medium	♦ Environment is in a near-natural condition with some human-induced modification; most environmental benchmarks i.e., water quality criteria, are met. ♦ Environment supports physical properties or processes that are well represented at the local scale and experience low inter-decadal variability from extreme events (e.g., cyclones and floods).
Low	♦ Environment is moderately degraded compared to equivalent areas or as measured by environmental benchmarks i.e., water quality criteria. ♦ Environment supports physical properties or processes that are resilient to change, experiencing extreme natural events (e.g., cyclones and floods) every few years.
Minimal	♦ Environment is highly degraded compared to equivalent areas or as measured by environmental benchmarks i.e., water quality criteria. ♦ Environment supports physical properties or processes that are very resilient to change, experiencing extreme natural events (e.g., cyclones and floods) every year.

Table 11.28 – Surface Water Quality Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Receptor				
	Very High	**High**	**Medium**	**Low**	**Minimal**
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.4.3 Identification of Potential Impacts

Potential impacts to surface water quality can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g. flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

The embedded design controls outlined in Section 11.1.3.3 are also relevant to addressing the potential impacts described in Sections 11.4.3.1 to 11.4.3.3.

11.4.3.1 Planned Wastewater Discharges

This section considers impacts associated with planned Project wastewater discharges, which include:

- Hydrotest waters from onshore pipelines.
- Treated sewage effluent from Project facilities and accommodation camps.
- Treated stormwater captured at wellpads and the CPF and, potentially, produced water.

Treated sewage effluent and treated contaminated stormwater from the CPF are planned to be discharged at an outlet to the Purari River downstream from the Logistics Base (Figure 11.9). Hydrotest waters for the onshore pipeline may also potentially be discharged at this location. Contaminated stormwater from the wellpads will also be captured and transported to the CPF stormwater system for treatment prior to release to the Purari River.

Discharges will be tested for compliance with emission limit values described in the Project's water discharge permit, TOTAL General Specifications (TOTAL, 2015) and the International Finance Corporation Environmental, Health and Safety guidelines (IFC, 2007a, 2007b).

Drilling muds or cuttings will not be discharged to surface waters. Cuttings generated during drilling will be separated from the mud so the mud can be reused. The cuttings will then be passed through a dewatering unit and subsequently mixed with cement to produce a stable product that will be disposed of at the general waste landfill. Water produced from dewatering will be reused for drilling.

Produced water generated at the CPF, which will consist only of condensation water since no formation water is expected from the reservoir, will be injected back into the reservoir at the ANT-11 wellpad. This produced water will be routed to a water treatment plant comprising a degassing drum and a flotation unit to achieve an oil concentration in the injected produced water of less than 50 mg/L. As a backup in times of injection outage, produced water will be retained in a tank with sufficient capacity to contain five days of water production. If an injection outage exceeds five days, produced water will be treated as required to meet PNG standards, TOTAL General Specifications (TOTAL, 2015) and IFC (2007b) effluent limits for produced water prior to any discharge to the Purari River.

Further description of planned discharges is provided in the following sections.

Hydrotest Waters

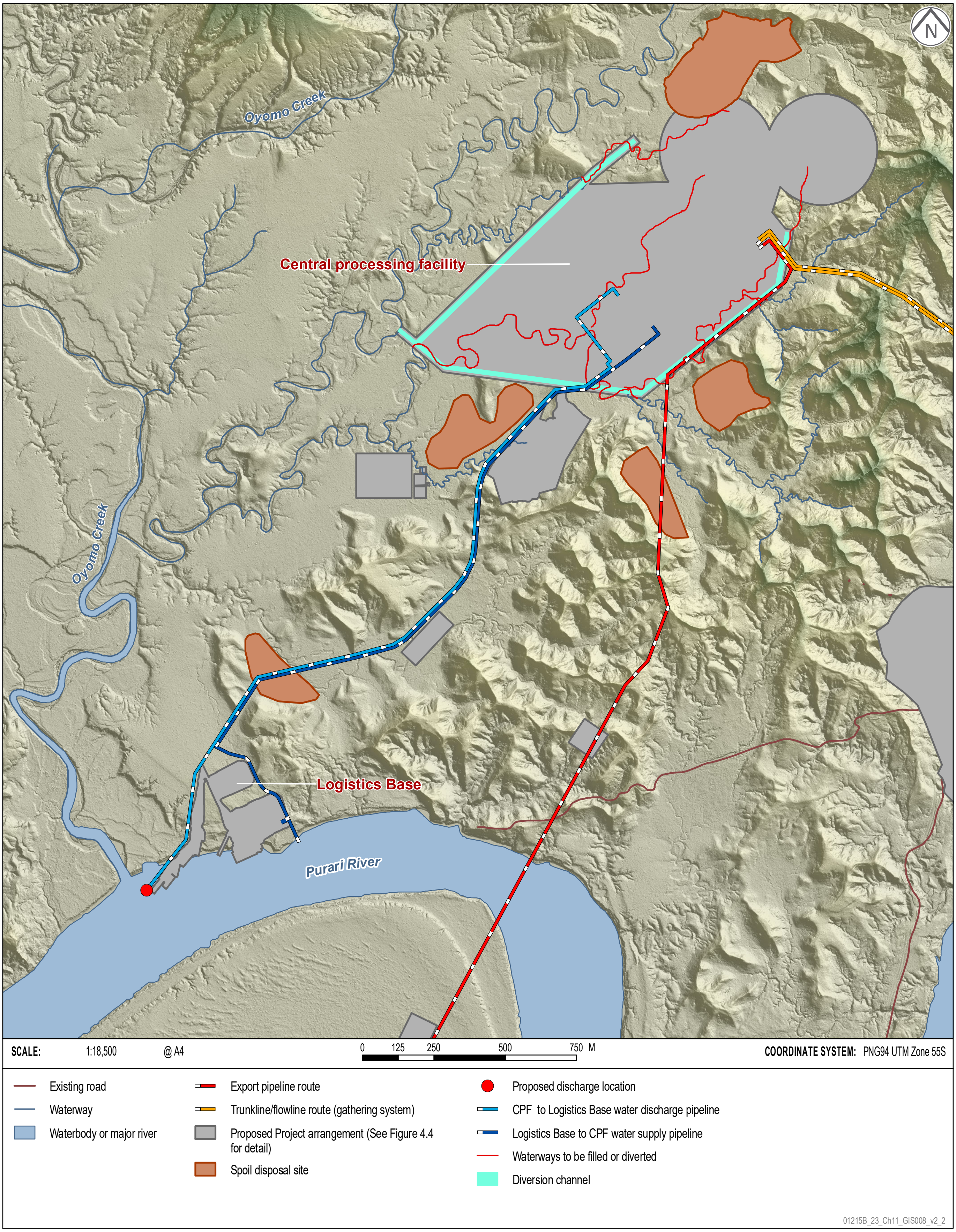
Hydrotesting involves pressurizing the pipeline with water to confirm the integrity of the welds (see Section 4.10.5.2). Hydrotest water will contain a small amount of an oxygen scavenger, such as sodium bisulfite, to inhibit corrosion and a biocide to prevent the development of bacteria that can produce hydrogen sulfide under anaerobic conditions.

The total volume of the onshore pipelines is 69,000 m^3, as described in Section 4.10.5.2; however, the amount of hydrotest water requiring discharge to the environment is expected to be much less than this volume since the pipeline will be tested in sections and the hydrotest water will be recycled from one section of pipe to another. When no longer required, all hydrotest water will be discharged, in accordance with the Project's environment permit. The discharge locations

PROPOSED LICENSED DISCHARGE LOCATION

Papua LNG Project | Environmental Impact Statement

FIGURE 11.9



Source: Figure theme data from BMT, 2019.

and discharge rates will be defined during FEED, and will potentially include discharge to the Purari River.

Sewage Effluent

The Project will discharge treated effluent from sewage produced at the accommodation camps, CPF and Logistics Base facilities. Sewage includes grey water (i.e., effluents from sinks, showers and laundries) and black water (i.e., toilet effluents). This effluent will be treated on site to relevant emission limit values before being discharged to the Purari River at the nominated discharge location. The sludge retained from the treatment process will be managed as part of the camp waste management system and contained to avoid any release to surface waters. The discharge of treated effluent to the environment from construction and operations is expected to meet emission limit values without dilution at least 95% of the time that the plant or unit is operating, in accordance with IFC (2007a); however, even with treatment, sewage discharges will contain elevated nutrient levels. Elevated nutrient concentrations can degrade water quality and aquatic ecosystems in receiving waters. Sewage discharges may also contain pathogens, including *Escherichia coli* (E. coli), *Salmonella* and fecal coliforms.

Treated Stormwater

Stormwater from potentially contaminated areas of the CPF will be captured and treated by the OD1 and OD2 open drain system water collection and hydrocarbon-water separator system treatment system at the CPF (see Section 4.11.1.2). Discharge will take place according to applicable limits. Any contaminated drainage from wellpad areas will drain to a dedicated sump for collection and transport to the CPF where it will be treated with other OD1 wastewater.

Other stormwater discharges to waterways in the PAOI will occur as uncontrolled releases that may also degrade water quality. These relate mainly to sediment from eroded soils (considered in Section 11.3) and hydrocarbon or chemical spills (considered in in Section 11.4.3.3).

11.4.3.2 Discharge of Firefighting Foams

Firefighting foams will primarily be used only in emergency situations (see Chapter 18); however, discharges may also occur when fire system testing and training activities are undertaken; which will occur periodically throughout the life of the Project.

Chemicals in firefighting foams can have direct and indirect acute and chronic impacts on aquatic flora and fauna in waterways due to their persistence, bioaccumulation, toxicity and biochemical oxygen demand (DEHP, 2016). Firefighting foams are also highly dispersive (i.e., they are completely water soluble) in the aquatic environment (DEHP, 2016). All firefighting foams have high biochemical oxygen demand and, if released into a waterway, can cause asphyxiation of aquatic organisms due to depletion of dissolved oxygen concentrations. Most firefighting foams have low acute toxicity; however, the persistence and bioaccumulation of firefighting foam chemicals can have chronic toxicity to aquatic organisms, depending on the foam type (DEHP, 2016). Firefighting foams will not be released in sufficient quantities to accumulate and cause sediment contamination.

11.4.3.3 Accidental Hydrocarbon and Chemical Releases

The OD1 and OD2 open drain networks will capture any accidental hydrocarbon and other chemical spills at the CPF and wellpads and spills will be treated through the hydrocarbon-water separator system (see Section 4.11.1.2). In other parts of the PAOI; however, small volumes of hydrocarbons (including condensate) and other chemicals can be accidentally spilt or leaked to the environment and mobilized during flood events through both riverine and overland flows. These contaminants can degrade receiving environment water quality, degrading aquatic ecosystems (see Section 11.5) and human uses of water resources (Chapter 13). The other parts of the PAOI most at risk of spills are the Logistics Base, jetty and Purari Airstrip (adjacent to the Purari River), where the largest volumes of fuels, oils and chemicals will be stored and handled. Spills and leaks may also potentially occur in other areas of Project activities, including from welded sections of the onshore export pipeline if a weld fails.

11.4.3.4 Dredging

Dredging undertaken adjacent to the jetty at the Logistics Base is not expected to mobilize contaminants from sediments into the water column. Baseline characterization has shown no evidence that metals and metalloids, total petroleum hydrocarbons or other organic contaminants have contaminated sediment in the Purari River or in other streams in PRL-15. The impact on water quality from contaminants mobilized by dredging is considered insignificant and not further assessed.

11.4.3.5 Summary of Potential Impacts

The following potential impacts to surface water quality have been identified:

- Contamination from planned wastewater discharges.
- Contamination caused by discharging firefighting foams during training and testing.
- Contamination caused by accidental hydrocarbon or chemical release.

The consideration of spills or leaks is related to releases that are accidental (but controllable), as part of construction, operation and decommissioning of large projects. Potential impacts of large-scale accidental spills associated with major natural hazards and unplanned events are considered in Chapter 18.

Impacts to water quality from contaminants mobilized by dredging and the potential for contaminants to accumulate in sediments as a result of planned or accidental discharges over time are considered negligible and are not assessed.

11.4.4 Proposed Mitigation and Management Measures

Table 11.29 describes mitigation and management measures to further reduce impacts to surface water quality.

11.4.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to surface water quality subject to the embedded design controls in Section 11.4.3 and the successful implementation of the proposed mitigation and management measures in Section 11.4.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

11.4.5.1 Planned Discharges of Wastewaters

Hydrotest Water

Waters of the Purari River are in near-natural condition with some potential human-induced modification of water quality, including high fecal coliform levels (see Section 7.4.2.1); however, apart from microbiological quality, ambient water quality guidelines are met and the sensitivity of the Purari River is ***Medium***.

Table 11.29 – Surface Water Quality Mitigation Strategies and Management Plans

Potential impact	Mitigation Strategy	Relevant Management Plan
Contamination from planned wastewater discharges	♦ Sewage effluents from Project facilities will be treated to meet the environment (waste discharge) permit before discharge, in accordance with applicable standards [EM008]. ♦ Water from trenches will be discharged in accordance with applicable water quality standards with erosion and sediment controls where relevant [EM011]. ♦ Hydrotest water management will consider: – The definition of volume and discharge rates and discharge locations. – Chemicals additives selection, according to requirements defined in embedded design controls. – Reusing hydrotest water to minimize the discharge volume. – Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. – Monitoring hydrotest water discharges to the environment against applicable limits [EM015].	Waste Management Plan; Water Management Plan
Contamination caused by discharging firefighting foams during training and testing	♦ Training and test releases of firefighting foams at the CPF are to be contained within appropriate drainage water treatment networks. [EM016].	Water Management Plan; Hazardous Material Management Plan
Contamination caused by accidental hydrocarbon or chemical release	♦ Vehicle wash down and fuel handling will be undertaken considering possible receptors e.g., streams, Purari River and the marine environment [EM017]. ♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site contingency plans, that will consider fire management measures. – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018]. ♦ Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and *Marine Pollution (Ships and Installations) Act 2013* [EM019].	Hazardous Material Management Plan; Emergency Response Plan

Small volumes of water (i.e., 0.05% of the daily flow of the Purari River) used for hydrotesting may potentially be discharged to the Purari River at the Logistics Base. Discharges will comply with effluent limits described in IFC Environmental, Health and Safety Guidelines for Onshore Oil and Gas Development (IFC, 2007b) and with criteria within relevant PNG environmental regulations. Chemical additives to hydrotest water will be selected considering lowest toxicity, lowest bioaccumulation potential and highest biodegradation. Therefore, any hydrotest water discharge impacts on the Purari River water quality would be highly localized, very short-term, and environmental values of waters would be maintained. The magnitude of impact is therefore expected to be ***Minimal***. This provides an overall impact significance rating of ***Negligible***.

Sewage Effluent

The sensitivity of the Purari River is ***Medium***. Treated sewage discharges to the Purari River will comply with effluent limits (IFC Environmental, Health and Safety General Guidelines (IFC, 2007a)) for discharges to receiving waters and with criteria within relevant PNG environmental regulations. Notwithstanding water treatment, sewage effluent contains nutrients. Increased nutrient concentrations can potentially cause algal blooms, leading to eutrophication; however, sewage discharges are unlikely to cause such impacts because of the rapid mixing and dilution that will occur given the high flow rates of the Purari River and the high turbidity of the river which will reduce light penetration and hence the potential for algal growth. Any impacts on the Purari River water quality from sewage discharge will therefore be highly localized, and existing environmental values will be maintained; hence, the magnitude of impact is ***Minimal***; therefore, the overall impact significance rating is ***Negligible***.

Contaminated Stormwater

The sensitivity of the Purari River is ***Medium***. Stormwater from potentially contaminated areas of the CPF and wellpads will be captured in the OD1 and OD2 open drain networks and treated by the water treatment system at the CPF. Discharge will take place according to applicable limits.

Impacts on the Purari River water quality will be highly localized and short-term given the large flow of the Purari River, and environmental values of waters will be maintained; hence, the magnitude of impacts is ***Minimal***, giving an overall impact significance rating of ***Negligible***.

Should produced water be required to be discharged to the Purari River in times of injection outage and exceedance of holding tank capacity, similar impacts would be expected given the similar water treatment that would be undertaken prior to discharge.

11.4.5.2 Discharge of Firefighting Foams

The sensitivity of the Purari River is ***Medium***. Firefighting foams will be selected in consideration of the lowest toxicity, lowest bioaccumulation potential, highest biodegradation and those subject to bans or phase-outs. They will only be tested in contained areas at the CPF, reducing the risk of pollution of waterways. The foams will be captured in the OD1 and OD2 open drain networks and directed to an observation basin where degradation will occur and the effluent will be treated prior to it being discharged to the Purari River. Such discharges will only occur following routine fire response training and equipment testing exercises, or in the event of a fire, which is considered in Chapter 18.

Given the proposed mitigation measures, impacts on Purari River water quality from these periodic fire response exercises will be highly localized and very short-term, and environmental values of waters would be maintained. The magnitude of impacts is therefore ***Low***, giving an overall impact significance rating of ***Minor***.

11.4.5.3 Accidental Hydrocarbon and Chemical Releases

Waterways in the PAOI are in near-natural condition, with some human-induced modification but with most ambient water quality criteria met, and therefore have ***Medium*** sensitivity.

The assessment addresses spills or leaks that are typically accidental (but controllable) as part of construction, operation and decommissioning of large projects. Large-scale accidental spills associated with major natural hazards and unplanned events are considered in Chapter 18.

Impacts on stream water quality from hydrocarbon or chemical spills or leaks will be avoided or contained and remediated by implementing the embedded design controls outlined in Section 11.1.3.3 and the mitigation measures described in Section 11.4.4. The OD1 and OD2 open drain networks will capture any fuel or chemical spills at the CPF and wellpads and treated prior to discharge to the Purari River. These discharges are planned discharges that are addressed in Section 11.4.5.1. For other areas of Project activities, e.g., construction activities along the export pipeline route, potential accidental releases to surface water would not be controlled to a known discharge location however, they would be avoided or contained in the first instance.

Given the dispersive nature of hydrocarbons due to their density being lighter than water and their propensity to be transported on the water surface, rather than to mix through the water column, should a spill reach surface waters, the impact on surface water quality may potentially extend up to 2 km downstream (see Table 11.25). Impacts from incidental spills of chemicals would be expected to extend to a smaller extent due to their less hydrophobic properties, depending on the particular chemical involved, allowing dispersion and dilution through the water column. Impacts would be for a short period, and the environmental values of the waterways will not be adversely affected over the longer term. The magnitude of impacts is therefore categorized to be ***Low***.

The overall significance rating for impacts on water quality of PAOI waterways due to accidental hydrocarbon or chemical releases is therefore ***Minor***.

Barge traffic and transfers at the Logistics Base may also cause small amounts of hydrocarbons or chemicals to be spilt or leaked into the Purari River. Such spills (particularly fuel) have the potential to be difficult to contain, despite implementing oil spill response procedures. Impacts on water quality from a spill would only be for a short period, given the high assimilative capacity of the river due to its large flows; however, such a spill may extend further than 2 km downstream, depending on the volume and nature of the spill. Water quality would be expected to recover to its previous condition prior to the spill within days. The magnitude of impact is therefore categorized to be ***Medium***. Given the sensitivity of the Purari River is ***Medium***; the overall impact significance rating is ***Moderate***.

11.4.6 Summary of Residual Impacts to Surface Water Quality

Table 11.30 provides a summary of the assessment of residual impacts to surface water quality, including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the specific mitigation measures provided in Table 11.29.

All residual impacts are assessed to be ***Negligible*** to ***Minor***, except impacts from accidental hydrocarbon or chemical spills directly into the Purari River. Any such accidental spills associated with barge traffic along the Purari River, and fuel and chemical transfers at the Logistics Base may potentially have ***Moderate*** residual impacts on surface water quality. This assessment assumes that, while impacts would only be of short duration, the spill would extend further than 2 km downstream, which would be dependent upon the volume and nature of the spill. Water quality would be expected to recover to its previous condition prior to the spill in hours.

Table 11.30 – Summary of Assessment of Residual Impact Significance for Surface Water Quality

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Contamination from planned wastewater discharges.	Disposal of pipeline hydrotest water.	Deterioration in the Purari River water quality.	PRL-15	C	♦ EM008 ♦ EM011 ♦ EM015	Medium/ Minimal	Negligible
	Sewage effluent discharge.	Deterioration in the Purari River water quality.	PRL-15	C, O		Medium/ Minimal	Negligible
	Treated stormwater discharge and produced water discharge.	Deterioration in the Purari River water quality.	PRL-15	O		Medium/ Minimal	Negligible
Contamination from discharge of firefighting foams.	Firefighting foam discharge during fire response training and equipment testing.	Deterioration in the Purari River water quality.	PRL-15	O	♦ EM016	Medium/Low	Minor
Contamination from accidental hydrocarbon or chemical releases.	Use of hazardous materials.	Deterioration in water quality of the PAOI waterways.	PRL-15 Onshore pipeline routes	C, O	♦ EM017 ♦ EM018 ♦ EM019	Medium/Low	Minor
		Deterioration in the Purari River water quality.	River transport corridor	C, O		Medium/ Medium	Moderate

C = Construction, O = Operations.

11.5 Freshwater and Estuarine Biodiversity

11.5.1 Context

Several different types of waterways and aquatic ecosystems occur in the PAOI, including:

- The main channel of the Purari River and the delta distributaries (i.e., the Purari, Urika-Ivo, and Wame-Varoi rivers), which are characterized by high turbidity and morphological variability.
- High-, moderate- and low-gradient tributary streams of the Purari and Era river catchments.
- Freshwater swamp forests and woodlands.
- Oxbow lakes and off-river waterbodies.
- Estuarine wetlands and mangroves.

These ecosystems are located in the Southwest New Guinea – Trans-Fly Lowland ecoregion (No. 815) (Abell et al., 2008). This region is noted for high levels of endemism (mostly in the Fly and Kikori river catchments) and strong affinities to the north Australian fauna.

Many freshwater fish and macrocrustacean species of the lower Purari and Era river catchments have marine origins or complete part of their lifecycle in marine and estuarine environments. Estuarine areas have higher species numbers than freshwater environments, and many of the species occurring in estuaries also are found in freshwater habitats. The most abundant species recorded in the Purari River surveys are estuarine glass perchlet (*Ambassis macracanthus*), spoon-snouted catfish (*Nedystoma novaeguineae*) and greenback mullet (*Planiliza subviridis*), while a variety of freshwater prawns, gudgeons, gobies, grunters and rainbowfish dominated tributary streams.

Threatened and otherwise important aquatic vertebrate species known or likely to occur in the Purari River include sawfish (*Pristis pristis*, *P. zijsron*, *Anoxypristis cuspidata*), sharks (*Glyphis garricki*, *G. glyphis*, *Carcharhinus leucas*), rays (*Glaucostegus typus*, *Urogymnus granulatus*), river dolphin (*Sousa sahulensis*, *Orcaella heinsohni*), freshwater turtle (*Carettochelys insculpta*, *Pelochelys bibroni*) and crocodile (*Crocodylus porosus*).

A variety of aquatic macroinvertebrates are supported in these ecosystems, with mayflies and copepods dominating in freshwater habitats, and polychaete worms in estuarine areas. Two species of endemic aquatic macroinvertebrate (*Ciliometra setosa* and *Iobates ivimka*) could occur in the PAOI, based on Polhemus et al. (2004) but have not been confirmed.

No exotic fish species were identified in the PAOI during baseline surveys; however, anecdotal evidence indicates the potential presence of common carp (*Cyprinus carpio*) and tilapia (*Oreochromis mossambica*) in the Purari River catchment. Similarly, only one aquatic weed species, the water hyacinth (*Eichhornia crassipes*), was identified in the PAOI; but other species that may occur or present a future threat include the giant salvina (*Salvinia molesta*), water cabbage (*Pistia stratiotes*) and hydrilla (*Hydrilla verticillata*).

11.5.2 Discipline-specific Impact Assessment Method

The freshwater and estuarine biodiversity impact assessment is based on the significance assessment approach. Tables 11.31 to 11.34 present magnitude and sensitivity descriptors and impact matrices which have been developed by specialists based on expertise, experience and precedents from other peer reviewed impact assessments. Magnitude is assessed considering combinations of (1) geographic extent and (2) the higher of severity and duration. Sensitivity ratings have been assigned for ecosystems and habitats or species based on a conservative approach (i.e., if descriptors from a range of ratings apply, the highest rating is assigned).

Table 11.31 – Impact Magnitude Descriptors Relevant to Freshwater and Estuarine Biodiversity

Geographic Extent of Impact*		Severity and Duration of Impact		
		Severity		Duration
5	Impact to: ♦ >15% of an ecosystem's or habitat type's range in the region; or ♦ >10% of a species' distribution in the subregion.	5	Impact to habitat, ecosystem or species that: ♦ Is very large or severe relative to natural variability; or ♦ Severely reduces ecosystem viability in the affected area; or ♦ Causes a significant change in the ecosystem community composition, including functional loss of keystone species and potentially leading to ecosystem collapse; or ♦ Causes a very large decline in a species population that threatens the viability of a subregional population or that may threaten the viability of the regional population.	Impact lasts >30 years.
4	Impact to: ♦ 5 to 15% of an ecosystem's or habitat type's range in the region; or ♦ 5 to 10% of a species' distribution in the subregion.	4	Impact to habitat, ecosystem or species that: ♦ Is large relative to natural variability; or ♦ Reduces ecosystem viability in the affected area; or ♦ Causes a loss or decline of multiple species populations that alters the composition and may reduce the viability of ecosystem communities or keystone populations; or ♦ Causes a large decline in a species population that may threaten the viability of a subregional population.	Impact lasts 5 to 30 years.
3	Impact to: ♦ <5% of an ecosystem's or habitat type's range in a region; or ♦ 1 to 5% of a species' distribution in a subregion.	3	Impact to habitat, ecosystem or species that: ♦ Is moderate and readily detectable with respect to natural variability; or ♦ May reduce ecosystem viability in the affected area; or ♦ Causes a decline of multiple species' populations, with moderate changes to community composition that is unlikely to reduce the viability of ecosystem communities or keystone populations; or ♦ Causes a moderate decline in a species population that is unlikely to threaten the viability of a subregional population.	Impact lasts <5 years.
2	Impact to: ♦ <1% of a species' distribution in a subregion; or ♦ Any environmental feature in a localized area.	2	Impact to habitat, ecosystem or species that: ♦ Is low and marginally detectable with respect to natural variability and is readily able to regenerate on remaining habitat; or ♦ Causes a minor decline in one or more species populations, although with no detectable change in the composition or viability of ecosystem communities and populations; or ♦ Causes a minor decline that does not threaten the viability of a subregional population.	Impact lasts <1 year.
1	Impact to any environmental feature in a highly localized area.	1	Impact to habitat, ecosystem or species that: ♦ Is very low and undetectable with respect to natural variability; or ♦ Causes no measurable decline in a species population.	Impact lasts days to weeks.

**Region* = Area greater than 15,000 km^2 (25% of the Kikori-Purari river basin).
Subregion = Area more than 2 km from the Project footprint but less than 15,000 km^2.
Localized = Area up to 2 km from the Project footprint.
Highly localized = Area up to 0.5 km from the Project footprint.

Table 11.32 – Impact Magnitude Matrix Relevant to Freshwater and Estuarine Biodiversity

Severity/ Duration	Geographic Extent				
	1	2	3	4	5
1	Minimal	Low	Medium	Medium	High
2	Low	Low	Medium	High	High
3	Low	Medium	High	Very high	Very high
4	Medium	Medium	High	Very high	Very high
5	Medium	Medium	Very high	Very high	Very high

Table 11.33 – Freshwater and Estuarine Biodiversity Sensitivity of Resource or Receptor

Rating	Descriptor – Ecosystems and Habitats	Descriptor - Species
Very High	♦ Ecosystem or habitat supports IUCN Critically Endangered species (or equivalent based on expert opinion). ♦ Ecosystem or habitat is critical to the survival of a species. ♦ Ecosystem or habitat is unique or very rare locally and regionally.	♦ IUCN Critically Endangered species. ♦ Lower-listed IUCN species whose true conservation status is likely to be equivalent to IUCN Critically Endangered at the national or global scale, according to expert opinion. ♦ Endemic or restricted-range species with very low abundance in the area of occurrence.
High	♦ Ecosystem or habitat supports high or regionally important concentrations of conservation-listed species (or equivalent based on expert opinion) or endemic or restricted-range species. ♦ Ecosystem or habitat supports a unique assemblage or high proportion of habitat specialist species. ♦ Ecosystem or habitat is of local or regional importance for migratory species. ♦ Ecosystem or habitat is in a protected area. ♦ Ecosystem or habitat is unmodified. ♦ Ecosystem or habitat is rare locally and regionally with limited connectivity to comparable ecosystems or habitats.	♦ IUCN Vulnerable or Endangered species. ♦ Lower-listed IUCN species whose true conservation status is likely to be equivalent to IUCN Vulnerable or Endangered at the national or global scale, according to expert opinion. ♦ Endemic or restricted-range species with low abundance in the area of occurrence. ♦ Species that are highly adapted habitat specialists.
Medium	♦ Ecosystem or habitat supports viable assemblages of native flora and fauna species that are largely unaltered from the original composition; conservation-listed species may be present. ♦ Ecosystem or habitat has not been significantly modified in terms of primary ecological functions and composition. ♦ Ecosystem or habitat has local and regional equivalents with some connectivity to comparable ecosystems or habitats.	♦ Species Protected under the *Fauna (Protection and Control) Act 1966*. ♦ CITES Appendix I species. ♦ IUCN Near Threatened species. ♦ IUCN Data Deficient, Not Evaluated or Least Concern species whose true conservation status is likely to be equivalent to IUCN Near Threatened at the national or global scale, according to expert opinion. ♦ Endemic or restricted-range species with moderate to high abundance in the area of occurrence. ♦ Species that are habitat specialists but able to occur in other marginal habitat. ♦ Fish or macrocrustacean species of fisheries significance.

Table 11.33 – Receptor Sensitivity Descriptors Relevant to Freshwater and Estuarine Biodiversity (cont'd)

Rating	Descriptor – Ecosystems and Habitats	Descriptor - Species
Low	♦ Ecosystem or habitat supports viable assemblages of some native species, but flora and fauna communities are significantly altered from original composition found elsewhere locally; invasive species may be present. ♦ Ecosystem or habitat has some degradation. ♦ Ecosystem or habitat is common locally and regionally with moderate connectivity to other comparable ecosystems or habitats.	♦ CITES Appendix II species. ♦ IUCN Least Concern species. ♦ IUCN Data Deficient or Not Evaluated species considered to be common or widespread, according to expert opinion.
Minimal	♦ Ecosystem or habitat supports few or no native species, or invasive species are prevalent. ♦ Ecosystem or habitat is highly degraded. ♦ Ecosystem or habitat is common and widespread locally, regionally and nationally, and has high connectivity to other comparable ecosystems or habitats.	♦ Native species well adapted to habitat loss or degradation. ♦ Invasive species.

Note: these sensitivity ratings differ from those assigned as part of the baseline characterization in Chapter 7, which were specific to species, ecosystems and sensitive habitat features. Ratings in this table consider the descriptors for these baseline sensitivity ratings and how they relate to broader receptors discussed in the impact assessment.

Table 11.34 – Freshwater and Estuarine Biodiversity Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Receptor				
	Very High	High	Medium	Low	Minimal
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.5.3 Identification of Potential Impacts

Potential impacts to freshwater and estuarine biodiversity can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

11.5.3.1 Direct Disturbance and Habitat Fragmentation

11.5.3.1.1 Vegetation Clearing and Earthworks

Figures 11.10 to 11.12 show the Project infrastructure footprint and the different types of aquatic biotopes. They show that the aquatic biotopes that occur in infrastructure footprints and that will be directly disturbed are mostly moderate- and low-gradient tributary streams.

The largest area of direct disturbance is the filling of tributary streams located in the CPF footprint (see Figure 11.6 and Figure 11.11). Approximately 5.5 km of streams will be lost, all of which occurs in the unnamed eastern tributaries of the Oyomo Creek catchment.

DIRECT DISTURBANCE TO AQUATIC HABITATS IN THE HOU CREEK AND ERA RIVER CATCHMENTS

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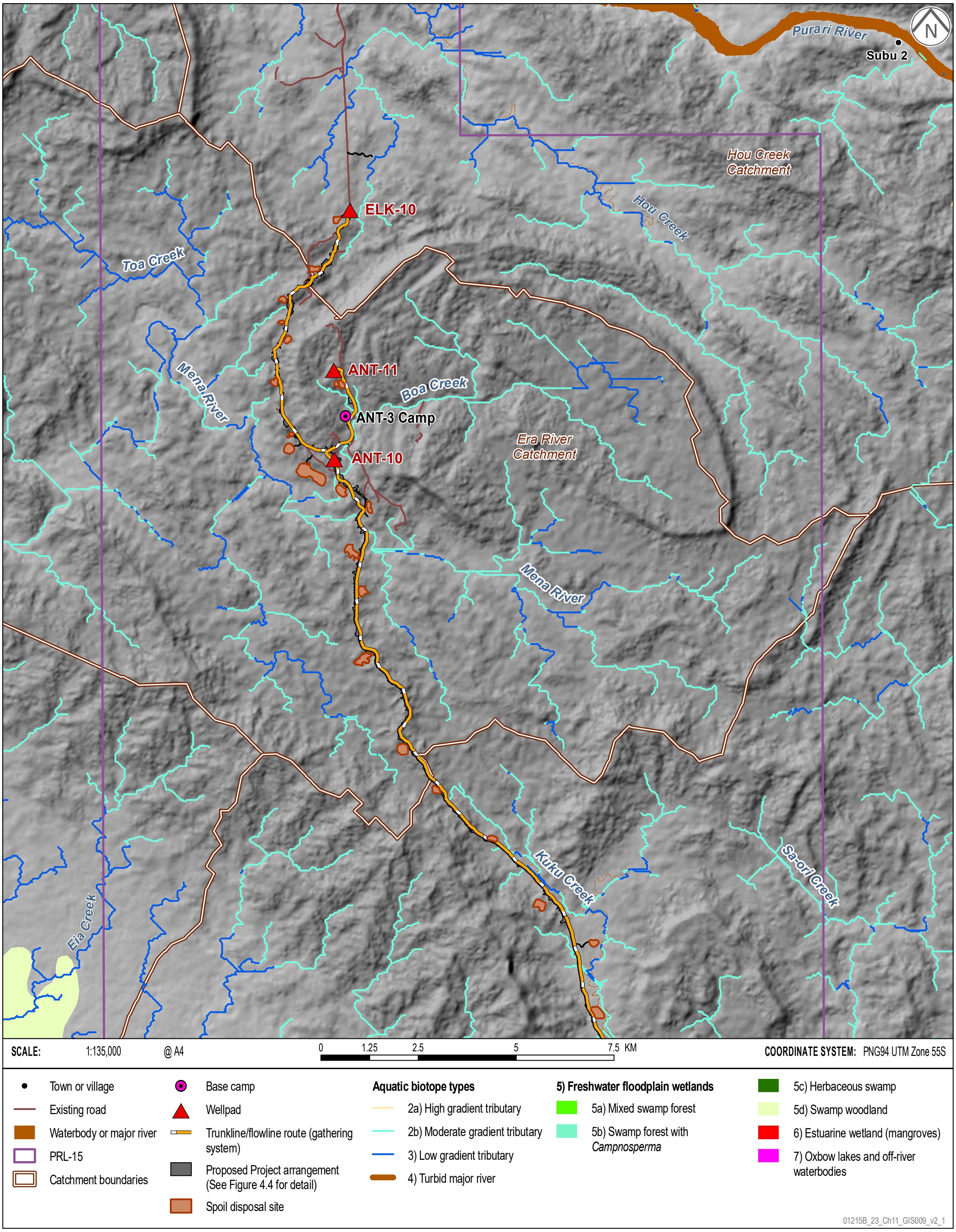
FIGURE 11.10



Source: Figure theme data from BMT, 2019.

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DIRECT DISTURBANCE TO AQUATIC HABITATS IN THE KUKU CREEK AND OYOMO CREEK CATCHMENTS

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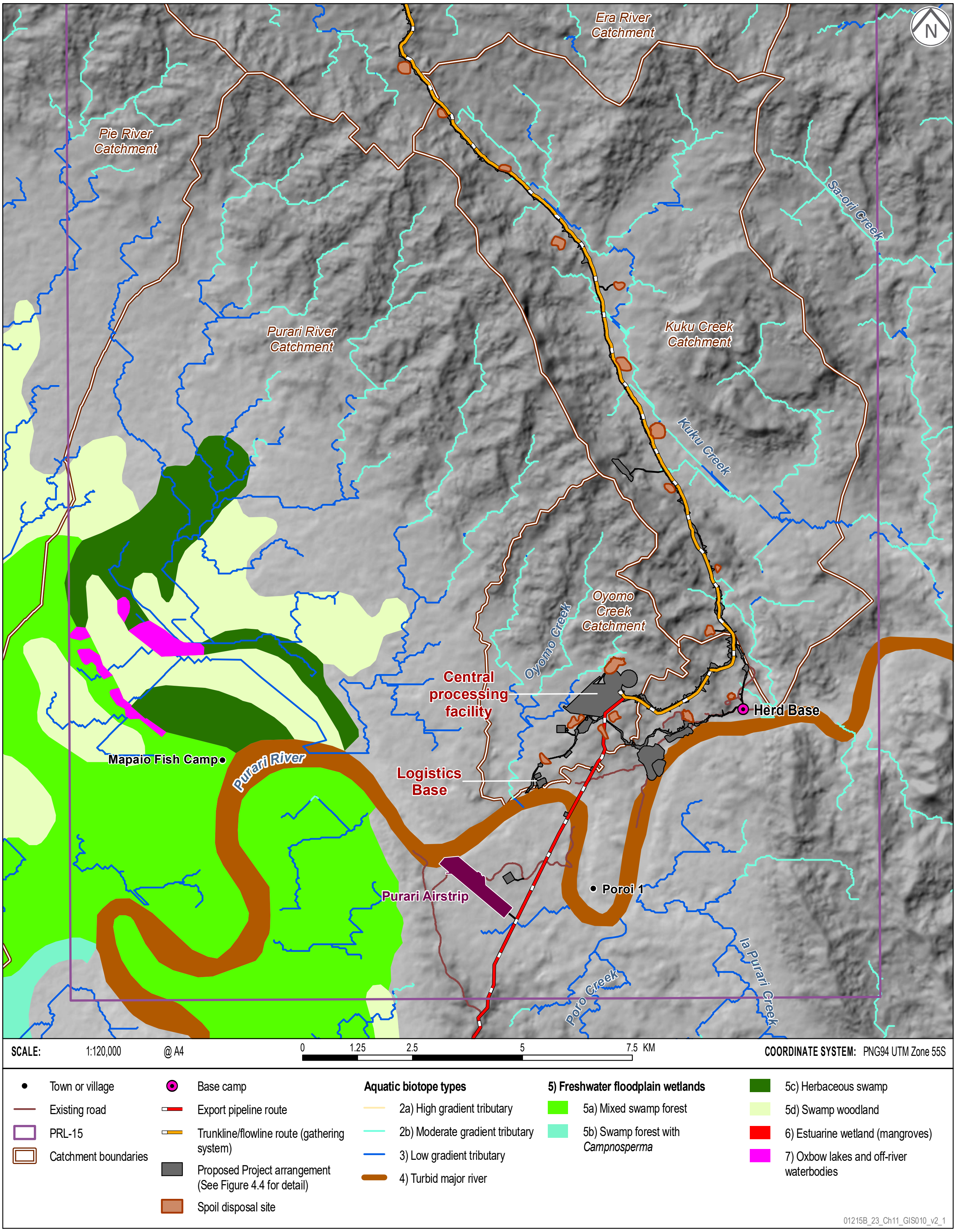
FIGURE 11.11



Source: Figure theme data from BMT, 2019.

DIRECT DISTURBANCE TO AQUATIC HABITATS ALONG THE EXPORT PIPELINE ROUTE

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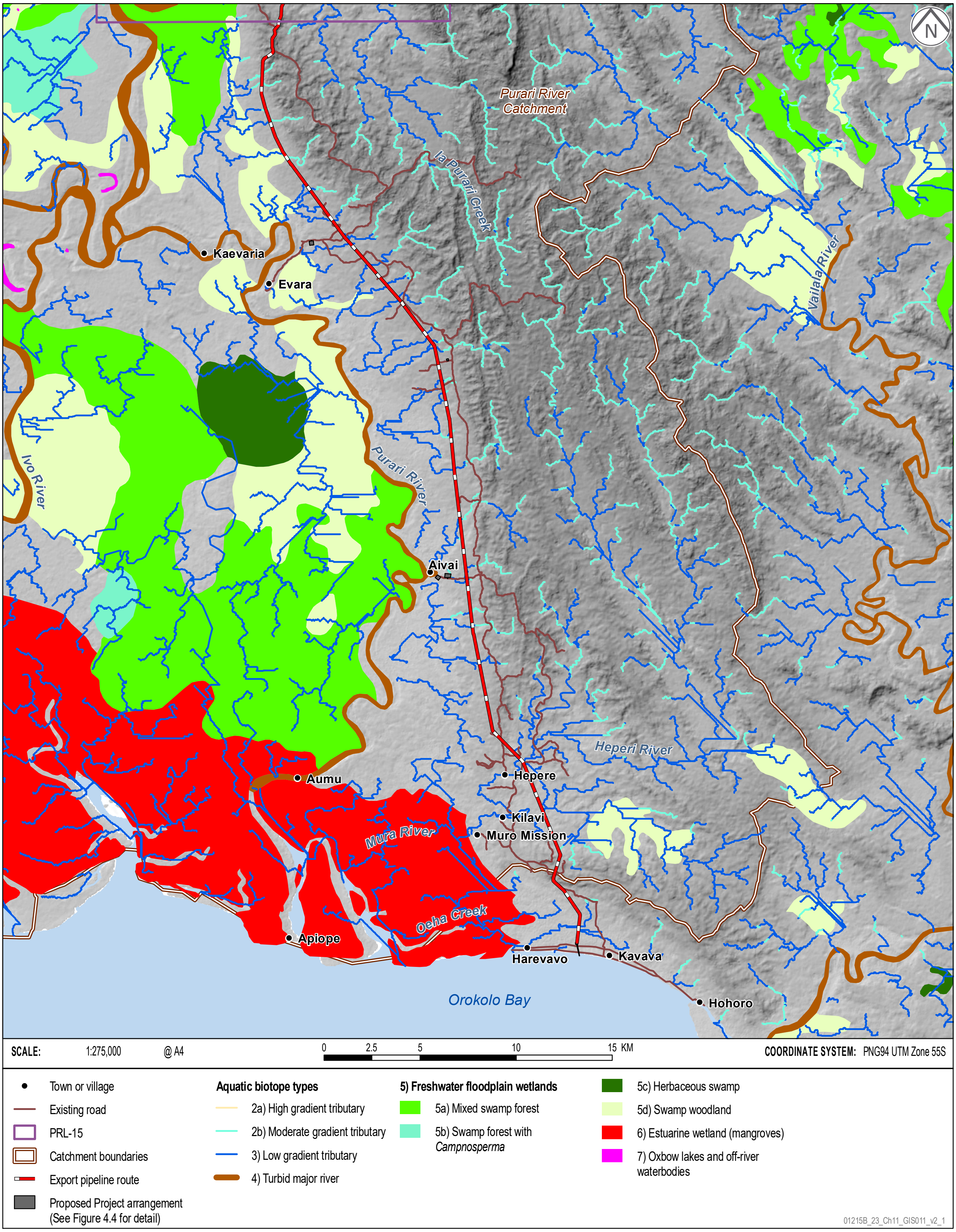
FIGURE 11.12



Source: Figure theme data from BMT, 2019.

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Plate 11.6 – Oyomo Creek Tributary (Site 2) During July 2016

Photo: BMT WBM.

Plate 11.7 – Oyomo Creek Tributary (Site 2) During February 2017

Photo: BMT WBM.

Habitat loss associated with road crossings is discussed in Section 11.5.3.1.2. The affected waterways are low-gradient tributary streams that are largely intact, as shown in Plates 11.6 and 11.7, which show a tributary of Oyomo Creek sampled during the freshwater baseline survey in July 2016 and February 2017 (Site 2). These streams:

- Provide habitat for a wide range of stream-dwelling invertebrate species and a fish fauna mostly comprising small-bodied fish species and freshwater prawns. The small area of habitat that will be affected is well represented outside the CPF footprint in the Oyomo subcatchment in the wider Purari River catchment.
- Are unlikely to provide critical habitat for threatened aquatic species. All stream reaches upstream of the CPF footprint are headwater streams; therefore, habitat loss in the CPF would not fragment or isolate important habitat for threatened aquatic species in upstream areas.
- Are not unique in the PAOI, as similar waterways occur nearby, including the tributary streams of Nea and Kuku creeks.

11.5.3.1.2 Pipeline and Road Crossings of Waterways

Project pipeline and road infrastructure will cross waterways, as shown in Figures 11.10 to 11.12. The pipeline crossing of the Purari River will be undertaken using horizontal directional drilling (see Section 4.10.5.3). For all other waterways, open trenches will be developed into which pipes will be laid before immediate backfilling. The likely method for watercourse crossings will be to temporarily dam the watercourse and pump water around the work area. Each pipeline crossing location will also involve a road crossing, using a flume pipe to maintain flows.

The waterways crossed by roads and open trenching include Hou Creek, Boa Creek, Mena River and Kuku Creek in PRL-15, and several named and unnamed waterways along the export pipeline route.

Construction of waterway crossings has the potential to cause the following impacts:

- Direct loss or degradation of in-stream habitat during construction.
- Creation of barriers to aquatic fauna movements and associated fragmentation of aquatic habitat.

Direct Loss or Degradation of Habitat

Trenching for the pipeline crossings will likely involve installing coffer dams on both sides of the trench to prevent the ingress of stream waters, excavating a trench using a backhoe or other excavating machine, placing the pipeline in the trench, and the subsequent filling of the trench (with parent bed material) and burial of the pipeline. The excavation, removal and subsequent refilling of the pipeline trench will disturb bed and bank environments. Coffer dams will be removed following installation of the pipeline.

Trenching and culvert construction will also cause localized impacts to bed and bank structure (i.e., bed and bank erosion, slumping and bed aggradation), which could cause temporary disturbance or mortality to aquatic fauna.

Construction works will also cause sedimentation and higher turbidity near the works footprints. These impacts are discussed in Section 11.5.3.2.

Habitat Fragmentation and Fish Movement Barriers

Aquatic habitat in the footprint of road crossings will be permanently altered due to:

- Shading in the culvert: inadequate light can deter fish passing through culverts.
- Changes to local hydraulic conditions in the culvert: inadequately sized culverts can create excessive turbulence and flow velocities or reduce water depths, presenting a barrier to fish movements.

Instream barriers could restrict migratory and daily movement patterns of aquatic fauna. Several catadromous and potamodromous fish species and invertebrates (freshwater prawns) occur in the PAOI and rely on passage between upstream and downstream environments to complete their life cycles. Inappropriately sized or positioned culverts for road crossings can limit the ability of these species to navigate through the infrastructure under certain flow conditions. Design measures will be required to maintain flow conditions and fish passage.

11.5.3.1.2 Water Extraction and Impoundment

Several water supply options are under consideration for the Project, as discussed in Section 11.3.3.2:

- Extraction from the Purari River to supply water for the CPF and accommodation camps.
- Extraction from Hou and Boa creeks to supply water for drilling wells during the construction period. This will involve direct extraction and temporary installation of a dam and extraction of impounded waters.

The approximate locations of proposed extraction points are shown in Figure 11.8.

Extraction from the Purari River will have a negligible impact on flow, as discussed in Section 11.3.3.2, and has no implications for aquatic biodiversity.

Impoundment of parts of Hou and Boa creeks during the installation period for the temporary dams has the potential to change downstream hydraulic habitat conditions and modify and fragment habitat. The dams will be in place for up to 25 months and are likely to be constructed using water diversion techniques (e.g., coffer dams) to provide a dry construction area.

The two potential dam sites correspond closely to two freshwater baseline survey sites: Site 4 (Boa Creek) and Site 9 (Hou Creek). These sites are shown in Plates 11.8 to 11.11 and description of the existing conditions at these locations is provided in Table 11.35. While both waterways are high- to moderate-gradient streams, Site 9 is in the headwaters of the Hou Creek catchment, while Site 4 is further downstream and fed by multiple upstream tributaries.

Table 11.35 – Description of Existing Condition of Potential Dam Sites

Parameter	Site 4 (Boa Creek)	Site 9 (Hou Creek)
Aquatic ecosystems represented	Lotic: perennial stream (high gradient)	Lotic: perennial stream (moderate gradient)
Hydraulic habitat units	Run, riffle cascades and pool	Run, riffle, glide and pool
Approximate mean stream width – southeast winds season	30 m	3 m
Approximate mean stream width – northwest monsoon season	30 m	3 m
Maximum stream depth – southeast trade winds season	>2 m	0.3 m
Maximum stream depth – northwest monsoon season	1.5 m	0.3 m

Due to the smaller flows of Boa and Hou creeks, compared with the Purari River, water extraction has a greater potential to degrade downstream aquatic ecosystems, especially during periods of low flow. Potential impacts to downstream aquatic ecosystems due to changes in flow regimes include changes to aquatic habitat availability and connectivity, altered fauna movement patterns, alterations to reproductive processes, and loss of aquatic productivity.

Plate 11.8 – Boa Creek (Site 4) During Southeast Trade Winds Season (July 2016)

Photo: BMT WBM

Plate 11.9 – Boa Creek (Site 4) During Northwest Monsoon Season (February 2017)

Photo: BMT WBM

Plate 11.10 – Hou Creek (Site 9) During Southeast Trade Winds Season (July 2016)

Photo: BMT WBM.

Plate 11.11 – Hou Creek (Site 9) During Northwest Monsoon Season (February 2017)

Photo: BMT WBM.

Modifications to Hydraulic Conditions

Smakhtin et al. (2004) undertook a global-scale pilot assessment of environmental water requirements for freshwater-dependent ecosystems, which included Papua New Guinea. They suggested that freshwater-dependent ecosystems required approximately 20 to 50% of the total renewable water resources (i.e., long-term mean annual runoff) to maintain ecosystems in ‘fair’ condition. Papua New Guinea streams were estimated to require approximately 37% of the total renewable water resource to maintain ecosystem condition, but this greatly depended on site-specific conditions and sensitivities. Aquatic biota in catchments with more stable, perennial flows, as occurs in most tributary streams in the PAOI, are considered to be more intolerant of extended periods of low to no flow and are therefore more sensitive to human-induced flow changes. Furthermore, low flow requirements are considered important in maintaining environmental water requirements for aquatic biota in such systems. Water extraction by the Project; therefore, has the potential to alter aquatic ecosystems in receiving environments downstream of impoundment points if inappropriately managed.

Aquatic Habitat Modification and Fragmentation

The dam impoundments will represent a change to aquatic habitat conditions. Depending on the dam design, this could include:

- Conversion of waters in the impoundment from lotic (flowing waters) to lentic (non-flowing) habitat.
- Increase in waterway extent and depth in the impoundment, potentially flooding riparian vegetation.
- Creation of suitable habitat for aquatic macrophytes, including aquatic weeds.
- Creation of suitable habitat for aquatic fauna that prefer non-flowing waters, including a range of alien fish species and pest insects.

The severity of impact from waterway impoundment is largely dependent on the dam design and site characteristics.

The dams may also present an aquatic fauna movement barrier, depending on dam design (e.g., wall height, spillway height, spillway water depth). Aquatic macroinvertebrate taxa most affected by ‘barrier effects’ are those typically without adult winged stages, such as crustaceans and mollusks (Brooks et al., 2018). Various fish species found in the Purari River catchment undertake movements as part of their day to day foraging activities, and many species also undertake migrations as a part of their life cycles.

11.5.3.1.3 Dredging

Construction activities at the Logistics Base will include dredging of a small basin in front of the jetty to allow barge access (see Figure 11.7 for the expected dredging area). The dredge depth will be determined during FEED, but the change to bed elevation is expected to be less than 2 m relative to its existing level. The total volume of material to be dredged is estimated to be approximately 6,000 m^3 over 1.5 ha, to provide a water depth of 3.5 m. Maintenance dredging may also be required.

Dredging will remove soft sediment habitat and benthic biota from the dredge footprint. These direct impacts are assessed in Section 11.5.5.1.4.

The dredge footprint is likely to have lower fish feeding habitat values than adjacent undisturbed areas. The dredge footprint does not; however, occur in an area known to be of high importance to fish species for feeding or other activities. Furthermore, given the very small dredge area compared to the total area of available habitat in the Purari River, modifications to benthic communities are extremely unlikely to cause flow-on effects to species populations that feed on benthic fauna. These potential indirect effects from disturbance of benthic habitat are therefore not considered further in the residual impact assessment.

11.5.3.2 Increased Suspended Sediment and Sedimentation Levels

11.5.3.2.1 Earthworks and Spoil Stockpiling

The Project's construction phase includes earthworks and spoil stockpiling for roads, pipelines, the CPF, Logistics Base and Purari Airstrip extension. The location of these works in relation to aquatic environments is shown in Figures 11.10 to 11.12. These earthworks and the relevant infrastructure are described further in Chapter 4. These works will cause increase suspended sediment and sedimentation levels in waterways, with the streams most adversely affected expected to be the tributary streams in PRL-15 (i.e., Hou, Boa, Kuku and Oyomo creeks, and the Mena and Era rivers) (see Section 11.3.5.1).

Sediment deposition in aquatic ecosystems can lead to adverse impacts on fauna species, and degradation or loss of aquatic habitat. Potential impacts to biota and changes in habitat condition from sediment loading and deposition are described in the following sections. Few aquatic macrophytes occur in the PAOI; hence, these are not considered as ecological receptors.

Sedimentation Effects on Aquatic Biota

Potential sedimentation impacts on biota include:

- Smothering and burial of sedentary species, such as benthic microalgae and benthic invertebrates.
- Increased turbidity reducing light in the water column, thus reducing phytoplankton and benthic microalgae productivity.
- Increased turbidity reducing water clarity and the ability to detect prey.
- Physiological stress from high sediment loads, e.g., blocking of respiratory or feeding structures.

Studies have not specifically examined the tolerances of aquatic invertebrates from the Purari River catchment to high sediment concentrations. Background turbidity and sediment transport conditions of the study area are important considerations when assessing the risk to resident aquatic flora and fauna communities and their habitat. Highly turbid environments are unlikely to support biota that are highly sensitive to suspended sediment. Turbidity varies markedly among tributary streams and over time, with most sites in the range of 0.1 to 90 NTU (described in Section 7.4.2). Turbidity in the Purari River typically ranges between 200 and 400 NTU (based on measurements at Herd Base) with spikes up to 1,000 NTU (see Figure 7.13). Resident aquatic fauna of the study area would; therefore, need to tolerate high turbidity levels.

A long-term change in turbidity; however, could cause the loss of some species in the impacted area with sediment-tolerant species possibly replacing them. This includes invasive species expected to occur in the Purari River catchment (see Section 11.5.3.5).

Crocodiles and turtles are not known to be sensitive to high suspended sediment levels.

Habitat Disturbance from Sediment Loading and Deposition

Increased sediment loading and deposition may change benthic habitat, with fine sediment smothering coarse substrate such as gravel and cobbles, which could lead to a decline in abundance and diversity of macroinvertebrates, algae and fish communities.

11.5.3.2.2 Dredging

Dredging adjacent to the jetty at the Logistics Base will also mobilize sediment into the water column increasing turbidity and suspended sediment levels, with potential associated sedimentation impacts on aquatic biota (as described in Section 11.5.3.2.1).

11.5.3.3 Contamination of Waterways

Waterways may potentially be contaminated by the following releases (see Section 11.4.3), with associated toxicity effects on aquatic biota:

- Planned wastewaters discharges, including:
  - Hydrotest waters from onshore pipelines.
  - Sewage effluent from Project facilities and accommodation camps.
  - Treated stormwater captured at the wellpads and the CPF and, potentially, produced water.
- Discharges of firefighting foams.
- Accidental hydrocarbon or chemical releases. The potential impacts of these releases on aquatic biota are described in the following sections, and the embedded design controls relevant to addressing these are outlined in Section 11.1.3.3.

Dredging of the Purari River adjacent to the jetty is expected to have insignificant impacts on water quality due to contaminant mobilization (see Section 11.4.3.4).

11.5.3.3.1 Planned Wastewater Discharges

Hydrotest Water

Hydrotest water will contain a small amount of an oxygen scavenger, such as sodium bisulfite, to inhibit corrosion and a biocide to prevent bacteria developing. Any oxygen scavengers present in discharges to surface waters will decrease dissolved oxygen levels and may kill fish. Biocides, if present at sufficiently high concentrations, may also be toxic to aquatic biota.

Sewage Effluent

Effluent generated from operations and construction camps will be treated and discharged to the Purari River from a nominated discharge point at the Logistics Base. Even after treatment, effluent will contain elevated nutrient levels, i.e., nitrogen and phosphorus.

The release of waters with elevated nutrients can cause eutrophication, i.e., excess production of microalgae, which occurs as dense algal blooms. This can stress aquatic species due to depleted dissolved oxygen levels from microbial decomposition of decaying algae. These zones of low dissolved oxygen levels can kill fish and change aquatic community structure.

Captured Stormwater and Produced Water

Stormwater from the wellpads and CPF that could mix with hydrocarbons and other contaminants will be captured and treated before being discharged to the Purari River. Additionally, produced waters could be discharged at this point during injection outages and when the backup storage tank capacity is exceeded. Discharge will take place according to applicable limits

Oils and petroleum hydrocarbons are less dense than water and are biodegradable. The most toxic fractions of oils to aquatic biota are lighter fractions that contain higher proportions of aromatic hydrocarbons; however, exposure of aquatic organisms to such fractions is usually limited due to their high volatility. Apart from direct toxic effects to aquatic biota, oils and hydrocarbons can also cause tainting of fish flesh, loss of invertebrates and food sources, and increases in algal growth (ANZECC/ARMCANZ, 2000).

11.5.3.3.2 Discharge of Firefighting Foams

Firefighting foams have high biochemical oxygen demand and constituents that may be toxic to aquatic fauna (DEHP, 2016). Releasing firefighting foams with high biochemical oxygen demand into surface waters may asphyxiate aquatic organisms due to depleted dissolved oxygen concentrations, as naturally occurring aerobic microorganisms degrade organic components of the foam. The occurrence of this impact is dependent on the level of biochemical oxygen demand of the firefighting foam and environmental factors such as water temperature, dilution and the existing waterway condition. Most firefighting foams are not acutely toxic; however, the persistence and bioaccumulation of some chemicals present in firefighting foams can cause chronic impacts to aquatic organisms, depending on the foam type. The extent of these chronic impacts is currently not well understood; however, evidence exists that all classes of perfluorochemicals potentially have such adverse effects (DEHP, 2016).

11.5.3.3.3 Accidental Hydrocarbon and Chemical Releases

Accidental release of fuel and other chemicals into the environment may be toxic to aquatic biota. Key potential contaminants are polycyclic aromatic hydrocarbons, metals, metalloids and a range of other synthetic compounds, which may have lethal or sublethal toxic effects or may bioaccumulate in biota.

The potential risk to aquatic biota depends on several factors, most notably the spatial extent of contamination, the duration of exposure, the contaminant type and the hydrological (flushing) characteristics of the affected waterway. Many contaminants are persistent in the environment, particularly when present in sediments, and can have long-term impacts if remediation is not undertaken. Aquatic environments with poor flushing (i.e., smaller tributary streams with low flow and palustrine wetlands) are most at risk of chemicals persisting in the environment.

Waterways most at risk of accidental releases are those closest to areas where large hydrocarbon and chemical volumes are stored or transferred. The Purari River near the Logistics Base and the Purari Airstrip; therefore, has a higher risk of occurrence of accidental hydrocarbon and chemical releases. This reach of the Purari River provides habitat for a wide range of aquatic fauna, including threatened sawfish, river shark and ray species (*P. pristis*, *G. garricki*, *G. glyphis*, *C. leucas*, *Glaucostegus typus* and *Urogymnus granulatus*), turtles (*Carettochelys insculpta* and *Pelochelys bibroni*), potentially river dolphins (*Orcaella heinsohni* and *Sousa sahulensis*) and macrocrustacean and macroinvertebrate species.

11.5.3.4 Fauna Strike

Vessels traversing the Purari River may collide with aquatic fauna, causing injury or death. Dredging of the Purari River adjacent to the jetty at the Logistics Base also has the potential to injure or kill any fauna in the dredging area. Such injuries could occur due to vessels or the backhoe dredge arm or bucket striking fauna.

11.5.3.5 Introduction and Spread of Aquatic Pest Species

11.5.3.5.1 Introduction of New Species to the PAOI

Project construction material, equipment and vessels will be brought from outside the Purari and Era river catchments. These elements could contain seeds or other fragments of aquatic weeds in quarry material or in sediment lodged in equipment and machinery.

Aquatic weeds introduced into the PAOI can degrade existing habitat and out-compete native species. Three aquatic weed species known to occur in Papua New Guinea, but not identified in the PAOI to date, are *Salvinia molesta*, *Pistia stratiotes* and *Hydrilla verticillata*. All three species are high-risk species that can form dense vegetation mats that may damage aquatic ecosystems by shading and altering flows. Additionally, dense vegetation mats provide breeding grounds for mosquitoes, which are disease vectors for malaria. Vessels and machinery that have operated in areas containing infestations are key potential weed vectors relevant to the Project.

Introduced fish species can change indigenous fish and invertebrate species populations by out-competing native species for food resources, predation and changing habitats. Introduced fish species known to occur in Papua New Guinea include rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), mosquitofish (*Gambusia holbrooki*), green swordtails (*Xiphophorus helleri*), blue panchax (*Aplocheilus panchax*) and gourami (*Trichogaster pectoralis* or *Trichogaster trichopterus*) (Polhemus et al., 2004). These species are not presently known to occur in the PAOI but may possibly occur in the upper catchment of the Purari River. The main vector for introduced fish species is deliberate introductions by people. Table 11.36 describes the potential impacts associated with introduced fish species.

11.5.3.5.2 Spread of Existing Pest Species

Project construction works have the potential to spread existing aquatic pest species by:

- Creating habitat preferred by pest species.
- Spreading environmental weeds in machinery, soil and other materials from an area of the PAOI in which they currently occur to an area in which they do not occur.

This can lead to aquatic habitat degradation from aquatic weeds and impacts on aquatic fauna from alien fish, as stated in Section 11.5.3.5.1.

Water hyacinth (*Eichhornia crassipes*) is the one confirmed aquatic weed species in the PAOI. This species is currently known to occur in Nea Creek, the associated PRL-15 oxbow wetlands, and near the Purari Airstrip. This weed can form large floating rafts that can change aquatic habitat conditions (e.g., by reducing water flow, light penetration through the water column, or dissolved oxygen concentrations), which can directly and indirectly harm or kill native aquatic flora and fauna species. Water hyacinth prefers still or slow flowing waters, so drainage ditches and backwaters of tributary streams are most at risk of infestations. The weed may spread by seeds or other plant parts attached to machinery and equipment being transported from areas of existing outbreaks to unaffected waterways.

Fisheries resource interviews indicate that the common carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambica*) and Putitor mahseer (*Tor putitora*) already occur in the PAOI. Additionally, as described in Part 5 of Volume 2, other invasive fish species may possibly occur; although, they have not been observed during baseline surveys. Table 11.36 describes these species and their preferred habitat. In addition, pest insect species such as mosquitos and biting midges also occur in the catchment.

Table 11.36 – Invasive Species Known or Possibly Occurring in the PAOI and Their Preferred Habitat

Common Name	Scientific Name	Preferred Habitat	Flow Regime	Potential Impacts
Philippine catfish	*Clarias batrachus*	Swamps, particularly in stagnant, pools with low dissolved oxygen levels.	Low to no flows	Preys on small native fish, out-competes native fish for food.
Common carp	*Cyprinus carpio*	Rivers, creeks and wetlands with low to no flow, particularly in areas with abundant aquatic vegetation.	Low to no flows	Riverbed disturbance causing increased turbidity, competition with native species for food and space.
Mosquitofish	*Gambusia affinis/holbrooki*	Shallow rivers, creeks, lagoons and wetlands with low flow, particularly in clear waters.	Low to no flows	Preys on native fish eggs and larvae, competition for food and space.
Mozambique tilapia	*Oreochromis mossambicus*	Shallow rivers, creeks, lagoons and wetlands with low flow, but they can also colonize faster-flowing waters.	Low to no flows, tolerates moderate flows	Out-competes native species for food and space.
Putitor mahseer	*Tor putitora*	Streams and rivers, particularly rapid streams with a rocky bottom, riverine pools and lakes.	Moderate to high flows	Impacts unknown.
Green swordtail	*Xiphophorus helleri*	Generalist; occurs in rivers, creeks, lakes, wetlands, typically in areas with low flow and with aquatic vegetation.	Low to no flows	Impacts unknown.
Striped snakehead	*Channa striata*	Streams and ponds, particularly in stagnant pools with low dissolved oxygen levels. Tolerant of turbid and clear waters.	Low to no flows	Preys on native fish, out-competes native species.
Climbing perch	*Anabas testudineus*	Pond, swamps and drainage channels. Adaptive air-breathing organ allowing it to survive outside of water.	Low to no flows	Out-competes native species for food and space. Well-developed gill plates and spines that may choke and kill predatory species.
Blue panchax	*Aplocheilus panchax*	Wetlands, ponds, ditches and reservoirs.	Low to no flows	Impacts unknown.

Table 11.36 – Invasive Species Known or Possibly Occurring in the PAOI and Their Preferred Habitat (cont'd)

Common Name	Scientific Name	Preferred Habitat	Flow Regime	Potential Impacts
Snakeskin gourami	*Trichogaster pectoralis*	Wetlands, ponds and ditches, particularly in stagnant pools with low dissolved oxygen levels	Low to no flows	Impacts unknown.
Rainbow trout	*Oncorhynchus mykiss*	Lakes and streams with gravel substrate and well oxygenated water.	Low to moderate flows	Preys on native fish for food, out-competes native species for food and space.
Brown trout	*Salmo trutta*	Streams, lakes and reservoirs.	Low to moderate flows	Preys on native fish for food, out-competes native species for food and space.

Most of these alien fish species and pest insects prefer low-flow environments, such as quiescent pools. Creating and modifying drainages, and changing stream flows (e.g., by constructing water supply dams and sediment and erosion control infrastructure) could create preferred habitat for these species. As described in Table 11.36, the potential impacts of introduced species include:

- Predating native fish species, including eggs and larvae.
- Outcompeting native fish species for food and habitat.
- Disturbing bed and banks, leading to decreased water quality with associated impacts to flora and fauna sensitive to increased suspended sediment or sedimentation.

Such impacts could lead to localized declines in native fauna populations and fauna displacement of fauna from existing habitat. Alien species are likely to persist in the PAOI once introduced and they can be difficult to eradicate.

11.5.3.6 Underwater Noise

The impact of underwater noise on freshwater and estuarine fauna is addressed in the marine impact assessment in Section 12.4.

11.5.4 Proposed Mitigation and Management Measures

Table 11.37 describes mitigation and management measures to further reduce impacts to freshwater and estuarine biodiversity.

11.5.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to surface water quality subject to the embedded design controls in Section 11.5.3 and the successful implementation of the proposed mitigation and management measures in Section 11.5.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

11.5.5.1 Direct Disturbance and Habitat Fragmentation

11.5.5.1.1 Vegetation Clearing and Earthworks

The Project will remove 5.5 km of Oyomo Creek tributary stream habitats in the CPF footprint. The habitat that will be removed has a ***Medium*** sensitivity since the streams:

- Are presently in an unmodified condition, like most other streams in the PAOI.
- Provide good-quality habitat for invertebrate and fish species but are not habitat for threatened aquatic species recorded in the Purari River.
- Are not unique but rather are representative of the tributary stream habitat found throughout the PAOI and broader region.

The impact is irreversible but is not expected to extend beyond the CPF footprint or to threaten the viability of a subregional population. Drainage channels will be constructed to divert runoff and stream flows around the CPF. Depending on their design, the drainage channels could create habitat for aquatic biota, albeit of a lower quality and modified nature to the habitats that they replace. This provides for a ***Medium*** magnitude rating. Combining these scores, the direct disturbance to waterways in the CPF footprint will have a ***Moderate*** impact significance.

Table 11.37 – Freshwater and Estuarine Biodiversity Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Direct disturbance of habitat from vegetation clearing and earthworks.	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024].	Biodiversity Action Plan
Direct disturbance of habitat and fragmentation of waterways by pipeline and road crossings.	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g., drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipaters, sediment control ponds, mulch berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated [EM004]. ♦ Maintain hydraulic and biological connectivity during construction and operations in natural flow lines across linear infrastructure, such as pipelines and roads, and in relation to water extraction, e.g., dams, including: – Install appropriately sized culverts, drains and structures to allow fish passage, according to good international industry practice standards. – Rehabilitate waterways after construction and decommissioning to a sustainable, stable state, that reflects the original character, and maintains waterway flows and connectivity [EM020]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams.	Water Management Plan; Biodiversity Action Plan

Table 11.37 – Freshwater and Estuarine Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Direct disturbance of habitat and fragmentation of waterways by pipeline and road crossings (cont'd).	– Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024].	See above
Direct disturbance and fragmentation of habitat from water extraction and impoundment.	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Maintain hydraulic and biological connectivity during construction and operations in natural flow lines across linear infrastructure, such as pipelines and roads, and in relation to water extraction, e.g., dams, including: – Install appropriately sized culverts, drains and structures to allow fish passage, according to good international industry practice standards. – Rehabilitate waterways after construction and decommissioning to a sustainable, stable state, that reflects the original character, and maintains waterway flows and connectivity [EM020]. ♦ Minimize fish entrainment by water extraction equipment e.g. screens [EM021]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024].	Water Management Plan; Biodiversity Action Plan
Increased levels of suspended sediment and sedimentation in waterways from earthworks and stockpiling.	♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Cut trees where practicable to retain the rootstock and maintain soil stability [EM003]. ♦ Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g., drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipaters, sediment control ponds, mulch	Soil Management Plan; Site Restoration and Rehabilitation Plan; Water Management Plan

Table 11.37 – Freshwater and Estuarine Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Increased levels of suspended sediment and sedimentation in waterways from earthworks and stockpiling (cont'd).	berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated [EM004]. ♦ Stabilize spoil stockpiles and areas of ground disturbance as soon as practicable after initial disturbance using, e.g., mulched vegetation, aggregates and soil binders [EM005]. ♦ Areas of higher risk of landslides e.g., steep gradients, previously disturbed land, likely to occur from the works, or likely to be exacerbated by the works, will be stabilized to reduce the landslide risk. [EM006]. ♦ Minimize or avoid sidecasting during construction (e.g. for road, pipeline, wellpad and CPF works). Any sidecasting that does occur will avoid defined stream channels [EM010]. ♦ Water from trenches will be discharged in accordance with applicable water quality standards with erosion and sediment controls where relevant [EM011]. ♦ Maintain buffer zones between permanent surface water and project infrastructure, except to carry out works associated with the construction of watercourse crossing or where facilities are proposed to be located within that buffer [EM012]. ♦ Minimize in-stream and stream bank disturbance during high rainfall [EM013].	Soil Management Plan; Site Restoration and Rehabilitation Plan; Water Management Plan
Increased levels of suspended sediment and sedimentation in waterways from dredging.	♦ Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species [EM037].	Water Management Plan
Contamination from planned wastewater discharges.	♦ Sewage effluents from Project facilities will be treated to meet the environment (waste discharge) permit before discharge, in accordance with applicable standards [EM008]. ♦ Hydrotest water management will consider: – The definition of volume and discharge rates and discharge locations. – Chemicals additives selection, according to requirements defined in embedded design controls. – Reusing hydrotest water to minimize the discharge volume. – Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. – Monitoring hydrotest water discharges to the environment against applicable limits [EM015].	Water Management Plan; Waste Management Plan
Contamination from discharge of firefighting foams during training and testing.	♦ Training and test releases of firefighting foams at the CPF are to be contained within appropriate drainage water treatment networks. [EM016].	Hazardous Material Management Plan

Table 11.37 – Freshwater and Estuarine Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Water contamination from accidental release of hydrocarbons or chemicals.	♦ Vehicle wash down and fuel handling will be undertaken considering possible receptors e.g., streams, Purari River and the marine environment [EM017]. ♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site contingency plans, that will consider fire management measures – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018]. ♦ Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and *Marine Pollution (Ships and Installations) Act 2013* [EM019].	Hazardous Material Management Plan; Emergency Response Plan; Oil Spill Contingency Plan
Vessels striking fauna.	♦ Implement lower speeds past aquatic fauna when observed in the water [EM022].	Traffic and Transport Management Plan; Biodiversity Action Plan
Introduction or spread of invasive species, diseases and pathogens.	♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna; – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna [EM023]. ♦ All Project personnel, workers, contractors and third-party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028].	Biodiversity Action Plan

11.5.5.1.2 Pipeline and Road Crossings of Waterways

Waterways being crossed by roads or pipelines have a ***Medium*** sensitivity considering that they are not unique habitat but rather are representative of the riverine habitats found throughout the PAOI and broader Purari River catchment and threatened aquatic species are unlikely to occur.

If Project roads are maintained beyond the life of the Project, this will permanently modify tributary stream habitats in culvert footprints for the roads. However, mitigation is proposed to rehabilitate waterways after construction and decommissioning to a sustainable, stable state, that reflects the original character, and maintains waterway flows and connectivity. Even if roads become permanent, this represents a highly localized loss of habitat in the crossing footprint.

Culverts will be sized and constructed to maintain stream flows. If culverts are inappropriately designed, fish passage may be affected under certain flow conditions (e.g., very low flows if the culvert dries or high flows if water velocities are too high for fish movement); however, since waterway crossings are to be constructed according to good international industry practice guidelines to promote fish passage, habitat fragmentation is unlikely to occur under such flow conditions.

Fragmentation and disturbance during construction activities will be for a limited time and is unlikely to have any residual impacts on species populations once connectivity is restored. Aquatic macroinvertebrates, which have limited mobility, will be temporarily lost in the trenching and culvert footprints; however, impacts are expected to be short-term, with recolonization and recovery expected to occur in weeks to months. Most fish (i.e., bony and cartilaginous fish) and crocodiles will avoid the construction areas and therefore are unlikely to be directly impacted. Impacts are expected to be highly localized, short-term and not to result in measurable declines in species populations over a broader area, the magnitude of impact is therefore assessed to be ***Low.***

The waterway crossings therefore have a ***Minor*** impact significance on aquatic habitat and species.

11.5.5.1.3 Water Impoundment and Extraction

Hou and Boa creeks at the likely dam and extraction sites both have a ***Medium*** sensitivity based on the following:

- Both waterways are in a mostly unmodified condition, although historical disturbance such as sediment inputs from earthworks is possible at both sites from the nearby drilling sites. Additionally, a road that potentially limits fish passage crosses Boa Creek, downstream of the likely dam location.
- Both waterways provide habitat for invertebrate and fish species but are unlikely to support threatened aquatic species as the key species occur in larger waterways.
- Neither site is a unique habitat feature but rather is representative of the riverine habitats found throughout the PAOI and broader Purari River catchment.

The Project will temporarily modify tributary stream habitats in the water extraction infrastructure footprint (i.e., water extraction pipelines and dams on Hou and Boa creeks). Habitat may be modified for approximately two years; however, impacts will be highly localized (measured in meters to tens of meters), marginally detectable with respect to natural variability, with populations readily able to regenerate on remaining habitat. This provides a ***Low*** magnitude rating.

Water extraction from these tributary creeks will be undertaken in such a way that flow regimes (i.e., base, low, medium and high flows) past the dams are maintained to protect environmental values in downstream environments. Upstream environments will not be affected by water extraction. On this basis, impacts to aquatic biodiversity associated with water extraction are unexpected. Water extraction from the Purari River for use at the CPF and potable water for the accommodation camps is expected to cause negligible impacts to flow regimes (see Section 11.3.5.2); hence, no impacts on aquatic communities in the Purari River are expected.

Impoundment dams are expected to have over-dam flow to allow fish passage when flooded; however, fish passage could be blocked during periods of low flow. As these structures will only be installed for about two years, implementation of special measures to maintain fish passage during periods of low flow is considered unnecessary. This temporary fragmentation of fish passage during these periods is expected to have low impact on fish species, being marginally detectable with respect to natural variability, and with the fish species readily able to reproduce in the remaining habitat. This is due to the location of the impoundments in the upper part of the tributaries, thereby limiting the extent of waterway that is fragmented. Fish entrainment by water extraction equipment will be minimized through the installation of physical barriers, such as screens.

Installing dams will also modify some habitat immediately upstream of the dam (i.e., change from run to pool habitat). These impacts will be highly localized, not affect viability of ecosystem communities (i.e., without significant change compared to natural variability), and would only occur for two years. Based on these considerations, the impact to aquatic biodiversity due to water impoundment and extraction for drilling is assessed to have a ***Low*** magnitude.

Combining these scores, water impoundment and extraction will have a ***Minor*** impact significance in relation to both direct habitat loss from dam and water extraction infrastructure and habitat modification from water impoundment and extraction.

11.5.5.1.4 Dredging

The habitat in the proposed dredging footprint has a ***Medium*** sensitivity based on it:

- Being in an unmodified condition.
- Providing habitat for invertebrate and fish species, and potentially providing suitable habitat for threatened aquatic species recorded in the Purari River.
- Not being unique, but rather being representative of riverine habitat throughout the broader Purari River.

Initial construction dredging and ongoing maintenance dredging will lower the river bed in the dredging footprint and modify aquatic habitat for the life of the Project.

Dredging will remove soft sediment habitat and biota from the dredging footprint, causing a temporary loss of biota from the footprint. Biota will rapidly recolonize the dredging footprint but may continue to be subject to similar disturbance through ongoing maintenance dredging, if it is required to maintain the required water depth. The new benthic fauna community in the dredging footprint is likely to have a lower fauna abundance and diversity compared to undisturbed soft sediment habitats nearby, but changes are unlikely to affect habitat or benthic species populations outside of the range of natural variability. The impact will also occur only in the dredging footprint. The magnitude of impact is therefore considered to be ***Low***.

Combining these scores, direct habitat loss from dredging is assessed to have ***Minor*** impact significance.

11.5.5.2 Increased Suspended Sediment and Sedimentation Levels

11.5.5.2.1 Earthworks and Spoil Stockpiling

Increases in suspended sediment levels and in-stream sedimentation from earthworks and spoil stockpiling will occur in waterways located directly adjacent to construction sites subject to ground disturbance, including the:

- Purari River, adjacent to the Purari Airstrip and Logistics Base and downstream of most Project earthworks.
- Oyomo Creek catchment, which includes the CPF, roads and pipelines, and spoil stockpiling locations.
- Hou Creek, Boa Creek and Mena River catchments, which include the wellpads, roads and pipelines, and spoil stockpiling locations.
- Kuku Creek and Era River catchments and the waterways catchments along the export pipeline route, which include roads, pipelines and spoil stockpiling locations.

These waterways have low levels of human disturbance except for several creek crossings on the Herd Base Road over Mena River and Boa Creek, and catchments along the export pipeline route that have existing high levels of disturbance and sediment loading due to commercial logging activities. The PRL-15 waterways and the Purari River provide good-quality habitat for a wide range of invertebrate and fish species. This includes the threatened and endemic aquatic species identified as occurring or possibly present in the PAOI (see Section 11.5.1). These waterways; therefore, have a ***Medium*** sensitivity. The disturbed waterways along the export pipeline route are likely to have lower habitat values and are considered unlikely to support threatened or endemic species due to existing sedimentation impacts and; therefore, have a ***Low*** sensitivity.

Localized sediment loading impacts to these waterways (see Section 11.3.5.1) are likely to occur, even with the application of mitigation measures. These impacts will be most severe during the construction phase, with higher turbidity and possibly smothering of creek bed habitats, especially immediately downstream of works areas.

Localized declines in microalgae, invertebrate and fish communities are expected to occur, especially in stream reaches directly adjacent to construction footprints and in downstream depositional environments. These impacts are expected to exceed natural variability for the tributary streams in PRL-15; although, they are less likely to be significant in the Purari River and export pipeline route waterways due to existing high sediment loads. Long-term impacts (i.e., the life of the Project) could occur immediately downstream of works areas. Habitat and biological community recovery is expected post-construction outside the immediate zone of influence of sediment discharges. The recovery timeframes of biological communities further downstream will depend on the effectiveness of control measures, and therefore the spatial extent of the impact, and sediment transport capacity of waterways (i.e., the habitat recovery timeframes).

Based upon these considerations, and the residual sedimentation impacts identified in Section 11.3.5.1, the expected magnitude of impact on aquatic biodiversity and residual impact significance for each waterway is shown in Table 11.38.

Table 11.38 – Significance of Sedimentation Impacts for PAOI Waterways

Waterway	Catchment	Sensitivity of Receptor	Construction Phase		Operations Phase	
			Magnitude of impact	Impact Significance	Magnitude of Impact	Impact Significance
Boa Creek	Era	Medium	Medium	Moderate	Low	Minor
Mena River	Era	Medium	Medium	Moderate	Low	Minor
Era River	Era	Medium	Minimal	Negligible	Minimal	Negligible
Hou Creek	Purari	Medium	Minimal	Negligible	Minimal	Negligible
Kuku Creek	Purari	Medium	Medium	Moderate	Low	Minor
Oyomo Creek	Purari	Medium	High	Moderate	Low	Minor
Purari River	Purari	Medium	Low	Minor	Low	Minor
Waterways along the export pipeline route	Purari	Low	Low	Minor	Low	Minor

11.5.5.2.2 Dredging

Any sediment plumes due to dredging at the new jetty in the Purari River are expected to be highly localized and restricted to the short period of dredging (i.e., weeks) due to the strong river flows and high sediment advection (see Section 11.3.5.1.3). Given the high ambient turbidity, the plume is expected to be difficult to visually detect more than 0.5 km downstream of the dredging site (i.e., will be highly localized); however, given that Oyomo Creek flows into the Purari River approximately 100 m downstream from the proposed jetty, plumes may potentially extend into this tributary during periods of reverse flow of the creek, should such flow conditions occur during the period of dredging. This could increase the sediment loads delivered to this system during high flows. The highly localized impacts to habitat and ecosystems due to dredging are; however, expected to be very low and undetectable with respect to natural variability. The magnitude of impact is therefore rated to be ***Minimal***.

The Purari River and Oyomo Creek are considered to have ***Medium*** sensitivity (see Section 11.5.5.2.1). This provides an overall impact significance rating of ***Negligible*** for both waterways.

11.5.5.3 Contamination of Waterways

11.5.5.3.1 Planned Wastewater Discharges

Hydrotest Water

As described in Section 11.5.5.2, the sensitivity of the Purari River for aquatic habitat and species is ***Medium***. Hydrotest water discharge locations and discharge rates, to either land or water, will be defined during FEED. Any discharges to surface waters will comply with designated water quality standards. Hydrotest water may contain a small amount of an oxygen scavenger, such as sodium bisulfite, to inhibit corrosion and a biocide to prevent bacteria developing. Any impacts from residual amounts of these chemical additives in the hydrotest water discharges to the Purari River would be localized with no detectable change in the composition or viability of ecosystem communities and populations. The expected magnitude of impact of such discharges is ***Low**, p*roviding an overall impact significance rating of ***Minor***.

Sewage Effluent

The discharge of treated sewage effluent is likely to have only highly localized (i.e., within 0.5 km of the discharge point) impacts on water quality in the Purari River. Discharged water quality will meet designated water quality standards, and the significant flow volumes in the Purari River are expected to rapidly dilute treated effluent. Any increase in nutrient levels at the discharge point is unlikely to cause detectable flow-on effects, particularly given that the high turbidity and fast flow of the Purari River limits the potential for algal blooms and hence effects due to eutrophication. The expected magnitude of impact is; therefore, ***Minimal***. Given the sensitivity of the Purari River for aquatic habitat and species is ***Medium***, the overall impact significance is assessed to be ***Negligible***.

Captured Stormwater and Produced Water

Hydrocarbon-contaminated stormwater and potentially produced water discharges from the CPF and wellpads, will contain only residual amounts of hydrocarbons following water treatment. High flow volumes in the Purari River are expected to rapidly disperse residual pollutants and; therefore, acute toxic impacts are not expected. Any impacts to habitat, ecosystem and species would be localized and only marginally detectable with respect to natural variability and therefore have a ***Low*** magnitude. The sensitivity of the Purari River to this impact is ***Medium***, providing an overall impact significance rating of ***Minor.***

11.5.5.3.2 Discharge of Firefighting Foams

Using low-toxicity, biodegradable firefighting foams in contained areas at the CPF will reduce the risk of polluting waterways (see Section 11.4.4). The firefighting foams will be captured in the OD1 and OD2 open drain networks and directed to an observation basin, where degradation will occur, and the water will be tested for suitability for release prior to it being discharged into the Purari River. Such discharges will only occur following routine fire response training and equipment testing exercises. Impacts to habitat, the ecosystem and species from these controlled releases are expected to be localized and cause no measurable decline in species populations, and; therefore, are of ***Low*** magnitude. The sensitivity of habit, the ecosystem and species of the Purari River is ***Medium***, providing an overall significance rating of ***Minor***.

11.5.5.3.3 Accidental Hydrocarbon or Chemical Releases

Any fuel or chemical spills at the CPF and wellpads will be captured by the OD1 and OD2 open drain networks, treated and discharged to the Purari River. These discharges are planned discharges that are addressed in Section 11.5.5.3.1. For other areas of Project activities, potential releases to surface water would not be controlled to a known discharge location.

Incidental small spills and leaks from barge traffic, and fuel and chemical storages and transfers at the Logistics Base are considered to present the highest Project risk to the Purari River (see Section 11.4.5.3). Given the fast-flowing nature of the Purari River and that hydrocarbons float on the surface of water, a spill could potentially extend beyond 2 km; however, water quality deterioration from an accidental spill would only be for a short period given the high assimilative capacity of the river due to its large flows. Water quality would be expected to quickly recover to its previous condition prior to the spill (within hours). Given that most fauna of the Purari River are demersal (i.e., bottom-dwelling), their exposure to hydrocarbons in surface waters would be limited. An accidental spill would only be expected to cause a minor decline in a localized species population and would not threaten the viability of a subregional population. The magnitude of impact to aquatic biodiversity is; therefore, categorized to be ***Low***. Given the sensitivity of the habit, ecosystem and species of the Purari River is ***Medium***, the overall impact significance rating is ***Minor***.

Other waterways in the PAOI have a sensitivity rating similar to or less than the Purari River and are considered less likely to be exposed to spills than the Purari River. Similar or lesser residual impacts to other waterways in the PAOI are; therefore, expected in the event of accidental hydrocarbon or chemical releases, depending on the quantity and nature of the spill, extent of remediation possible and the characteristics of the receiving waterbody.

11.5.5.4 Fauna Strike

Most fauna of the Purari River are demersal, fast-moving or present in low abundance, which reduces the risk of vessels striking them. Additionally, most Project vessels will be slow-moving barges, which are unlikely to strike aquatic fauna. Lower speeds will be implemented past aquatic fauna when observed in the water.

Dredging operations are unlikely to strike fauna. The dredger will be stationary most of the time, and it will only move at slow speeds. Fauna will be readily able to evade the dredge. The dredge arm will also move slowly, reducing the likelihood of strikes injuring or killing fauna. Noise and vibration generated by the dredge will also deter fauna from being present in the dredging area.

Based on the above, the magnitude of impact of fauna strike is assessed to be ***Minimal***. Given the sensitivity of aquatic species in the Purari River is ***Medium***, the overall impact significance rating is ***Negligible***.

11.5.5.5 Introduction and Spread of Aquatic Pest Species

11.5.5.5.1 Introduction of New Species to the PAOI

Waterways most likely to be affected are those near Project infrastructure, i.e., the upper reaches of Hou Creek, Boa Creek, Mena River, Kuku Creek and Oyomo Creek. These waterways and the Purari River provide good quality habitat for a wide range of invertebrate and fish species, including the threatened and endemic aquatic species identified as occurring or possibly present in the PAOI (see Section 11.5.1) and; therefore, have a ***Medium*** sensitivity.

The disturbed waterways along the export pipeline route are likely to have lower habitat values and are considered unlikely to support threatened or endemic species due to existing sedimentation impacts and have a ***Low*** sensitivity.

The Project is unlikely to be responsible for introducing new aquatic pest species into the PAOI with appropriate biosecurity measures, including a quarantine program for imported equipment and supplies. No measurable decline in a species population is expected due to new pest species, and the magnitude of impact is considered to be ***Minimal***.

The overall impact significance on habitat and species due to the introduction of new pest species is assessed to be ***Negligible*** for all streams in the PAOI.

11.5.5.5.2 Spread of Existing Pest Species

Implementing risk-based hygiene protocols will reduce the risk of aquatic weeds spreading in the PAOI; however, a risk of isolated outbreaks remains. Habitat condition and ecosystem viability may be reduced in the affected area over a medium duration; hence, the magnitude of impact is rated as ***Low***.

Waterways most likely to be affected due to existing weed species being spread are those near Project infrastructure, particularly around the Purari Airstrip where water hyacinth (*Eichhornia crassipes*) is known to be present.

Invasive fauna could colonize and proliferate in impounded and ponded waters and drainage depressions across the PAOI. Eradicating invasive fish is feasible when these areas are contained; however, eradication is difficult without impacts to non-target native species if invasive species spread to other waterways from these areas. Localized residual impacts to aquatic fauna populations (especially fish) may occur. The magnitude of impact is therefore categorized to be ***Low***.

The sensitivity of the various waterways in the PAOI is as described in Section 11.5.5.5.1.

Based on the sensitivity of the habitats and species, the overall impact significance for biodiversity is ***Minor*** for all streams in the PAOI.

11.5.6 Summary of Residual Impacts to Freshwater and Estuarine Biodiversity

Table 11.39 provides a summary of the assessment of residual impacts to freshwater and estuarine biodiversity, including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the specific mitigation measures provided in Table 11.37.

All residual impacts are assessed to be ***Negligible*** to ***Minor***, except for impacts described below which are assessed to have a ***Moderate*** residual impact:

- Aquatic habitat degradation and declines in fauna populations in Oyomo Creek from direct fragmentation, habitat removal and increased suspended sediment and sedimentation levels due to CPF construction.
- Aquatic habitat degradation and declines in fauna populations in the Mena River, Kuku Creek and Boa Creek from increased suspended sediment and sedimentation levels due to pipeline laying and road construction.

Table 11.39 – Summary of Assessment of Residual Impact Significance for Freshwater and Estuarine Biodiversity

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Habitat disturbance and fragmentation	Earthworks and physical infrastructure.	Direct loss of aquatic habitat in Oyomo Creek catchment.	PRL-15	C, O	♦ EM001 ♦ EM024	Medium/Medium	Moderate
	Construction works and onshore pipeline construction – pipeline and road crossings of waterways.	Direct loss of aquatic habitat at stream crossings and blockage of fish passage leading to population declines.	PRL-15 Export pipeline route	C	♦ EM001 ♦ EM004 ♦ EM020 ♦ EM024	Medium/Low	Minor
	Construction of water supply dams on Hou and Boa creeks.	Direct loss of aquatic habitat in the footprints of extraction infrastructure in Hou and Boa creeks.	PRL-15	C	♦ EM001 ♦ EM020 ♦ EM021 ♦ EM024	Medium/Low	Minor
		Modification of aquatic habitat and fish movement in Hou and Boa creeks.	PRL-15	C		Medium/Low	Minor
	Dredging at the Logistics Base.	Direct loss of aquatic habitat in the dredging footprint in the Purari River.	River transport corridor	C, O	None	Medium/Low	Minor
Increased suspended sediment and sedimentation levels	Earthworks and spoil disposal.	Smothering of fauna and habitat from sediment generated by construction phase ground disturbance and changes in surface cover – Oyomo Creek.	PRL-15	C	♦ EM002 ♦ EM003 ♦ EM004 ♦ EM005 ♦ EM006 ♦ EM010 ♦ EM011 ♦ EM012 ♦ EM013	Medium/High	Moderate
		Smothering of fauna and habitat from sediment generated by construction phase ground disturbance and changes in surface cover – Mena River, Kuku Creek and Boa Creek.	PRL-15	C		Medium/Medium	Moderate

Table 11.39 – Summary of Assessment of Residual Impact Significance for Freshwater and Estuarine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
Increased levels of suspended sediment and sedimentation (cont'd).	Earthworks and spoil disposal (cont'd).	Smothering of fauna and habitat from sediment generated by construction phase ground disturbance and changes in surface cover – Era River and Hou Creek.	PRL-15	C	See above	Medium/Minimal	Negligible
		Smothering of fauna and habitat from sediment generated by construction phase ground disturbance and changes in surface cover – Purari River.	PRL-15 Export pipeline route	C		Medium/Low	Minor
		Smothering of fauna and habitat from sediment generated by construction phase ground disturbance and changes in surface cover – waterways along export pipeline route.	Export pipeline route	C		Low/Low	Minor
		Smothering of fauna and habitat from sediment generated from roads during operations phase – Boa Creek, Mena River, Kuku Creek and Oyomo Creek.	PRL-15	O		Medium/Low	Minor
		Smothering of fauna and habitat from sediment generated from roads during operations phase – Hou Creek and Era River.	PRL-15	O		Medium/Minimal	Negligible

Table 11.39 – Summary of Assessment of Residual Impact Significance for Freshwater and Estuarine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Increased suspended sediment and sedimentation levels (cont'd).	Earthworks and spoil disposal (cont'd).	Smothering of fauna and habitat from sediment generated from roads during operations phase – Purari River.	Export pipeline route	O	See above	Medium/Low	Minor
		Smothering of fauna and habitat from sediment generated from roads during operations phase – waterways along export pipeline route.	Export pipeline route	O		Low/Low	Minor
	Dredging at the Logistics Base.	Smothering of fauna and habitat from sediment generated from dredging – Purari River and Oyomo Creek.	River transport corridor	C, O	♦ EM037	Medium/Minimal	Negligible
Contamination of waterways.	Planned wastewater discharges.	Impacts on aquatic ecosystems and biota from discharge of hydrotest water – Purari River.	PRL-15	C	♦ EM008 ♦ EM015 ♦ EM016	Medium/Low	Minor
		Impacts on aquatic ecosystems and biota from discharge of treated sewage effluent – Purari River.	PRL-15	C, O		Medium/Minimal	Negligible

Table 11.39 – Summary of Assessment of Residual Impact Significance for Freshwater and Estuarine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Contamination of waterways (cont'd).	Planned wastewater discharges (cont'd).	Impacts on aquatic ecosystems and biota from discharge of contaminated stormwater and produced water – Purari River.	PRL-15	O	See above	Medium/Low	Minor
		Impacts on aquatic ecosystems and biota from firefighting foams discharges during fire response training and equipment testing – Purari River.	PRL-15	O		Medium/Low	Minor
	Accidental hydrocarbon or chemical releases; use of hazardous materials.	Impacts on aquatic ecosystems and biota from hydrocarbon or chemical spill or leaks – Purari River and other PAOI waterways.	PRL-15 Export pipeline route River transport corridor	C, O	♦ EM017 ♦ EM018 ♦ EM019	Medium/Low	Minor
Fauna strike.	Logistics and transport (barging along waterways).	Vessel strike causing fauna injury or death.	River transport corridor	C, O	♦ EM022	Medium/Minimal	Negligible
Introduction and spread of aquatic pest species.	Logistics and transport; vegetation clearing.	Introduction of new pest species to the PAOI reducing habitat quality and outcompeting and preying on native aquatic biota.	PRL-15 River transport corridor	C, O	♦ EM023 ♦ EM028	Medium/Minimal	Negligible
			Export pipeline route	C, O		Low/Minimal	Negligible
		Spread of existing aquatic weeds reducing habitat quality for native aquatic biota.	PRL-15 River transport corridor	C, O		Medium/Low	Minor

Table 11.39 – Summary of Assessment of Residual Impact Significance for Freshwater and Estuarine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Introduction and spread of aquatic pest species (cont'd).	Logistics and transport; vegetation clearing (cont'd).	Spread of existing aquatic weeds reducing habitat quality for native aquatic biota (cont'd).	Export pipeline route	C, O	See above	Low/Low	Minor
		Spread of existing invasive fauna outcompeting and preying on native aquatic biota.	PRL-15 River transport corridor	C, O		Medium/Low	Minor
			Export pipeline route	C, O		Low/Low	Minor

C = Construction, O = Operations.

11.6 Terrestrial Biodiversity

11.6.1 Context

The information assessed in this section is based on the baseline characterization of terrestrial biodiversity (Part 6 of Volume 2 and summarized in Chapter 7) and the Project description (Chapter 4).

The Project is located in the Kikori-Purari biogeographic region which is a biologically diverse and endemically rich terrestrial region. It is divided into five ecological zones; the Middle Purari Hills, Southeast Hills, Delta Swamps and Plains, Mangroves and Southeast Coast; each of which supports a distinct assemblage of terrestrial flora and fauna. The study area is of very high conservation value due to its large size, remoteness, low human population and high degree of connectivity amongst a variety of intact and biodiversity-rich habitats that support numerous species of conservation significance (Chapter 7).

The study area qualifies as Tier 1 Critical Habitat under the International Finance Corporation's (IFC's) Performance Standard 6 (IFC, 2012a), due to the presence of three International Union for the Conservation of Nature (IUCN) Critically Endangered and nine Endangered terrestrial flora and fauna species, more than 100 terrestrial restricted-range species, the presence of threatened and unique ecosystems, and inclusion of part of the Crater Mountain Wildlife Management Area.

The area is covered almost entirely in natural vegetation (i.e., 98.9%, including regenerating logged forest), which is arranged into five broad vegetation groups: hill forest, alluvial forest, freshwater swamp vegetation, mangroves and littoral forest. Hill forest is widespread and covers nearly half the Middle Purari Hills and Southeast Hills ecological zones. Freshwater swamp vegetation and alluvial forest covers much of the Delta Swamps and Plains zone, and the Mangroves ecological zone occurs along the coast (Part 6 of Volume 2).

Nine types of focal sites[3] are recognized in the various ecosystems. Focal sites include caves, nesting sites, large trees and forest pools.

Ninety-two IUCN listed and nationally Protected species are known or likely to occur in the study area. These include three Critically Endangered species (*Diospyros lolinopsis, Guioa hospita* and Bulmer's fruit bat (*Aproteles bulmerae*)) and nine Endangered species (*Diospyros insularis*, *Pterocarpus indicus* and *Flindersia pimenteliana*, two tree kangaroo (*Dendrolagus*) species, giant bandicoot (*Peroryctes broadbenti*), far eastern curlew (*Numenius madagascariensis*), great knot (*Calidris tenuirostris*) and pig-nosed turtle (*Carettochelys insculpta*)). A further 65 species are scientifically undescribed, including 49 new-to-science species (i.e., 34 plants, two small nonvolant mammals, two reptiles, three frogs and eight odonates), and 119 species are restricted-range species.

Ninety-seven invasive alien plant species have been recorded in the study area, including seven 'Priority 1' weed species that have the potential to invade undisturbed natural habitats, i.e., Angelonia (*Angelonia angustifolia*), water hyacinth (*Eichhornia crassipes*), anglestem willow (*Ludwigia leptocarpa*), mile-a-minute vine (*Mikania micrantha*), bamboo daka (*Piper aduncum*), African tulip tree (*Spathodea campanulate*) and coconut palm (*Cocus nucifera*, a commercial cultivar). Among invasive alien fauna, four rodent species, feral pigs and dogs, the Eurasian tree sparrow (*Passer montanus*) and the cane toad (*Rhinella marina*) are all confirmed present.

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3 Various localized terrain and habitat features upon which multiple species or multiple individuals of one or more species are ecologically dependent.

11.6.2 Discipline-specific Impact Assessment Method

11.6.2.1 Approach

General Approach

The impact assessment for terrestrial biodiversity follows the significance assessment method outlined in Chapter 3. The level of significance is derived from a combination of the value's sensitivity and the impact's magnitude.

This assessment adopts a high-level, combined approach in determining the overall residual significance of Project-related impacts. Individual impact processes are initially discussed separately, but in many cases the mechanisms of change are interrelated, and their effects are accumulative such that examining each factor in isolation can lead to a misleading assessment. Section 11.6.5 considers the significance of residual impacts as a combined function of all direct and indirect impact processes. The approach was developed by specialists based on expertise, experience and precedents from other peer reviewed impact assessments.

Assessing Impacts to Species Known Only from the Study Area

Potential impacts to species that are presently known only from the study area are assessed under the precautionary principle. A lack of basic information on distribution and abundance from which to infer rarity exists for many taxa, both globally and those known to occur in the study area. Most species presently known only from the study area are likely to occur more widely across the Gulf Province and country, and across a broader range of suitable habitat types. A precautionary approach is required until such records exist. This assessment conservatively considers that where species ecologies are incomplete, one or more may be restricted to the study area where they may be constrained by specific habitat requirements or be locally uncommon or rare.

Features Not Assessed in This Chapter

The following biodiversity values are not assessed in this chapter:

- Those species and ecosystems judged in Part 6 of Volume 2 to be ***Not Sensitive*** or to have ***Low Sensitivity***. The impact magnitude for each of these values is deemed to be ***Medium*** or lower, and the impact significance is therefore ***Negligible*** or ***Minor***.
- The IUCN Critically Endangered mangrove tree *Bruguiera hainesii* and the associated '*Bruguiera hainesii* zone' focal site, located at the eastern edge of the Mangroves ecological zone approximately 550 m north of Harevavo village. A recent genetic study has found this taxon to be a hybrid form and thus not a valid species (Ono et al., 2016). Hybrids are not assessed under the IUCN Red List of Threatened Species and it is not considered further here.
- Hill forest on limestone is a ***Very Sensitive*** terrestrial ecosystem restricted to areas outside of the PAOI and is not expected to be adversely impacted directly or indirectly by Project activities; it is therefore not assessed in this report.
- The Wi'i Creek cave which potentially harbors a colony of IUCN Critically Endangered Bulmer's fruit bat. This site will be avoided by the Project and induced, and indirect impacts are unlikely given its remoteness from villages. Thus, the Wi'i Creek cave will not be considered further.

- Impacts to freshwater ecosystems are considered in detail in Sections 11.3 to 11.5. This chapter will only assess impacts in relation to terrestrial flora and fauna that rely on these environments.
- The PRL-15 oxbow wetlands and other oxbow lakes will be avoided during construction and are not predicted to be impacted from Project generated noise disturbance and are not expected to be adversely affected by potential induced population influx associated with Project construction to nearby communities (i.e., Poroi 1, 2 and 3) that use the wetlands (see Section 13.1.7). Thus, impacts to oxbow lakes are not assessed further.
- Impacts to marine ecosystems are considered in detail in Chapter 12. This chapter will only assess impacts in relation to terrestrial flora and fauna.

11.6.2.2 Sensitivity

Biodiversity values (i.e., ecosystems, focal sites and species) present in the study area are assigned a sensitivity ranking in Part 6 of Volume 2, where the methods used to assign sensitivity and the features relevant to biodiversity values of conservation significance are described in detail. Briefly, the sensitivity of each biodiversity value is assessed according to its inherent value and sensitivity to change. These qualities are aligned with the key concepts of ‘irreplaceability’ and ‘vulnerability’ outlined in IFC Performance Standard 6 and related guidance note (IFC, 2012b). Relevant sensitivity attributes include:

- Intrinsic worth – including the value’s importance to supporting sensitive species or communities, and conservation status as applied by governments and other authorities.
- Intactness – the degree to which the biodiversity value under consideration remains unchanged by anthropogenic impact processes.
- Replacement potential – a measure of the value’s abundance and distribution within and beyond the study area and biogeographic region, incorporating the potential for a representative or equivalent example to be found to replace or buffer any losses.
- Resilience – a measure of the value’s ability to withstand, buffer (ecosystems and focal sites) or adapt to (species) changing conditions without affecting its intrinsic worth (e.g., a habitat’s potential to support species and communities) or other sensitivity attributes (e.g., a species’ conservation status, abundance or rarity).

Each attribute is assessed independently for each biodiversity value. The sensitivity rating is assigned based on the average sensitivity of a biodiversity value’s attributes and the professional judgement and experience of experts. Based on this, biodiversity values are assigned one of five sensitivity rankings: ***Minimal***, ***Low***, ***Medium***, ***High***, ***Very High***.

Tables 11.40 and 11.41 summarize the guideline criteria used to assign sensitivity to ecosystems, focal sites and species. Section 7.7 summarizes the sensitivity ranking of the biodiversity values present in the study area.

11.6.2.3 Impact Magnitude

The magnitude of impacts resulting from various Project activities is defined by the amount and type of change incurred by the biodiversity value. Aspects considered in quantifying and ranking impact magnitude include:

- Severity – a measure of the intensity of impact through the scale or degree of change from existing conditions due to the impact.
- Geographic extent – the spatial extent of the impact.

- Duration – the length of time during which the impact effects persist.

The overall impact magnitude ranking is assigned based on the average magnitude across all aspects with respect to a biodiversity value.

Table 11.42 provides the guideline criteria used to determine the magnitude of impacts. These have been developed specifically for the Project and draw partly on criteria used to assess impacts to biodiversity associated with the development of other petroleum projects in Papua New Guinea (e.g., CNS, 2009 and 2015) and have been refined to heighten their relevance to the current context.

When characterizing impacts to focal sites and common or widespread species, impacts to ecosystem values (i.e., habitats) are often used as a surrogate to inform the significance of impacts to the values the ecosystems support. In addition to taxa confirmed present in the study area, this assessment considers sensitive species that have not been recorded but that may occur based on current information regarding their distribution and habitat preferences (Part 6 of Volume 2). Methods used to assess impacts on additional potentially occurring species are the same as those applied to taxa confirmed to be present.

Table 11.40 – Terrestrial Biodiversity Sensitivity Criteria for Species

Sensitivity	Conservation-listed Species*	New-to-Science, Undescribed and Restricted-range Species**
Very High	♦ IUCN CR. ♦ IUCN non-CR species whose true conservation status is likely to be equivalent to IUCN CR at the national or global scale, according to expert opinion.	A rare to very rare species known only from the study area, with highly specialized habitat requirements and low dispersal potential (flora).
High	♦ IUCN VU and EN. ♦ IUCN non-Threatened (DD, NT, NE or LC) species whose true conservation status is likely to be equivalent to IUCN VU or EN at the national or global scale, according to expert opinion.	An uncommon to rare species known only from the study area, with specialized habitat requirements and low to moderate dispersal potential (flora).
Medium	♦ Protected under the Fauna Act. ♦ CITES Appendix I. ♦ IUCN NT. ♦ IUCN DD, NE or LC species whose true conservation status is likely to be equivalent to IUCN NT at the national or global scale, according to expert opinion.	An uncommon species, restricted-range or known only from the study area, with moderately specialized habitat requirements and moderate dispersal potential (flora).
Low	♦ CITES Appendix II. ♦ IUCN LC. ♦ IUCN DD or NE species considered to be common and/or widespread according to expert opinion.	A common species known from outside the study area, with low habitat specialization and high dispersal potential (flora).
Minimal	♦ Invasive species. ♦ Native species well adapted to habitat loss or degradation.	An undescribed species common or widespread beyond the study area that is not restricted range and is well adapted to habitat loss or degradation.

* IUCN = International Union for Conservation of Nature, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, LC = Least Concern, NT = Not Threatened, DD = Data Deficient, NE = Not Evaluated.
** Adapted from a numeric score-based approach developed specifically for the Project and described in detail in Part 6 of Volume 2.

Table 11.41 – Terrestrial Biodiversity Sensitivity Criteria for Ecosystems and Focal Sites

Score	Intrinsic Worth	Intactness	Replacement Potential	Recovery Potential
Ecosystems				
Very High	A natural ecosystem or habitat that: ♦ Supports IUCN CR or other Extremely Sensitive species. ♦ Is critical to the survival of a species or ecological community. ♦ Is a Tier 1 IFC Critical Habitat.	An ecosystem that is unmodified by human activity. Its ecological functions and species composition are unmodified, and its wilderness values are recognized.	The ecosystem is unique or very rare locally and regionally.	Recolonization by or revegetation with native species to restore ecosystem structure and function is problematic, with success unlikely.
High	A natural ecosystem that: ♦ Supports a high or regionally important concentration of IUCN Threatened or other Very Sensitive species. ♦ Supports important populations of endemic, restricted-range, migratory or congregatory species. ♦ Supports a unique species community or a high proportion of habitat-specialist species in a small area. ♦ Is a protected area or classed as Tier 2 IFC Critical Habitat.	An ecosystem that is essentially unmodified by human activity and the primary ecological functions and species composition of which are intact. Its wilderness values are recognized.	An ecosystem that is rare locally and regionally or has a moderate number of regional equivalents that have been extensively degraded with limited connectivity to comparable environments outside the Project area.	Recolonization by or revegetation with native species to restore ecosystem structure and function requires significant intervention or is only successful in a minority of cases.
Medium	A natural ecosystem that supports viable communities of native species that are largely unaltered from the original composition. Conservation-listed species may be present.	An area of natural habitat where human activity has not significantly modified the area's primary ecological functions, species composition or forest structure.	An ecosystem that has a moderate number of local and regional equivalents, with some connectivity to comparable environments outside the Project area.	Recolonization by or revegetation with native species to restore ecosystem structure and function is slow or partially successful without intervention.
Low	An ecosystem that supports viable communities of some native species, but species communities are significantly altered from the original composition. Invasive species may be present.	Converted land that retains some native vegetation cover, or natural vegetation that has been extensively or heavily degraded by human activity.	An ecosystem that is common locally and regionally, with moderately high connectivity to comparable environments outside the Project area.	Recolonization by or revegetation with native species to restore ecosystem structure and function occurs and is expected to be successful in most cases without intervention.

Table 11.41 – Terrestrial Biodiversity Sensitivity Criteria for Ecosystems and Focal Sites (cont'd)

Score	Intrinsic Worth	Intactness	Replacement Potential	Recovery Potential
Ecosystems (cont'd)				
Minimal	An ecosystem that supports few or no native species or in which invasive species are prevalent.	Areas with little or no remnant vegetation or areas that are highly degraded.	An ecosystem that is common and widespread locally, regionally and nationally, with high connectivity to comparable environments outside the Project area.	Recolonization by or revegetation with native species to restore ecosystem structure and function occurs without intervention and is expected to be successful in all cases.
Focal sites				
Very High	A local landscape feature upon which one or more IUCN CR or other Extremely Sensitive species are ecologically dependent.	Unmodified and undisturbed by human activity and has evidence of recent and frequent use.	The feature has very limited local availability and is extremely difficult to replace or relocate.	The feature is fragile and is unlikely to recover from disturbance.
High	A local landscape feature upon which one or more IUCN Threatened or other Very Sensitive species are ecologically dependent.	Unmodified and undisturbed by human activity and has evidence of recent or regular use.	The feature has a restricted regional distribution and limited local availability. The feature is difficult to replace or relocate.	The feature is relatively fragile and may not recover from disturbance.
Medium	A local landscape feature upon which multiple species or multiple individuals of one or more species (excluding not sensitive species) are ecologically dependent.	Modified by human activity and/or subject to some disturbance but has evidence of use.	The feature is not common but is widespread locally and regionally. The feature can be replaced or relocated with moderate effort.	The feature is likely to recover from disturbance over a long time.
Low	A local landscape feature that multiple species or multiple individuals of one or more species will opportunistically use.	Largely modified by human activity; may be used opportunistically.	The feature is common and widespread locally and regionally. The feature can be replaced or relocated with minimum effort.	The feature is relatively robust and will recover from disturbance in a moderate time.
Minimal	A local landscape feature that is likely to only be used by a limited number of species or a limited number of individuals of one or more species that are not sensitive or low sensitivity.	Converted or highly modified by human activity; rarely used.	The feature is common and widespread locally, regionally and nationally. Numerous replacements exist within the territory or home range of the species.	The feature is robust and will recover from disturbance in a short time.

IUCN = International Union for the Conservation of Nature, CR = Critically Endangered.

Table 11.42 – Terrestrial Biodiversity Magnitude of Impact Criteria

Magnitude	Severity	Geographic Extent	Duration
Very high	♦ Ecosystems – impact very large with respect to natural variability; greatly reduces ecosystem function or viability in the affected area. ♦ Focal sites – feature lost or no longer ecologically functional. ♦ Species – very large decline that greatly reduces the viability of the population.	Impact very widespread; affects a very high proportion (approximately 15% or more) of the value's extent or distribution in the ecological zone or study area and potentially a high proportion of its regional occurrence.	Impact very long term (more than 25 years) or potentially permanent.
High	♦ Ecosystems – impact large with respect to natural variability; reduces ecosystem function or viability in the affected area. ♦ Focal sites – a large reduction in the feature's ecological function. ♦ Species – large decline that reduces the viability of the population.	Impact widespread; affects a high proportion (up to 15%) of the value's extent or distribution in the ecological zone or study area.	Impact long term (15 to 25 years).
Medium	♦ Ecosystems – moderate impact readily detectable with respect to natural variability; limited reduction in ecosystem function or viability in the affected area. ♦ Focal sites – a moderate reduction in the feature's ecological function. ♦ Species – moderate decline with limited reduction to the viability of the population.	Impact contained to 5% or less of the value's extent or distribution in the ecological zone or study area.	Impact medium term (5 to 15 years).
Low	♦ Ecosystems – low impact marginally detectable with respect to natural variability; unlikely to affect ecosystem function or viability. ♦ Focal sites – a minor reduction in the feature's ecological function. ♦ Species – minor decline that does not threaten the viability of the local population.	Impact restricted to 1% or less of a species distribution in the ecological zone or study area.	Impact temporary or short term (2 to 5 years).
Minimal	♦ Ecosystems – very low impact not detectable with respect to natural variability. ♦ Focal sites – no measurable effect on the feature's ecological function. ♦ Species – no measurable population decline.	A highly localized impact to a value restricted to the Project footprint.	Impact very short term (less than 1 to 2 years).

11.6.2.4 Impact Significance

The interaction between the sensitivity of a value and the magnitude of impact is combined to determine the level of significance of impacts arising from Project development (see Chapter 3). Table 11.43 presents the significance assessment matrix used to determine the significance of impacts to terrestrial biodiversity values.

Table 11.43 – Terrestrial Biodiversity Significance Assessment Matrix

Magnitude of Impact	Sensitivity of Value				
	Very High	High	Medium	Low	Minimal
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

11.6.3 Identification of Potential Impacts

Potential impacts to terrestrial biodiversity can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. The following embedded design controls will address potential impacts to terrestrial biodiversity:

- The Project will design its plant to meet the applicable emission standards and relevant ambient air quality criteria beyond the proposed facility boundary [ED002]
- All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is:
  - To account for local rainfall conditions and catchment size of works areas.
  - To allow avoiding unseasonal waterlogging
  - To allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable [ED014].
- All vehicles and machinery (including vessels and aircraft), plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired [ED019]
- The flares will be used only for safety flaring in alignment with the TOTAL no routine flaring policy [ED023].
- During the first years of production when it is not possible to dispose of acid gas by injection, a sulfur recovery unit will be installed and operated at the CPF to remove sulfur-containing compounds from the acid gas after it has passed through a thermal oxidizer [ED024].
- Once the Elk reservoir has been depleted, acid gas removed from the raw gas using the AGRU will be disposed of by injecting it into the reservoir [ED025].

- The sulfur recovery unit will remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible [ED026].
- Fixed or mobile equipment will be used and / or located in consideration of people and other sensitive receptors [ED030].
- Minimize noise from mechanical plant, as far as practicable [ED031].
- The Project will design its plant and undertake activities to comply with the applicable noise criteria [ED032].

11.6.3.1 Overview

This section describes the impact processes that may affect terrestrial biodiversity values due to Project development. They are grouped into the following categories:

- Habitat loss and fragmentation, including loss of important features and impacts from barrier effects.
- Habitat degradation, including impacts from edge effects, erosion and movement of soil and spoil, sedimentation and contamination of waterways, reduction in air quality, fire, deforestation and acid rain.
- Natural regeneration failure following vegetation clearing.
- Loss of individuals and populations.
- Mortality or injury to fauna, including vehicle strike and impacts from trenching.
- Disturbance to fauna and focal breeding and roosting sites, for example, through noise and light emissions.
- Introduction and spread of invasive alien species, including weeds, pathogens and pests.
- Indirect impacts from social and commercial aspects, including increased hunting, exploitation of forest resources and clearing of land for housing and gardens.

The various processes may impact biodiversity values directly or indirectly, where:

- Direct impacts occur due to planned Project activities, e.g., removing forest habitat to develop infrastructure during the Project construction phase.
- Indirect impacts would not have occurred without Project development but do not directly result from planned Project activities. They include:
  - Impacts due to the actions of Project personnel but that arise unintentionally and where the impact does not directly involve materials required for Project development, e.g., accidental fires caused by Project workers outside of authorized Project activities.
  - Impacts mediated by non-Project personnel, e.g., increased hunting or habitat loss due to changes in the population size or the subsistence activity patterns of local residents or changes in land use by third-party commercial developments.

11.6.3.2 Habitat Loss and Fragmentation

Habitat Loss

Habitat loss is the primary cause of global biodiversity loss (Pimm and Raven, 2000) and is recognized as a major cause of population decline for most IUCN Red Listed New Guinean flora and fauna (e.g., Leary et al., 2016; Wooley et al., 2016). The immediate consequence of vegetation clearing for the Project is the loss of vegetation, habitat and associated terrestrial biodiversity. Factors influencing the magnitude of the impact of habitat loss include:

- The amount and type of habitat lost.
- The extent and distribution of remnant areas of similar (or better quality) habitat.
- The duration of loss and the extent to which regeneration occurs.

Associated impacts for fauna resident in development footprints is discussed in Section 11.6.3.5. Additional loss of suitable habitat from habitat degradation processes may exacerbate the impacts of habitat loss to some biodiversity values (Section 11.6.3.3).

Loss of Focal Features

Focal features, such as large trees which provide roosting, breeding, nesting, mating and food resources, are assumed to be uniformly distributed in forest ecosystems. Proportional ecosystem losses provide a useful surrogate measure to predict the loss of these features.

Numerous plant species are important to fauna, as specialist food items, and keystone food plants support a broad diversity of taxa. These species may be lost or degraded by construction and operations activities. Loss of these species may affect local populations of sensitive fauna that rely on them. In terms of conservation significant fauna present in the Project area, specialist food plants include:

- Figs (*Ficus* spp.) are widely regarded as a keystone food resource in tropical forests (Lambert & Marshall, 1991; Mackay et al., 2018) and are a prominent dietary component of sensitive bird species such as Blyth's hornbill (*Rhyticeros plicatus*), manucode birds-of-paradise (*Manucodia* and *Phonygammus* spp.), and Pesquet's parrot (*Psittrichas fulgidus*).
- Vines of the family Aristolochiaceae are the sole food source for the larvae of birdwing butterflies (*Ornithoptera* spp.), including the southern tailed birdwing (*O. meridionalis*), which feeds exclusively on the vine *Pararistolochia meridionaliana*; the paradise birdwing (*O. paradisea*), which consumes a select variety of *Pararistolochia* and *Aristolochia* food plants; and the Goliath birdwing (*O. goliath*), which feeds on the vines *A. goliathiana* and *A. crassinervia*.

Other focal features that may be lost or damaged by Project development include breeding and roosting sites, such as caves and rocky outcrops, nest mounds, nesting, lekking or roosting trees and nesting banks. Section 11.6.3.6 discusses impacts to fauna from the loss of these features.

Social drivers of change, including additional clearance by local residents (Section 11.6.3.8) may exacerbate loss or degradation of these features.

Loss of Watercourse and Wetland Habitats

Project construction will cause the loss of some small-scale watercourses, wetland habitat and hill forest pools important to the ecology of some terrestrial taxa. Large watercourses are avoided where possible but some streams in the CPF footprint will be permanently diverted and some hill forest pools will be lost to infrastructure development.

Terrestrial species dependent on these features include various frogs (e.g., *Hylarana* spp., *Litoria* spp.) and odonates (most taxa) that require forest streams and pools to reproduce, stream bank specialist flora, and microhylid frogs that may be specialist inhabitants of streamside vegetation in hill forest (*Cophixalus* sp. 3, *Oreophryne* sp. 2). Most of these species occur widely in suitable habitat and declines in their populations from the loss of these habitats and associated resources are considered to be low. Species most at risk include two new-to-science species known from only a few individuals recorded at one or two locations; the stream bank specialist herb *Begonia* sp. 5 in the CPF footprint, and the damselfly *Teinobasis* sp. 1 recorded at a single forest pool alongside the road leading northwest from the ANT-10 wellpad.

Barrier Effects

Barrier effects occur when connectivity is lost between habitat areas thus restricting the movement of a broad range of species, limiting their access to resources and reducing their potential for survival. Roads, large forest gaps and linear clearings act as effective barriers for many mammals, forest birds, reptiles and amphibians (Laurance et al., 2004; Andrew et al., 2015; van der Ree et al., 2015). Barrier effects are typically avoided where connectivity is retained. Roads and clearings created for the Project are unlikely to effectively fragment populations and are unlikely to affect the movement or population viability of conservation significant fauna given that most species are highly vagile or known to cross anthropogenic clearings, and that forest cover throughout the PAOI will remain.

11.6.3.3 Habitat Degradation

Edge Effects

Edge effects occur when clearing vegetation changes the condition of adjacent remnant habitats. They include (Murcia, 1995):

- Abiotic effects from increased exposure of the forest edge to sun and wind, leading to changes in forest microclimate that include lighter, hotter and drier conditions.
- Direct biological effects, including changes in the presence and abundance of various species in direct response to the change in physical conditions.
- Indirect biological effects from changes in species interactions, for example, predation, competition, herbivory and seed dispersal.

Edge environments are more susceptible to desiccation and burning, and trees located in edge habitats are at a higher risk of mortality from wind throw. Edge habitats provide a suitable environment for invasive alien species to establish and may provide corridors for such species to expand their range and impacts (see Section 11.6.3.7). Local species may be outcompeted in edge habitats for space and resources leading to the loss of individuals and changes in the character and functioning of the ecosystem.

Edge effects will impact most on forest interior specialist species that are adapted to dark, humid microclimates or shaded streamside habitats, for example, some riparian plants, microhylid frogs, understory-dwelling bird species and damselflies. Where forest streams are exposed to increased sunlight, water temperature may increase, reducing the long-term breeding success of frog species requiring cool waters (e.g., Welsh & Ollivier, 1998).

Clearing for the Project will directly impact adjacent forest habitat through the creation of edge habitats and their associated effects. Few studies have investigated the influence of edge effects in New Guinean forests. Recent work in lower montane limestone forests in a high rainfall zone of Papua New Guinea have found no strong evidence for an influence of edge effects on the distribution and abundance of frogs, bats or terrestrial birds and mammals (Richards 2017; Woxvold and Legra, unpublished data). Studies in other tropical regions have shown that different components of edge effects may penetrate different distances into the forest (Laurance and Bierregaard 1997; Laurance et al. 2000, 2004). In Amazonian forests, some birds may stay 50 m away from the forest edge, microclimatic changes may be detectable at 100 m, and increased tree mortality and open-habitat invertebrates may penetrate at least 300 m. In fragmented rainforests of north Queensland, edge effects can impact forest structure 200 m into the forest and may be detectable up to 500 m from the edge. Mammal communities in degraded edge habitats typically include fewer species than the original forest and have different community structures (Asquith and Mejia-Chang 2005). Based on this information, this assessment, precautionarily assumes edge effects penetrate 100 m into vegetation surrounding linear infrastructure and facility sites that are less than 150 m wide. For clearings more than 150 m wide, edge effects are assumed to penetrate 150 m into surrounding habitats.

Edge effects may be locally intensified by other factors, such as Project-related erosion and soil or the spread of invasive alien species. Additional clearance by local residents for housing and subsistence activities may also increase the extent of edge effects (Section 11.6.3.8).

Erosion and Movement of Soil and Spoil in Terrestrial Environments

Substrates in the PAOI, including in both hill and alluvial terrain, are highly erodible. Rock falls, landslides, flows and gullying are common geohazards, and transported sediments will also exhibit poor stability. Across much of PRL-15, the soft mudstones and siltstones of the Orubadi Beds are particularly unstable.

Ground disturbance at Project facilities and infrastructure sites located on unstable substrates, particularly during construction where vegetation clearing and earthwork activities occur, may lead to erosion and smothering of vegetation and related habitats adjacent to infrastructure footprints located in areas with poor soil stability. Soil and spoil exposure, disturbance and stockpiling may lead to erosion and the uncontrolled transfer of soil into adjacent terrestrial habitats, degrading vegetation, killing flora and potentially causing habitat loss beyond the Project footprint. Regeneration may also be inhibited due to the reduced availability of essential topsoil and the changed soil conditions for germination.

Impacts could be highest for new-to-science species known from only a few localities near the Project footprint that are precautionarily presumed to be rare. Species most at risk include the *Begonia* sp. 5 population at the edge of the CPF footprint, the riparian plant *Medinilla* sp. 1 near ANT-10, *Archidendron* sp. 1 and any unidentified *Syzgium* sp. 1 near high activity construction areas and spoil dump areas near the CPF, the IUCN Endangered timber tree *Diospyros insularis* near the Logistics Base, and *Pseuduvaria* sp. 1, *Ficus* sp. 1, *Discocalyx* sp. 1, *Syzygium* sp. 4 and the IUCN Critically Endangered timber tree *Diospyros lolinopsis* in the proposed export pipeline corridor.

Among fauna, Scheepmaker’s crowned pigeon (*Goura scheepmakeri*) has a restricted distribution in its hill zone habitat, preferring the narrow strips of gentle terrain in valley floors. Uncontrolled soil deposition typically accumulates in these areas, which may result in localized losses of suitable habitat and the potential decline in IUCN Vulnerable Scheepmaker’s crowned pigeon populations.

The potential impacts from soil erosion may be exacerbated when local residents clear additional forest (Section 11.6.3.8) exposing and destabilizing topsoil. The effects; however, would be localized to areas near villages.

Sedimentation of Waterways and Changes to Hydrology

Construction of Project facilities, roads and pipeline ROWs may increase sediment loads and modify hydrological patterns in some waterways. In acute cases, large influxes in sediment loads and damming or drainage of various habitats for constructing causeways and roads can alter flood regimes. Forests adapted to dry-land conditions die if flooded for even short periods.

Swamp forests and woodlands, which are adapted to permanent or periodic flooding episodes, may die if the flooding and drying dynamics change.

Impacts would be most prevalent in hill terrain and where roads and pipelines cross watercourses. Construction of the CPF is expected to increase sediment loads in the upper portions of the Oyomo Creek system and dredging of the Logistics Base may increase sediment loads in the Purari River system. Turbid plumes from dredging could extend down river into Oyomo Creek during periods of high flow in the Purari River (see Section 11.3.). Runoff from spoil disposal sites, if not engineered correctly, may also affect adjacent watercourses such as Boa Creek and Kuku Creek in hilly terrain, and Oyomo Creek tributaries on the alluvial plain near the CPF.

Terrestrial flora and fauna potentially impacted include plants growing in riparian, swamp or other environments sensitive to changes in sedimentation (including mangroves) and animals dependent on clean and clear watercourses as a source of food or for reproduction. Sediment deposition may smother stream microhabitats, such as interstitial spaces among rocks, and alter streamside vegetation. This may reduce the abundance and diversity of aquatic resources, cause the loss of some species and cause other species to relocate to tributaries with better water quality.

Influxes in sediment load and changes in hydrology may cause population declines of amphibians and odonates (Ashton et al., 2006; Luke et al., 2017), which require cool, clear forest streams to breed and complete early life stages. Other taxa, including those that hunt in clear watercourses, such as kingfishers, Salvadori’s teal (*Salvadorina waigiuensis*), forest bittern (*Zonerodius heliosylus*) and the semi-aquatic new-to-science rodent *Hydromys* sp. 1, may also experience declines if their foraging ability is impeded. Crocodiles (New Guinea freshwater crocodile (*Crocodylus novaeguineae*) and estuarine crocodile (*C. porosus*)) and freshwater turtles (pig-nosed turtle (*Carettochelys insculpta*) and striped New Guinea soft-shelled turtle (*Pelochelys bibroni*)) occupying the already turbid larger watercourses of the lower Purari River system will not be greatly impacted. In contrast, a significant increase in sediment loads to Oyomo Creek (see Section 11.3.5) may impact nesting behavior and reduce nesting success of IUCN Threatened freshwater turtle species if the morphology of nest banks is considerably altered (see Section 11.6.3.6).

Altered hydrological regimes may exacerbate influxes in sediment loads. Sections 11.3 to 11.5 considers impacts to freshwater ecosystems in detail.

The potential impacts of sedimentation and hydrological change may be intensified where local residents clear additional vegetation, thereby increasing the potential for erosion and runoff (Section 11.6.3.8). These impacts are expected to be greatest for waterbodies near existing communities and, to a lesser degree, along infrastructure routes such as the export pipeline access road.

Contamination of Terrestrial and Aquatic Environments

The construction, operation and decommissioning of Project facilities and infrastructure, including wells, roads and pipelines, will require the use, production and management of hazardous and non-hazardous substances and waste streams. Accidental contamination may degrade habitat and reduce species health.Section 13.6 discusses potential impacts to human health from the contamination of terrestrial and aquatic environments.

Contamination can also alter the structure and floristics of riverine vegetation by encouraging alien plant species that are suited to the altered water chemistry to establish (Richardson et al., 2007) and displace native species.

Contamination of terrestrial and aquatic habitats may impact any species. Biodiversity values most likely to be directly and indirectly impacted in the Project area include watercourses and wetlands, associated riparian habitats, and the flora and fauna that rely on these environments. Terrestrial flora and fauna likely to be impacted include plants growing in riparian or swamp environments (including mangroves); frogs requiring water for reproduction; and turtles, crocodiles, waterbirds, odonates, and forest birds and mammals that specialize in eating aquatic fauna. The most likely species to be directly impacted are rare new-to-science streambank specialist flora that occur close to planned infrastructure footprints, such as *Begonia* sp. 5, *Syzygium* sp. 1, *Medinilla* sp. 1 and *Glochidion* sp. 1.

The potential for ecosystem contamination may be elevated due to Project-induced population growth, which could be associated with an increase in the use of potential contaminants, e.g., fuels and oils for outboard motors and generators.

Reduction in Air Quality

Project development may reduce air quality due to gaseous and particulate emissions, including dust. Air quality impacts associated with gaseous emissions from Project activities comply with adopted Project criteria (Part 2 and 5 of Volume 3). As such, the greatest potential impacts to terrestrial biodiversity from air quality will likely occur from fugitive dust. Potential sources include earthworks, transporting spoil, quarrying, vehicle and equipment movement on unsealed roads, and wind erosion of exposed surfaces, e.g., soil stockpiles or disposal areas.

Dust may coat plant leaves, hindering or preventing photosynthesis and respiration, and allowing the penetration of phytotoxic gaseous pollutants. This causes decreased plant productivity and visible injury symptoms or mortality. Most forms of vegetation are affected; although, lichens and mosses are among the most susceptible (Farmer, 1993). Rain generally washes dust off vegetation; although, repeat events of dust deposition, such as those that occur along roads or near spoil disposal sites and quarries, may have long-term effects on the health and survival of individuals which may lead to changes in the structure and composition of local vegetation communities. Excessive dust circulating during dry periods may temporarily displace local fauna, and dust coating vegetation may displace invertebrates that are a food source for a variety of vertebrate fauna.

Species most likely to be affected are new-to-science flora, precautionarily presumed to be rare, that occur close to planned infrastructure footprints, such as *Begonia* sp. 5, *Archidendron* sp. 1 and *Syzygium* sp. 1 in the CPF area, *Syzygium* sp. 4 along the proposed export corridor and *Medinilla* sp. 1, and *Glochidion* sp. 1 located in the gas field. Overall, impacts will be localized to the degradation buffer outlined for edge effects and temporary given the high rainfall, low wind speeds (Part 19 of Volume 2) and dense vegetation in the area. Impacts will be higher during dry years and during construction.

Unplanned and Uncontrolled Fire

Under exceptional circumstances, Project activities may directly cause fires through sparks from machinery and equipment, from vehicles, from workers smoking and from accidental leaks of flammable gases from facilities and pipelines if ignited.

The likelihood of wildfire, including frequency and severity may be exacerbated by desiccated or weed infested forest edges which increases their flammability and provides a starting point for more extensive forest fires.

Once established, a wildfire has the capacity to degrade or destroy extensive areas of natural habitat well beyond its ignition source. Animals that fail to escape its path will be lost, and limited resources such as fruiting trees and trees with nesting hollows may be damaged or destroyed.

The potential for fire is greatest during dry years when even normally wet forests can burn. Major fires during the 1997 to 1998 El Niño event resulted in the loss of large areas of forest in Papua New Guinea[4] (Haberle et al., 2001; Johns et al., 2007; Bryan & Shearman, 2015). Recent climate modelling suggests that the rate of occurrence of 'extreme' El Niño events, such as those that occurred in 1982 to 1983 and 1997 to 1998, may double in frequency during this century (to one in every 10 years) due to climate change (Cai et al., 2014).

There is minimal evidence of previous major local fire events and such events are likely limited by the high monthly rainfall experienced by most of the Project area during most years.

Deforestation and Habitat Degradation from Logging

Commercial forestry is the largest industrial land use activity to have operated in the Project area. Approximately 1,300 km^2 of forest have been logged; and a further 3,370 km^2 of unlogged, commercially viable hill and alluvial forest remains. Most of the remaining commercially viable forest (66.9%) occurs in the Baimuru Blk 3 concession in the northern half of the Project area. Most of the primary hill and alluvial forest present in PRL-15 is included under the Baimuru Blk 3 concession.

Commercial developments may indirectly contribute to the degradation of forest environments where they influence the amount or pattern of industrial logging activity; however, Project development will not affect commercial logging. Commercial logging is expected to continue at the same rate and to move north of the Purari River, as the Baimuru Blk 3 concession is developed, including into areas of hill and alluvial forest in PRL-15. This would have occurred regardless of Project development and there is no evidence to suggest that Project activities will influence the rate or pattern of deforestation across the Project area. Chapter 17 provides discussion on the predicted cumulative impact of future logging activities.

Acid Rain

The reservoir contains sulfur, which could produce acid rain if not appropriately recovered. Acid rain occurs when sulfur dioxide and nitrogen oxides emitted into the atmosphere react with water, oxygen and other chemicals to form sulfuric and nitric acids. These then mix with water and other materials before falling to the ground. Acid rain can become a regional problem when winds carry sulfur dioxide or nitrogen oxides beyond the local source.

Ecological impacts of acid rain include:

- Acidification of aquatic environments, with associated declines in fauna health or animal mortality.
- Interference with soil chemistry and processes from acid-induced leaching of beneficial cations, interfering with plants abilities to absorb nutrients and potentially causing long-term damage to or mortality of floristic communities (Likens et al., 1996). As such impacts on soil chemistry is generally considered the most pervasive effect of acid rain on terrestrial environments.

4 Comparable losses were recorded for multiple other drought events. Much of the lowland rain forest in New Guinea burned during the droughts of 1877–1878, 1888, 1891, 1902, 1914–1915, 1940–1942, 1982–1983, and more recently in 1991 (Johns et al., 2007; Bryan & Shearman, 2015).

- Visible injury to leaves reducing photosynthetic and respiratory capacity which may in turn reduce their resilience to other environmental stressors, e.g., drought, and alter habitats.

The Project's acid gas recovery strategy is estimated to capture up to 95% of sulfur emissions and will largely negate the potential for acid rain. In the unlikely event of acid rain, direct impacts will be restricted to areas immediately surrounding the CPF and will mostly likely occur during early stages of the operational phase prior to the injection of acid gas to the Elk reservoir.

11.6.3.4 Natural Regeneration Failure

The ability of cleared areas to naturally regenerate from existing seed or parent stock, in some cases following preparatory activities and surface stabilization is compromised by factors affecting:

- Topsoil availability and condition, including the intensity of construction-related disturbance, erosion and soil compaction.
- The sensitivity of the vegetation type and associated soil disturbance.
- The level of weed infestation.

Natural regeneration is most successful when the topsoil is intact, as it contains the best physical, chemical and biological properties to promote plant growth, including a high-density soil seed bank of mostly pioneer species that are adapted to colonize disturbed sites.

Natural regeneration may be compromised on the steep slopes and unstable landforms of the Middle Purari Hills and Southeast Hills ecological zones where critical topsoil may be lost, exposing mudstone/siltstone bedrock, which provides an inhospitable substrate for natural regeneration. Mudstone bedrock typically remains bare or partly colonized by invasive grass species, such as *Paspalum conjugatum.* Sensitive vegetation types in which natural constraints to regeneration are highest include:

- Littoral forest (including scrub components) which has thin topsoil that is difficult to salvage and easily eroded.
- *Pandanus*-dominated swamp woodland which is highly sensitive to soil disturbances, changes to the natural drainage and the availability of raised mound regeneration microsites.
- Mangrove which is sensitive to sediment erosion and associated modified tidal flows.

Natural regeneration failure may also occur where excess spoil is deposited, as spoil can be an unsuitable substrate for regeneration if not appropriately managed. Under such conditions, spoil sites may become weed hotspots.

11.6.3.5 Loss of Individuals and Populations

For most taxa, the proportion of suitable habitat lost through vegetation clearing and degradation provides a suitable surrogate measure for estimating local population decline (Hardner et al., 2015). Exceptions, however, include species that depend on microhabitats or other local landscape features that are not uniformly distributed in ecosystems and locally rare species that occur at very few sites. For these species, habitat loss may have a disproportionately high impact on the loss of individuals and populations.

Section 11.6.3.8 addresses the potential loss of individuals and populations as a result of induced hunting from population influx. Any increase in the loss of individuals and populations from an increase in hunting represents an additional loss to those described in this section.

Loss of Fauna

Fauna resident in Project infrastructure footprints have limited capacity to vacate developing sites and to survive in surrounding areas of habitat, since:

- Most non-volant mammals, reptiles and amphibians are likely to seek shelter in situ during habitat clearance.
- Larger and more agile species may be able to move into surrounding areas (e.g., birds, bats, wallabies), but many such species are territorial, and displaced individuals are likely to encounter existing populations of the same species. In such situations, within-species territorial interactions are likely to favor resident animals and cause poor survivorship of immigrant individuals (Burns, 2005).

For wider-ranging, non-territorial species, vegetation clearing causes the loss of foraging, sheltering and breeding habitat, and the loss of high value local landscape features, such as large trees that provide important nesting, breeding, roosting and food resources. This may ultimately cause local population declines.

Highly and ***Very Highly*** sensitive species most vulnerable include the giant bandicoot, Scheepmaker's crowned pigeon, starry owlet-nightjar (*Aegotheles tatei*), Goodfellow's tree kangaroo (*Dendrolagus goodfellowi*), ifola (*D. notatus*), eastern long-beaked echidna (*Zaglossus bartoni*), Salvadori's teal, striated lorikeet (*Charmosyna multistriata*) and banded yellow robin (*Poecilodryas placens*) and some odonate taxa.

Vehicle Strike and Boat Strike

Vehicle strike is a major cause of mortality for some terrestrial species, particularly those that interact frequently with roads (Marsh & Jaeger, 2015). Project traffic on roads and waterways may directly kill or injure susceptible terrestrial fauna such as echidnas, dasyurids, wallabies, bandicoots, cassowaries, crowned pigeons, a suite of small vertebrate fauna and some non-volant arboreal species that may be forced to the ground to cross roads. In waterways, the IUCN Threatened pig-nosed turtle and striped New Guinea soft-shelled turtle may collide with boats.

Fauna Falling in Project Excavations

Fauna may fall into Project excavations including quarries and pipeline trenches where they may be trapped, injured, killed or unable to escape and so may perish. Potentially affected species include reptiles, frogs, non-volant mammals and cassowaries.

Loss of Flora

The loss of plant taxa is anticipated to be proportional to the loss of suitable habitat (Hardner et al., 2015). Exceptions to this include:

- Species occurring in hill or alluvial forest whose actual habitat requirements may restrict them to areas near the ‘hill-foot’ boundary, in well-drained alluvial forest environments or at the base of the foothills near the alluvial plain.
- Rare plants known in the study area from only a few individuals recorded at one or two locations in or near planned infrastructure footprints. They include:
  - Near the proposed CPF and Logistics Base: *Begonia* sp. 5, *Syzygium* sp. 1, *Archidendron* sp. 1, and *Diospyros insularis*.
  - Along the proposed export pipeline corridor: *Pseuduvaria* sp. 1, *Ficus* sp. 1, *Discocalyx* sp. 1, *Syzygium* sp. 4, and *Diospyros lolinopsis*.

– Along the proposed new and upgraded road routes and flowlines near ANT-10: *Teinobasis* sp. 1 and *Medinilla* sp. 1.

11.6.3.6 Disturbance to Fauna and Disturbance to Feeding, Breeding, Nesting and Roosting Sites

Disturbance to Fauna from Noise, Vibration and Light

Project construction, operation and decommissioning may cause noise, localized vibration and light pollution that may disturb local fauna.

The operation of vehicles, equipment and machinery, vegetation clearing, and excavation will produce noise and vibrations, and dredging and construction of the new quay at the Logistics Base will generate underwater noise. Noise and vibration disturbances may displace taxa that communicate acoustically, including birds, bats and frogs (Parris, 2015). Underwater noise may upset the behavior of and displace crocodiles and freshwater turtles; although, potential consequences to these species will be low (see Section 12.4.5).

Some facilities, e.g., the CPF and accommodation area, will be artificially lit at night. Increases in light levels due to artificial lighting may extend the activity time of diurnal animals, disorient some nocturnal animals, and attract others, making them more susceptible to predation or bringing them in to feed (Longcore & Rich, 2004; Gaston et al., 2013). Fast-flying bats congregate at lights where they benefit from the higher density of insect prey, but slow-flying bats avoid lights. This benefit-differential among taxa may affect local community structures by favoring the survival of populations that respond positively to anthropogenic influences.

Noise, vibration and light disturbance to fauna will be localized to near Project infrastructure footprints, and potential impacts to terrestrial and underwater species are generally low or very low.

Sections 15.3 and 12.4 provide a detailed assessment of the potential impacts of above ground and underwater noise.

Disturbance to Focal Breeding, Roosting, Nesting and Feeding Sites

Project activities, such as vegetation clearing and earthworks, may destroy or damage focal breeding, roosting, nesting or feeding sites that provide important habitat for a variety of fauna. Impacts may occur:

- During Project construction.
- As part of regular planned operational activities.
- If Project personnel disturb fauna at key sites as part of unauthorized activities.
- If Project induced population growth influences disturbance-related activity by local residents at these sites.

Caves and Rock Shelters

Damage to caves or rock shelters may be incurred directly from blasting or earthworks activities during construction.

Caves and other rock shelters provide important habitat for some congregatory species, including the IUCN Critically Endangered Bulmer’s fruit bat and a variety of other bats and swiftlets (Chapter 7 and Part 6 of Volume 2). Physical damage to caves may cause the loss of colonies, and hunting and human disturbance may cause mortality, especially during the breeding season (Martin et al., 2000; Cardiff et al., 2009). Few caves and rock shelters are known from the study area and noise or other disturbance from nearby construction activities is not expected to impact these features.

Threatened Freshwater Turtle and Crocodile Nesting Sites

Damage or disturbance to crocodile and freshwater turtle nesting sites can reduce breeding success. Trampling nests and changes to the topography of nest banks can make habitual sites less suitable for nesting (Moll & Moll, 2004; Georges et al., 2008a), and increased river traffic may alter behaviors and damage nests through erosion of sand banks.

River traffic from the Purari River mouth to the logistics base will increase directly from the Project's transportation needs and indirectly by the Project potentially increasing the local population size, increasing household incomes and improving access to outboard motors and fuel.

Pig-nosed turtle nesting sites occur along the banks of the main river channels and tributaries (see Part 6 of Volume 2). Another nesting site occurs at the junction of Oyomo Creek and the Purari River 100 m downstream from the proposed Logistics Base jetty which will receive regular boat traffic and where dredging may be undertaken during the life of the Project.

Pig-nosed turtles nest on exposed sand or mud banks during the dry season (September-January, though may extend to February; Georges et al. 2008a) when the water level is at its lowest. Preferred nesting beaches are of low relief and nests are typically placed less than 1 m above the water line (Georges et al. 2008b). During this period, nesting banks and nests will be sensitive to increased levels of boat wash if these reach levels where erosion of nesting banks exposes nests, or if the wash floods nests. Egg clutches that are inundated for more than a brief period do not survive (Georges et al. 2008a).

Although sedimentation and other structural changes to the river bank are naturally affected by seasonal flooding events, substantial changes in the morphology of nesting banks due to increased sediment accumulation from boat-generated wash and dredging during the nesting season may potentially reduce their suitability for nesting. Other banks upstream of the Project or along downstream tributaries may provide suitable alternative nest sites; although nest-site fidelity is not well-understood.

Migratory Shorebird, Resident Marine Coastal Bird and Freshwater Wetland Bird Feeding, Breeding and Roosting Sites

Disturbance is a recognized threat to shorebirds, coastal birds and wetland birds worldwide (Kirby et al. 1993; Rogers et al. 2006; Rosa et al. 2006). Migratory, coastal and wetland birds are most susceptible to disturbance while congregating at low tide to feed, at high tide roost sites and during the breeding season. Disturbance from river traffic, construction work and Project workers can raise shorebird energy expenditure by restricting access to foraging areas and reducing food intake and enhancing predation risk (Fitzpatrick & Bouchez, 1998; Peters & Otis, 2007). Shorebirds are particularly vulnerable to disturbance as they have high energy demands (Finn, 2007).

Barge traffic is predicted to be audible to some villages along the transport route (see Chapter 15) and will therefore also have the potential to disturb these birds along the 65 km shorefront of the lower Purari delta in the Mangrove ecological zone and nearby wetland habitats, particularly along the tidal wetlands and extensive mud and sand bars that flank the distributary outlets (see Part 6 of Volume 2), during September to May.

Megapode Nest Mounds, Large Trees with Nesting Birds and Birds-of-paradise Display Trees

Damage or disturbance, e.g., from noise, vibration and edge effects, from Project activities to megapode nest mounds or to large trees with nests of Pesquet's parrot, hornbills or raptors may cause nest failure and cause birds to abandon habitual nesting sites. Similar disturbance to birds-of-paradise display sites, notably those of the Raggiana bird-of-paradise (*Paradisaea raggiana*), may interrupt reproductive behaviors. Sustained disturbance may cause birds to abandon a habitual display site and relocate, potentially missing a critical period in the annual breeding cycle. Consecutive missed breeding cycles may cause a decline in the local population.

11.6.3.7 Introduction and Spread of Invasive Alien Species and Pathogens

The Project may directly introduce new or contribute to the spread of existing invasive alien species when importing and transporting personnel, materials, equipment or machinery. The risk of introduction and spread of alien species from Project activities will be greatest during peak mobilization periods of equipment and personnel during construction. Potential impacts from invasive or alien species may intensify as populations become more firmly established during subsequent Project phases and are likely to persist beyond decommissioning.

Invasive alien species may predate upon, compete with, or displace native taxa and may introduce novel pathogens that have the potential to cause material declines in populations for local native flora and fauna. Areas of environmental disturbance provide optimal establishment sites for most weeds and pests (Sakai et al., 2001). Weeds, alien rodents, cane toads, snails and ants are all readily transported unwittingly over large distances with freight and building materials or with any other items that have been stored in areas with open access. Baseline studies show, except for feral pigs, that alien species are largely absent from intact natural environments in the Project area, including extensive areas of relatively remote and little-disturbed forest present in PRL-15 (Volume 2, Part 6). Once established, eradicating invasive species can be challenging depending on the ecology of the species, labor and time intensive, and may cause unexpected changes to other ecosystem components (Zavaleta et al., 2001).

Weeds, pests and diseases can permanently alter ecosystems, which makes introducing or spreading invasive alien species one of the most important impact processes to manage to sustain the long-term ecological health of the Project area.

The potential for introducing and spreading invasive alien species may be intensified through induced population growth, which may drive increased clearing, natural habitat disturbance and the creation of suitable habitat for weed establishment, and through increased human traffic along roads and ROWs, which will increase the potential to spread invasive alien species.

Weeds

Most weed species persist only in disturbed environments and cannot invade undisturbed forest or other intact native vegetation types where native species outcompete them. Weeds of highest concern include Priority 1[5] species with the potential to invade natural habitats (Section 7.7.6.6).

Potential impacts include the loss of biodiversity from natural habitats and the failure of native vegetation to regenerate on rehabilitation sites. Construction activities can create large areas of disturbance that provide ideal sites for weed species to establish, especially sites where complete vegetation removal has exposed topsoil or where topsoil is stockpiled.

5 Priority 1 species are species which can persist in unmodified native ecosystems, have the potential to cause ecosystem degradation by displacing native species or negatively impact on regeneration or rehabilitation measures.

Priority 1 weed species present in the study area with the potential to degrade terrestrial environments include:

- Bamboo daka readily outcompetes native flora and can invade both disturbed and primary forest. It can replace native vegetation with single species stands in extreme cases, reduce floral species diversity and degrade ecosystem diversity by simplifying vegetation structure. It typically establishes in forest gaps, on landslides, on freshly deposited sediments along watercourses, and along forest edges and road margins. It can persist in the soil seedbank for many years and can regenerate in response to a variety of natural or anthropogenic disturbance events. It is common along disturbed road margins and is present around Project facilities, including Herd Base, Wabo Camp and the Purari Airstrip.
- Mile-a-minute vine is a major threat to disturbed freshwater swamp vegetation and forested sites that are subject to prolonged inundation, causing forest dieback. Under favorable conditions, it smothers small to medium trees. In the Project area, it is known from along roads, the Purari Airstrip, undisturbed swamp grassland and coastal villages.
- African tulip tree can invade disturbed forest environments where it can become a dominant canopy tree species and persist for decades (Bito, 2007). In the Project area, it was recorded only near Muro Mission.
- Angelonia was planted as an ornamental at Herd Base by a previous operator and has been introduced to and has subsequently spread widely across some Project wellpads.
- Coconut palm is a commercial cultivar that has established in undisturbed mangroves in Orokolo Bay where it degrades the mangrove forest structure.

Infrastructure development, particularly roads, which provide disturbance suitable corridors for weed spread, establishment and growth, has facilitated weed invasion and establishment across the Project area.

Section 11.5.5.5 assesses potential weed impacts on riverine and wetland environments.

Rodents

Alien rodents, particularly *Rattus* species, are a potentially serious threat. The Pacific rat (*Rattus exulans*) and black rat (*R. rattus*) are patchily widespread in anthropogenic habitats in the Project area (Chapter 7). Neither is particularly invasive of natural habitats in New Guinea; although the black rat is capable of establishing in a variety of contexts, including areas with disturbed and weedy vegetation, and around human habitation. Interactions between alien rodents and native species are most likely to occur in degraded habitats such as forest edges where they may predate native fauna and transfer novel pathogens to native mammals. Black rats are known to be reservoirs and vectors for at least 60 zoonotic diseases (Weber, 1982); their introduction to other ecosystems has led to the native species decline or extinction from the spread of diseases (Ganzhorn, 2003; Wyatt et al., 2008). ***Very Sensitive*** native rodents, such as *Hydromys* sp. 1, *Pseudohydromys* sp. 1 and *Xeromys myoides*, are likely to be vulnerable to black rat expansion in the Project area.

Other Mammals

Local residents throughout the PAOI keep dogs (*Canis familiaris*) as pets, and residents in the area report that feral populations roam in PRL-15 north of the Purari River and towards the coast near Muro Mission where they may predate on native fauna. Domestic cats (*Felis catus*) are not well suited to feral existence in New Guinean rainforest environments. No evidence of feral cat populations was reported during baseline surveys (Part 6 of Volume 2); although, domestic cats may predate native species where they interact in villages. Dog and cat-induced population declines in native species are likely to be very localized to these areas.

Cane Toads

The cane toad is widespread but patchily distributed in anthropogenic habitats across the study area. It is not well suited to rainforest habitats but spreads rapidly through open and disturbed areas; they disperse well with human transport (e.g., boats, vehicles, crates and other containers) and can move along roads, including those through forest, to colonize new areas. Once established, they are almost impossible to eradicate (Australian Government, 2010). Cane toads produce a powerful toxin that is fatal to some individuals when consumed; it is present in the eggs, larvae and adults. Lizards, snakes, crocodiles, dasyurid marsupials and omnivorous bandicoots that prey on frogs are particularly susceptible to poisoning particularly where they overlap with cane toads in open or forest-edge environments (Shine, 2010). They are implicated in major population declines of multiple taxa in Australia, and Woolley et al. (2016) identified toads as a potential threat to the survival of quolls in New Guinea.

Invertebrates

A severe infestation of the giant East African snail (*Lissachatina fulica*) is present in the Southeast Coast ecological zone south of the Muro River. It is one of the world’s largest and most damaging land snail pests. It can cause extensive destruction and loss of vegetation, is a vector of plant pathogens and can compete intensely with native species. Local residents to the Muro River indicated that it recently spread to the area and that the Muro River is acting as a barrier to dispersal into areas to the north. There is a serious risk that it will pass this barrier and spread north into the Southeast Hills and Delta Swamps and Plains ecological zones. It moves readily with agricultural products, equipment, cargo and plant or soil matter. Should pipeline construction require a temporary bridge crossing at the Muro River, it would facilitate its spread, and there is also the potential for it to move into areas north of the Purari River. It is predominantly an agricultural pest but was observed during baseline studies to be common in alluvial forest where it may eat native vegetation. It targets smaller plants but may include saplings of large tree species. If Project activities introduced the snail to new ecological zones, the snail could cause widespread damage to vegetation, particularly seedlings, and alter vegetation communities. It would be most common in forest edges and forest degraded by logging or other relevant processes. Rare plant species in these environments may be lost or their health reduced.

Alien ant species pose a threat to local fauna. The yellow crazy ant (*Anoplolepis gracilipes*) and the little fire ant (*Wasmannia auropunctata*) are potentially the most destructive. Although they were not detected in the study area during baseline studies, both species are established in New Guinea and their introduction from the transport of equipment and materials from outside the Project area presents a potential threat. The yellow crazy ant is listed among the world’s 100 worst invasive species; it has invaded and degraded native ecosystems in numerous islands across the Pacific and Indian oceans. Both species may occur locally in open or highly degraded habitats; while they do occupy some drier natural forest environments, they are not known to infest intact wet rainforest habitats (ISSG, 2019). Yellow crazy ants prey on or interfere in the reproduction of a variety of arthropods, reptiles, birds and mammals on the forest floor and canopy. High densities have the potential to devastate native keystone species, causing a rapid alteration of ecosystem processes (ISSG, 2019). Ants are readily transported unintentionally over large distances with freight and building materials, or with any other items that have been stored in areas with open access. Incursions are most likely to occur where such items are received or stored. Preventing the introduction of invasive ants, and the introduction of other new invasive species is required to successfully manage potential Project impacts.

11.6.3.8 Impacts to Terrestrial Biodiversity from Induced Changes to the Livelihoods and Subsistence Activity Patterns and from Population Influx

Terrestrial biodiversity values may be impacted from induced changes in social conditions and subsequent changes to economic and livelihood activities beyond the control of the Project. In some instances, this may exacerbate impacts discussed in Sections 11.6.3.2 to 11.6.3.7. Most people living in the PAOI live a subsistence-based lifestyle. They rely heavily on local natural resources to grow food and meet household nutritional requirements, to provide building materials and medicines, to transport materials (e.g., canoe trees) and as a source of income (Chapter 9).

Project-induced changes in population size and associated changes in livelihoods and subsistence activities may reduce local biodiversity values. In-migration is expected to be greatest during construction around the Pawaian villages in PRL-15 (e.g., Wabo, Ura and Wabo Station) due to the perceived potential for economic opportunities from employment and access to Project financial benefits but is also expected to occur, albeit to a lesser degree, in villages towards the coast and at Orokolo Bay. Population influx is expected to be otherwise low across the PAOI (Chapter 13); thus, potential declines in species populations, except for hunting-sensitive fauna, and habitat degradation will be commensurate with this.

Multiple factors influence the degree to which local residents use local biodiversity values including household incomes, accessibility to natural resources (e.g., forest areas), accessibility to markets, and the availability of alternative sources of supply (e.g., building materials and processed foods) (Chapter 13).

Project development may induce:

- An increase in the sale of natural resources, garden produce and cash crops from a boost to the local cash economy, including increases of household incomes.
- Improved access to natural resources and to the markets at which those resources can be sold.
- Opportunities to supplement subsistence-based food sources with processed foods from an increase in the range and availability of processed foods.
- An increase in the availability of imported building materials, such as roofing iron.

The relationships between these factors are complex, and the overall impacts are difficult to predict, e.g., an increase in the average household income and in access to supplementary food sources, and a reduction in the time available to locally resident Project workers for subsistence activities (Section 13.4), may reduce the overall reliance on natural resources in many resident households and reduce pressures on terrestrial biodiversity. In contrast, an increase in the availability of processed foods may reduce the time required to grow foods for household consumption and release time for harvesting natural resources that may be sold or traded. Moreover, an increase in the availability of commodities such as fuel, outboard motors, vehicles and firearms, may increase the harvesting rate of some plants and animals that fetch a high price in local or regional markets.

For this assessment, the following are considered likely:

- Increased hunting.
- Increased forest resource use.
- Increased land clearing for dwellings and gardens.

Change in the Level of Hunting

Hunting is a major contributor to the rarity and decline of larger animals in Papua New Guinea (Papua New Guinea Department of Conservation, 2014). Large areas of forest remain intact across much of Papua New Guinea, as such, hunting pressure (rather than forest loss) is listed as a major threat contributing to the conservation status of almost all IUCN Threatened non-volant vertebrates considered in the assessment. Hunting-sensitive species of conservation significance include long-beaked echidnas, tree kangaroos, wallabies, giant bandicoot, Bulmer’s fruit bat, southern cassowary (*Casuarius casuarius*), Scheepmaker’s crowned pigeon, Papuan eagle (*Harpyopsis novaeguineae*), Pesquet’s parrot, Blyth’s hornbill, freshwater turtles, and multiple other large parrots, pigeons, birds-of-paradise, raptors and possums (e.g., George, 1978; Kocher Schmid, 1993; King and Nijboer, 1994; Flannery, 1995). Hunting has reduced the populations of many of these taxa already, and many are now rare or no longer occur near villages.

Hunting becomes a more serious ecological threat when it is commercialized to serve a wider demand for meat or *bilas* (traditional decoration) in addition to subsistence purposes. Where regular access to a market is available, the speed at which target species are depleted is greatly increased (Purcell et al., 2014; Brewer et al., 2012).

Baseline levels of hunting pressure vary among species. While most large fauna are scarce near settled areas, grey dorcopsis (*Dorcopsis luctuosa*), giant bandicoot, long-beaked echidnas, tree kangaroos, southern cassowary, Blyth’s hornbill, Pesquet’s parrot, palm cockatoo (*Probosciger aterrimus*) and both crocodile species remain locally widespread and common in suitable habitat. In contrast, annual harvesting of pig-nosed turtle and striped New Guinea soft-shelled turtle adults and eggs, along the banks of the Purari River and its tributaries is likely unsustainable (Eisemberg et al., 2011; 2015). Scheepmaker’s crowned pigeon is vulnerable to hunting pressure in its preferred primary alluvial forest habitat and remains common only in remote areas.

Hunting patterns and the importance of wildlife to local communities are described in detailed in Part 18 of Volume 2. Additional information on the hunting of particular species is provided in Part 6 of Volume 2 (including Annexes 2, 4 and 5).

Hunting pressure on local wildlife may increase from the following factors:

- Induced access to local forest environments, which were previously inaccessible or only accessible from walking tracks, from new Project roads, pipeline ROWs and facilities. This will increase foot traffic along these routes and subsequently increased wildlife encounters. The access road along the proposed export pipeline corridor will be open to public use and may permit non-Project vehicles into new forest areas.
- Induced regional access, causing readier access to potential markets for local wildlife products. A boost to the local cash-based economy, enabling fuel and outboard motors to be purchased, and the construction of the export pipeline access road will facilitate this access.
- Induced population growth increasing local wildlife exploitation.
- Induced change in the subsistence activity patterns of local residents including an increase in access to firearms.
- Increased demand for bush meat from Project staff and contractors, and from a larger local population. Customary land use rights and access to hunting grounds is exclusively vested in clans and may help moderate an increase in hunting activity driven by population influx or temporary contractors.

The loss of biodiversity from increases in hunting activity may occur during all Project stages and may continue after Project decommissioning.

Changes to Forest Resource Use

Resource harvesting is likely to increase with local population growth and improved vehicle access along the export pipeline maintenance track. The expected increase in wealth may also induce a requirement for local timber for construction (Section 13.4) and a modest improvement in housing and living conditions.

At-risk species include mangrove trees near the densely settled Orokolo Bay, which are harvested for firewood, and uncommon or rare timber trees growing along major waterways and, to a lesser degree, the proposed export pipeline corridor. Loss of individuals and associated harvesting damage will likely be localized to in-migration hot spots and is predicted to be minimal for most taxa and relevant ecosystems.

Unplanned impacts may arise if an induced increase in community wealth influences the harvesting activity of local residents, e.g., by increasing the number of small-scale sawmills.

Increased Clearing of Land for Dwellings and Gardens

Additional forest may be cleared for conversion to garden and housing to accommodate induced growth in local communities. The extent of these losses cannot be accurately predicted but are expected to be negligible relative to the available forest cover and localized to villages and, to a lesser degree, along infrastructure routes.

11.6.4 Proposed Mitigation and Management Measures

Table 11.44 describes mitigation and management measures to further reduce impacts to terrestrial biodiversity.

In addition to the measures presented in Table 11.44, additional measures relevant to mitigating and managing impacts to terrestrial biodiversity are outlined in Chapters 13, 15 and 16 and Sections 11.1, 11.3, 11.4 and 11.5. For example:

- Measures relevant to managing population influx, wealth inequality and other social factors that may indirectly reduce local biodiversity values (Chapters 13 and 16).
- Measures relevant to managing erosion, uncontrolled soil and spoil movement, waterway sedimentation and changes to hydrology (Sections 11.1, 11.3 and 11.5).
- Measures directed at minimizing river bank scour from boat wash (Section 11.3).
- Measures relevant to managing potential impacts from hazardous and non-hazardous materials (Sections 11.2, 11.4, 11.5 and 12.2).
- Measures relevant to managing potential impacts from air emissions and acid rain (Sections 15.1 and 15.5).
- Measures relevant to managing potential impacts from light and noise (Sections 13.8, 15.3 and 15.4).

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Habitat Loss and Fragmentation		
Habitat loss	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024].	Biodiversity Action Plan
Forest dieback from flooding	No additional mitigation measures are proposed.	NA
Habitat Degradation		
Forest degradation and destruction	♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Minimize damage to habitat surrounding planned footprints by safely felling trees into planned footprints or into less environmentally sensitive natural spaces between standing trees [EM025]. ♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape, e.g.: – Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g. rip the substrate, replace topsoil, apply mulch – Rehabilitate Pandanus habitats, e.g. recreate mounds, re-instate the intertidal surface between Pandanus mounds – Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion. – Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration.	Biodiversity Action Plan; Site Restoration and Rehabilitation Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Habitat Degradation (cont'd)		
Forest degradation and destruction (cont'd)	– Use native vegetation to revegetate sites when active rehabilitation measures are required. [EM029]. ♦ Implement dust control, where required [EM041].	See above
Unplanned, uncontrolled fire	♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site contingency plans, that will consider fire management measures – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018]. ♦ Avoid burning cleared vegetation, wherever practicable [EM026]. ♦ Project personnel, workers, contractors or third-party operators, while engaged in Project activities, will be prohibited: – To light and use fire except for specific work requirements controlled under the 'Hot Works' permit procedure and in designated smoking areas. – To hunt, fish, collect or disturb forest or wildlife resources. – To possess hunting or fishing equipment, including firearms, bow and arrows, spears, rubber guns, slingshots and other hunting tools. – To keep pets or to purchase, acquire or possess any wildlife or wildlife products [EM027] ♦ All Project personnel, workers, contractors and third-party party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028].	Biodiversity Action Plan; Emergency Response Plan
Contamination and degradation of wetland habitat	♦ Water from trenches will be discharged in accordance with applicable water quality standards with erosion and sediment controls where relevant [EM011].	Biodiversity Action Plan; Water Management Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Habitat Degradation (cont'd)		
Contamination and degradation of wetland habitat (cont'd)	♦ Maintain buffer zones between permanent surface water and project infrastructure, except to carry out works associated with the construction of watercourse crossing or where facilities are proposed to be located within that buffer [EM012]. ♦ Dispose of excess spoil material from Project earthworks in designated spoil disposal sites [EM030]. ♦ Minimize erosion and sediment runoff (see Sections 11.2.4, 11.3.4, 11.5.4).	See above
Natural Regeneration Failure		
Natural regeneration failure	♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Cut trees where practicable to retain the rootstock and maintain soil stability [EM003]. ♦ Stabilize spoil stockpiles and areas of ground disturbance as soon as practicable after initial disturbance using, e.g., mulched vegetation, aggregates and soil binders [EM005]. ♦ Backfill trenches as soon as practicable after disturbance, using material originally excavated from the trench as much as possible. The backfilled trenches should not exceed the preconstruction levels after the material has settled [EM009]. ♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna; – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna [EM023]. ♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape. e.g.: – Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g. rip the substrate, replace topsoil, apply mulch – Rehabilitate Pandanus habitats, e.g. recreate mounds, re-instate the intertidal surface between Pandanus mounds – Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion.	Invasive Species, Pests and Pathogen Management Plan; Site Restoration and Rehabilitation Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Natural Regeneration Failure (cont'd)		
Natural regeneration failure (cont'd)	– Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration. – Use native vegetation to revegetate sites when active rehabilitation measures are required [EM029]. ♦ Dispose of excess spoil material from Project earthworks in designated spoil disposal sites [EM030].	See above
Weed establishment in rehabilitation areas	♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna; – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna [EM023].	Invasive Species, Pests and Pathogen Management Plan
Loss of Individuals and Populations		
Loss of individuals or populations of forest flora and fauna from Project activities and hunting by Project workers	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g., roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable [EM002]. ♦ Project personnel, workers, contractors or third-party operators, while engaged in Project activities, will be prohibited: – to light and use fire except for specific work requirements controlled under the 'Hot Works' permit procedure and in designated smoking areas. – to hunt, fish, collect or disturb forest or wildlife resources. – to possess hunting or fishing equipment, including firearms, bow and arrows, spears, rubber guns, slingshots and other hunting tools. – to keep pets or to purchase, acquire or possess any wildlife or wildlife products [EM027].	Biodiversity Action Plan; Traffic and Transport Management Plan; Air Emissions and Greenhouse Gas Management Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Loss of Individuals and Populations (cont'd)		
Loss of individuals or populations of forest flora and fauna from Project activities and hunting by Project workers (cont'd)	♦ All Project personnel, workers, contractors and third-party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028]. ♦ Use a suitably trained fauna handler to relocate fauna, where practicable, before vegetation clearing [EM031]. ♦ When a significant impact remains on IUCN Threatened species or rare and localized plant species, translocation and propagation shall be considered when ecologically feasible [EM032]. ♦ Develop Traffic and Transport Management controls that include: – Posting speed limits on Project roads via posted speed limit signs. – Requiring vehicles to keep to posted speed limits – Keeping vehicles and mobile machinery to marked trafficable areas and work sites [EM033]. ♦ Implement dust control, where required [EM041]. ♦ See mitigations for Habitat Loss and Fragmentation, Impacts to Terrestrial Biodiversity from Induced Changes to the Livelihoods and Subsistence Activity Patterns and from Population Influx.	See above
Reduction in the viability of populations of forest flora and fauna	♦ See mitigations for Habitat Loss and Fragmentation and Habitat Degradation.	Biodiversity Action Plan
Loss of specialist feeding plants	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g., roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams.	Biodiversity Action Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Loss of Individuals and Populations (cont'd)		
Loss of specialist feeding plants (cont'd)	– Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024].	See above
Reduction in adult populations of IUCN Threatened freshwater turtles	♦ Implement lower speeds past aquatic fauna when observed in the water [EM022]. ♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024]. ♦ See mitigations for loss of individuals and populations of forest flora and fauna from Project activities and hunting by Project workers under the Loss of Individuals and Populations.	Biodiversity Action Plan; Traffic and Transport Management Plan
New-to-science plants with one of few known populations in or near Project footprints and regionally rare IUCN Threatened timber trees: Loss of only known plant individual (*Syzygium* sp. 1 and 4) or one or more of few known individuals	♦ See mitigations for Habitat Loss and Fragmentation and Habitat Degradation. ♦ When a significant impact remains on IUCN Threatened species or rare and localized plant species, translocation and propagation shall be considered when ecologically feasible [EM032]. ♦ Minimize in-stream and stream bank disturbance during high rainfall [EM013].	Biodiversity Action Plan
Injury to or mortality of forest fauna from vehicle strike and being trapped in trenches	♦ Backfill trenches as soon as practicable after disturbance, using material originally excavated from the trench as much as possible. The backfilled trenches should not exceed the preconstruction levels after the material has settled [EM009]. ♦ Develop traffic and transport management controls that include: – Posting speed limits on Project roads via posted speed limit signs. – Requiring vehicles to keep to posted speed limits.	Biodiversity Action Plan; Traffic and Transport Management Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Loss of Individuals and Populations (cont'd)		
Injury to or mortality of forest fauna from vehicle strike and being trapped in trenches (cont'd)	– Keeping vehicles and mobile machinery to marked trafficable areas and work sites [EM033]. ♦ Install ramps, e.g. unexcavated or backfilled earth plugs, in the pipeline trench at regular intervals and at other high-risk locations to permit fauna to exit [EM034]. ♦ Visually inspect open trenches and excavations in the morning and evening and use a suitably trained fauna handler to remove trapped wildlife, where practicable [EM035].	Biodiversity Action Plan; Traffic and Transport Management Plan
Disturbance to Fauna at Feeding, Breeding, Nesting and Roosting Sites		
Damage to or loss of IUCN Threatened freshwater turtle river bank and crocodile nest sites and nest failure	♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e., primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g., caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees,, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024]. ♦ Develop traffic and transport management controls that include: – Posting speed limits on Project roads via posted speed limit signs. – Requiring vehicles to keep to posted speed limits – Keeping vehicles and mobile machinery to marked trafficable areas and work sites [EM033]. ♦ Implement low speed limits through areas sensitive to vessel wash impacts [EM014]. ♦ See mitigations for the loss of individuals and populations of forest flora and fauna from Project activities and hunting by Project workers under the Loss of Individuals and Populations.	Biodiversity Action Plan; Traffic and Transport Management Plan
Loss of tree-hollow or cave roosting bats from loss of breeding or roosting sites	♦ Limit construction work, where practicable, to daytime hours [EM046]. ♦ See mitigations for Habitat Loss and Fragmentation.	Biodiversity Action Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Disturbance to Fauna at Feeding, Breeding, Nesting and Roosting Sites (cont'd)		
Loss of individual migratory shorebirds, resident marine coastal birds and freshwater wetland birds and disturbance to feeding or roosting congregations and breeding sites	♦ Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and *Marine Pollution (Ships and Installations) Act 2013* [EM019].	Emergency Response Plan
Loss of congregatory bats and birds and disturbance to feeding or roosting congregations and breeding sites	♦ Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: – Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. – Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. – Sites that support populations of IUCN Threatened or rare and localized plant species [EM024]. ♦ Project personnel, workers, contractors or third-party operators, while engaged in Project activities, will be prohibited: – to light and use fire except for specific work requirements controlled under the 'Hot Works' permit procedure and in designated smoking areas. – to hunt, fish, collect or disturb forest or wildlife resources. – to possess hunting or fishing equipment, including firearms, bow and arrows, spears, rubber guns, slingshots and other hunting tools. – to keep pets or to purchase, acquire or possess any wildlife or wildlife products [EM027]. ♦ All Project personnel, workers, contractors and third-party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028].	Biodiversity Action Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Disturbance to Fauna at Feeding, Breeding, Nesting and Roosting Sites (cont'd)		
Loss of congregatory bats and birds and disturbance to feeding or roosting congregations and breeding sites	♦ Avoid directly lighting areas at night and minimize fixed night lighting for safe operations, e.g., direct lighting away from the Purari Airstrip House, and the surrounding forest [EM047]. ♦ Limit construction work, where practicable, to daytime hours [EM046].	Biodiversity Action Plan
Introduction and Spread of Invasive Alien Species and Pathogens		
Introduction and spread of invasive alien pests, weeds and pathogens	♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna; – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna [EM023].	Invasive Species, Pests and Pathogen Management Plan
Weed invasion and rapid establishment in rehabilitation areas leading to poor or failed regeneration of native forest vegetation	♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna; – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna [EM023]. ♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape, e.g.: – Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g., rip the substrate, replace topsoil, apply mulch – Rehabilitate Pandanus habitats, e.g., recreate mounds, re-instate the intertidal surface between Pandanus mounds – Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion. – Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration. – Use native vegetation to revegetate sites when active rehabilitation measures are required [EM029].	Invasive Species, Pests and Pathogen Management Plan; Site Restoration and Rehabilitation Plan

Table 11.44 – Terrestrial Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Introduction and Spread of Invasive Alien Species and Pathogens (cont'd)		
Weed invasion and rapid establishment in rehabilitation areas leading to poor or failed regeneration of native forest vegetation	♦ Where possible, separate and stockpile cleared topsoil (with the inherent seed bank and any coarse woody debris) to use for future rehabilitation [EM036].	Invasive Species, Pests and Pathogen Management Plan; Site Restoration and Rehabilitation Plan
Impacts to Terrestrial Biodiversity from Induced Changes to the Livelihoods and Subsistence Activity Patterns and from Population Influx		
Increased hunting, forest resource use and land clearing for gardens and dwellings	♦ See Chapter 13 for management of in-migration to mitigate increased hunting pressure, forest resource use and land clearing for gardens and dwellings from population growth.	Biodiversity Action Plan; Project-induced In-migration Management Plan

NA: Not applicable.

11.6.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to terrestrial biodiversity subject to the embedded design controls in Section 11.6.3 and the successful implementation of the proposed mitigation and management measures in Section 11.6.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

This assessment adopts a high-level approach to determine the overall residual significance of Project-related impacts. Although Section 11.6.3 identified and discussed individual impact processes separately, the mechanisms of change are inter-related, and their effects are accumulative such that examining each factor in isolation can lead to a misleading assessment. Thus, in this section the significance of residual impacts is considered as a combined function of all impact processes on a value.

11.6.5.1 Sensitivity of Terrestrial Biodiversity

The sensitivity of terrestrial biodiversity values discussed are characterized in this section. Part 6 of Volume 2 identifies species and ecosystem sensitivities. Those identified as ***Not Sensitive*** or ***Low Sensitivity*** (see Section 7.7.8.1), and which are rated as having ***Low*** or ***Minimal*** sensitivity based on Tables 11.40 and 11.41, are not addressed, as impacts for each of these values are deemed to be ***Medium*** or lower, and the residual impact significance rating is therefore ***Negligible*** or ***Minor***. This section focuses on values ranked ***Medium*** sensitivity (or as ***Moderately Sensitive*** as in Chapter 7) or higher which, depending on the magnitude of the impact, are predicted to result in a ***Moderate*** or greater residual impact significance.

Terrestrial Ecosystems and Protected Areas

Terrestrial ecosystem-scale values considered in this assessment are major vegetation types and protected areas.

The sensitivities of major vegetation types in the Project area are:

- ***Medium*** – primary hill forest, logged alluvial forest, riverine seral forest, swamp forest, swamp woodland and low freshwater swamp vegetation.
- ***High*** – Hill forest on limestone, primary alluvial forest and Mangrove.

The sensitivity of the Crater Mountain Wildlife Management Area is considered to be ***High*** based on its protected area status and overlaps with the northern extremities of PRL-15 (11.9 km^2). No Project facilities are present or are planned to be developed in the Wildlife Management Area and thus any impacts to this site could be induced, e.g., associated with population influx at Wabo (see Sections 11.6.3.8 and 13.1.7).

No ecosystems have a sensitivity of ***Very High***.

Most ***Medium*** sensitivity ecosystems are locally widespread. Primary hill forest covers approximately 80% of PRL-15 and most of the rest of the Middle Purari Hills ecological zone. Logged alluvial forest, swamp forest, swamp woodland and low freshwater swamp vegetation occur in all parts of the onshore Project area.

Focal Sites and Features

Focal sites and features of highest conservation significance include ***Very High*** sensitivity IUCN Threatened freshwater turtle nesting sites and crocodile nesting sites which occur along the

Purari river and tributaries. The sensitivity of cave systems is considered ***Very High*** although none were identified during baseline surveys.

The loss or degradation of these sites may disproportionately affect the activities or survivability of multiple individuals in a local population, and in some cases jeopardize the viability of local populations that use these sites.

In contrast, ***Medium*** sensitivity focal sites and features are relatively widespread in suitable ecosystems and their value to fauna is thus more localized. Features with ***Medium*** sensitivity include rock shelters (other than caves), large trees, large fig trees and hill forest pools.

Watercourses and Wetlands

Watercourses and wetland habitats in the study area provide essential resources and habitat to terrestrial taxa. These habitats are considered to have ***Medium*** sensitivity as they provide key resources to a variety of fauna, including breeding, nesting and feeding resources and they support habitat-specialist flora.

Most are in their original condition. Open canopy watercourses occur in all parts of the onshore Project area, and forest streams are widespread in hill forest and in well-drained alluvial forest at the interior rim of the Delta Swamps and Plains.

Species

Ninety-two IUCN listed and nationally Protected species have been recorded in the study area or may occur based on current knowledge of distribution and habitat preferences. Two IUCN Critically Endangered species (***High*** sensitivity) are confirmed present; the timber tree *Diospyros lolinopsis* in primary alluvial forest in the export pipeline corridor and Bulmer’s fruit bat known from remains collected from immediately outside of the Project area. The IUCN Critically Endangered plant *Guioa hospita* has not been recorded but may occur in the study area.

High sensitivity conservation listed taxa recorded within the study area include:

- Eight IUCN Endangered species – the timber trees *Diospyros insularis*, *Pterocarpus indicus* and *Flindersia pimenteliana*, two tree kangaroo (*Dendrolagus*) species, giant bandicoot, far eastern curlew and pig-nosed turtle.
- Thirteen IUCN Vulnerable species.
- The IUCN Data Deficient starry owlet-nightjar.

Forty-nine new-to-science species were discovered for the first time during Project surveys; 34 plants, two small non-volant mammals, two reptiles, three frogs and eight odonates. Based on habitat associations and recorded distribution and abundance, one new-to-science species is ranked as ***Very High*** sensitivity; the terrestrial herb *Begonia* sp. 5, currently known only from a few individuals at two sites in and near the proposed CPF area. Another 26 new-to-science and undescribed species are ranked as ***Very High*** sensitivity.

At least 119 restricted-range species (area of occurrence less than 50,000 km^2) have been recorded or may occur in the study area, 94 of which are ranked ***Medium*** sensitivity or higher. Thirteen of these species are also conservation listed and fifty-five species are new-to-science or undescribed. Ten additional species not in these categories are ranked as ***High*** sensitivity; six plants known only from the type material collected previously from the study area, and four habitat-specialist damselflies known from outside the study area but only in neighboring regions.

Thirty-seven conservation listed, restricted-range or scientifically undescribed species are determined to have ***Low*** sensitivity (six plants, two non-volant mammals, four bats, two birds, eight reptiles,12 frogs and three damselflies).

11.6.5.2 Terrestrial Ecosystems, Protected Areas, Focal Sites and the Study Area Landscape

Terrestrial Ecosystems

The Project’s construction phase will involve vegetation clearing from planned infrastructure footprint areas and will cause the loss of natural habitat. Most footprints will remain clear of vegetation for the life of the Project, but some areas will be allowed to naturally regenerate after construction.

Table 11.45 summarizes the areal extent of natural vegetation that will be lost or degraded within affected ecosystems due to clearing for the Project. The following approaches and assumptions were used to calculate affected areas:

- Degradational effects, e.g., edge effects, were precautionarily assumed to penetrate 100 m into vegetation surrounding linear infrastructure and facility sites that are less than 150 m wide, and 150 m into habitats surrounding facility clearings that are more than 150 m wide.
- Areas of vegetation previously cleared from proposed footprints and degradational buffers were identified from satellite imagery (2016) and were deducted from the areas of natural vegetation predicted to be lost or degraded due to Project development. These areas are shown for each ecosystem in Table 11.45.
- Areas mapped as natural vegetation from the Project footprint are assumed to support complete cover of natural vegetation despite the presence of small-scale disturbances in some sites.
- Predictions of vegetation loss were calculated based on the Project description presented in Chapter 4. Changes to this description are unlikely to significantly alter the predicted outcomes (less than 0.5%) or the assessment of impacts to ecosystems or the species they support, given the proportional magnitude of the remaining ecosystem areas.

Construction activities will take place predominantly in hill forest (594.8 ha of primary and logged forest to be cleared), alluvial forest (237.4 ha of primary and logged forest to be cleared) and swamp forest (65.1 ha cleared) (Table 11.45). Proportional impacts will be highest for logged alluvial forest, with 0.43% of this ecosystem lost and a further 1.74% potentially subject to edge effects and other Project-related degradational processes described in Section 11.6.3.3. Less than 0.75% of the study area’s primary hill forest will be lost (less than 0.19%) or degraded (0.54%) and less than 0.5% of high value primary alluvial forest will be lost (0.13%) or degraded (0.32%). Approximately 0.38% of swamp forest will be lost or degraded. Other terrestrial ecosystems will either not be directly affected or will have less than 10 ha cleared. For all terrestrial ecosystems, the magnitude of direct impacts from vegetation clearing and associated edge effects will therefore be ***Minimal*** or ***Low***.

The magnitude of other impact processes is more difficult to quantify. The most widespread potential impacts are associated with increased levels of hunting potentially affecting faunal community composition, increased fire risk during dry years, and the establishment and spread of invasive species. There is a higher potential impact from processes such as wildfire and the spread of invasive species in already degraded logged forest environments. The potential magnitude of these impacts will be limited by a combination of environmental, social and Project controls.

Table 11.45 –Terrestrial Ecosystems Cleared and Degraded by Project Construction*

Ecosystem**	Sensitivity	Ecosystem Area (ha)	Footprint				Degradation Buffer				Total Affected Area
			Total Area (ha) †	Existing Clearance (ha)	Project Clearance (ha)	% Cleared by the Project	Total Area (ha)	Existing Clearance (ha)	Project Degradation (ha)	% Degraded by the Project	
Primary hill forest (H)	Medium	250,983	555	67	488	0.19	1,405	39	1,366	0.54	1,854
Logged hill forest (H)	Low	89,996	21	2	20	0.02	120	2	118	0.13	138
Primary alluvial forest (P)	High	85,001	107	0	107	0.13	271	<1	271	0.32	378
Logged alluvial forest (P)	Medium	30,340	156	25	131	0.43	532	5	527	1.74	658
Riverine seral forest (Fri)	Medium	853	0	0	0	0.00	0	0	0	0.00	0
Swamp forest (Fsw)	Medium	111,460	65	<1	65	0.06	358	2	356	0.32	421
Swamp woodland (Wsw)	Medium	60,286	8	0	8	0.01	45	<1	45	0.07	53
Low freshwater swamp vegetation (Hsw, Gsw, Gri)	Medium	7,497	1	0	1	<0.01	7	0	7	0.09	8
Mangrove (M)	High	60,363	<1	0	<1	<0.01	1	0	1	0.00	2
Littoral forest (B)	Low	178	0	0	0	0.00	0	0	0	0.00	0

*The areas calculated do not consider regeneration of some areas.
** The descriptive terms presented here are accompanied by their PNG Forest Inventory Mapping System (FIMS) code. They appear without the FIMS code in the text.
†The total footprint area varies from the Project disturbance footprint presented in Table 4.15 due to the exclusion of non-vegetated areas (i.e., dams), alignment of the various geospatial layers and refinements in the Project design subsequent to the calculations of habitat loss and degradation.

The magnitude of residual impacts to terrestrial ecosystems, both in terms of individual mechanisms of change and their aggregated effects, will be ***Low*** or ***Minimal*** in all cases provided the mitigation measures outlined in Section 11.6.4, are successfully implemented.

The resulting impact significance will be ***Negligible*** or ***Minor*** for most ecosystems, though with a ***Moderate*** residual impact to ***High*** sensitivity primary alluvial forest.

Protected Areas

No vegetation will be cleared for Project development from the Crater Mountain Wildlife Management Area. Population influx in Pawaian villages such as Wabo (see Section 11.6.3.8) may generate induced impacts such as hunting and localized small-scale vegetation clearing for dwellings and gardens, but they are not anticipated to have any significant impact on the Wildlife Management Area or biodiversity therein. The overall impact magnitude to this ***High*** sensitivity protected area will be ***Minimal*** resulting in a ***Minor*** residual impact significance.

Focal Sites

Caves and other rock shelters may harbor breeding or roosting colonies of congregatory bat or bird species. The main potential threat to these features, should they be identified, will arise from the direct impacts from the Project to these sites. Their avoidance, where practicable, of any caves and rock shelters following preconstruction surveys, and the prevention of hunting and disturbance of focal sites by the Project workers will reduce the impact magnitude to ***Minimal***. This will result in a ***Negligible*** residual impact significance to ***Medium*** sensitivity sites (rock shelters) and a ***Minor*** residual impact significance for ***High*** sensitivity cave sites.

Large trees, large fig trees and forest pools are of ***Medium*** sensitivity and assumed to be uniformly distributed in forest ecosystems. Proportional ecosystem losses are a useful surrogate measure for assessing potential impacts to these features. As with impacts to forest ecosystems, residual impacts to these features will be ***Low*** resulting in a ***Minor*** impact significance.

Impacts to freshwater turtle and crocodile nesting sites are considered in Section 11.6.5.3, ‘Hunting-sensitive Fauna’ and ‘Other Sensitive Fauna’, respectively.

11.6.5.3 Species

Forest-dwelling Species

Most species assessed occupy forest environments, occur widely in ecosystems with suitable forest habitat and are not targeted by hunters. In such cases, proportional losses of the ecosystems that species occupy provide a suitable surrogate measure for local population decline (Hardner et al., 2015). Most species are assessed in this manner.

Separate assessments are made for species that depend on microhabitats or other local landscape features that are not uniformly distributed in forest ecosystems, or locally rare species that occur at very few sites. These sites may support locally, regionally or internationally significant concentrations of particularly rare species. Rare species face a heightened risk when populations are located near proposed footprints. Hunting-sensitive fauna are also assessed separately.

Species Widespread in Forest Ecosystems

For species occupying hill forest, mangroves or freshwater swamp environments, suitable habitat is widespread and extends unbroken into adjacent regions. Most forest-dwelling taxa were recorded at multiple sites during Project field surveys and are expected to occur in multiple ecological zones. When species known from just one site do not display special habitat requirements, they are assumed to occur more widely in local ecosystems. Some rare plants are precautionarily considered an exception until further information regarding their distribution and status becomes available.

Hill forest is the most widespread ecosystem in the study area. Primary hill forest occurs throughout most of the Middle Purari Hills ecological zone, while logged hill forest occurs extensively throughout the Southeast Hills ecological zone. Less than 0.75% of primary hill forest will be lost (less than 0.19%) or degraded (0.54%), resulting in a ***Low*** impact magnitude to flora and fauna relying on primary habitats and occurring predominantly in the Middle Purari Hills ecological zone.

Proportional impacts are lower in the Southeast Hills where logging has already degraded much of the habitat. The magnitude of impacts to hill forest species occupying this ecological zone and species that are tolerant of habitat disturbance will be ***Minimal***.

Residual impacts to species preferring alluvial forest will be ***Low*** as combined losses of primary and logged alluvial forest from clearing and degradational processes will be less than 0.6%. Similarly, the overall magnitude of impacts to species occupying the foothill zone, including well-drained alluvial forest and adjacent low elevation foothills, will be ***Low*** given the extensive area of suitable and remote habitat remaining nearby.

For all widespread or common plant species potentially present but not recorded during Project surveys, potential impacts are predicted to be ***Minimal*** in magnitude. Residual impacts are also ***Minimal*** for species occupying hill forest in the northern margins of the study area beyond the PAOI, including the ***Medium*** sensitivity striated lorikeet and banded yellow robin.

The residual impact significance for most taxa is ***Minor*** or ***Negligible***. A ***Moderate*** residual impact significance is predicted for ***High*** sensitivity species that will incur an impact magnitude of ***Low***. This is applicable to the primary forest plants *Bulbophyllum* sp. 1 and *Oberonia* sp. 1 present only in the Middle Purari Hills ecological zone or adjacent well-drained alluvial terrain at the northern rim of the Delta Swamps and Plains, including

Species Dependent on Forest Streams, Forest Pools and Riparian Habitats

A variety of species depend on forest streams, forest pools, stream banks or other riparian habitats. These features have a more restricted availability than intervening forest habitat but for this assessment they are assumed to be relatively uniformly distributed across the hill forest landscape and in well-drained alluvial forest along the inland rim of the Delta Swamps and Plains ecological zone.

Infrastructure footprints are designed to avoid large watercourses, but larger sites do overlap some stream sections. The southern part of the CPF footprint area overlies more than 1.6 km of a 5 to 10 m wide Oyomo Creek tributary. Streams in the proposed CPF footprint will be permanently diverted around the CPF, modifying 124.5 ha of the 2,250 ha (<6%) Oyomo Creek catchment. Permanent stream diversions are assessed as a loss of watercourse habitat.

Proportional losses of forest streams and pools are precautionarily considered to be slightly higher than those calculated for forest environments given the disposal of excess spoil in forested valleys and low-lying areas in alluvial terrain. The overall losses; however, are predicted to be well below 1 to 2% and the magnitude of impacts to the dependent species are again predicted to be ***Low*** in magnitude. The magnitude of impacts to mobile odonates found in open and disturbed environments (forest or garden clearings) will be ***Minimal***.

The residual impact significance for ***Medium*** sensitivity taxa is ***Minor*** or ***Negligible***. The residual impact significance to ***High*** sensitivity species dependent on forest streams, pools or riparian habitats is ***Moderate***. The following taxa have received a ***Moderate*** residual impact significance:

- *Cophixalus* sp. 3 – a new-to-science microhylid frog that is a specialist inhabitant of moist stream banks; it is locally widespread but was not recorded during relevant surveys conducted in adjacent catchments.
- *Oreophryne* sp. 2 – a new-to-science microhylid frog that is known from a single specimen along a stream bank near the ANT-3 base.
- Six damselfly species requiring cool clear forest streams – *Argiolestes tuberculiferus*, *Pyrrhargiolestes angulatus*, *Nososticta Smilodon*, *Rhyacocnemis* sp. 1, *Drepanosticta taurulus*, *Palaeosynthemis* sp. 1.
- Two new-to-science damselfly species recorded only at forest pools at single sites in PRL-15 – *Teinobasis* sp. 1 and *Nososticta* sp. 1.

Rare Plants with One of a Few Known Populations Near the Project Footprint

Among the most at-risk species are those rare flora and fauna with one of a few known individuals or populations recorded in or near proposed the Project footprint. A balanced but precautionary approach is taken in considering the potential impacts to these species. The potential for transplanting or propagating individuals is considered where some individuals may be lost. The residual significance of impacts may be reduced below the levels presented here if additional individuals or populations are discovered away from the Project footprint. The success of these efforts are, however, difficult to predict and cannot be presumed.

New-to-science Plants

Thirty-four plant species discovered during the Project surveys are currently known only from the PAOI. They are locally rare or are habitat-specialist plants that are known from only a few individuals recorded at one or two locations in or near the Project footprint.

The terrestrial herb *Begonia* sp. 5 is known from only five specimens in two isolated populations growing on permanently moist, shaded stream banks in foothill and well-drained alluvial forest; one along the northwest edge of the CPF footprint, the other approximately 650 m to the northwest. The CPF population may be lost without translocation or a large shift in the edge of the CPF footprint with a significant buffer. Translocation may be a viable mitigation for this ***Very High*** sensitivity species, but the impact magnitude will remain ***Medium*** given the extensive developments planned for the only known area of occurrence. This results in a ***Major*** residual impact significance.

Similar threats face *Syzygium* sp. 1 and *Archidendron* sp. 1, respectively known from just one and three specimens located in or near the CPF footprint. Translocation is challenging for these larger woody species; although propagation is readily achieved for other species of *Syzygium* (cuttings) and *Archidendron* (seeds). Additional specimens may be located during preconstruction surveys. A ***Medium*** impact magnitude to these ***High*** sensitivity species will result in a ***Moderate*** residual impact significance.

Syzygium sp. 4 is known from a single specimen located in the middle of the export pipeline route ROW. Avoiding this individual, including the preservation of a suitable habitat buffer or propagation, would limit the impact magnitude to ***Medium***, however due to the lack of certainty of avoidance and the viability of alternative mitigation (i.e., propagation), the impact magnitude is assumed to be ***High***, for this ***High*** sensitivity species resulting in a ***Major*** residual impact significance.

Pseuduvaria sp. 1 is known from the proposed pipeline corridor and examples outside the Project area. Some plants may be avoided or transplanted to limit the direct losses. The magnitude of potential impacts to this ***High*** sensitivity species will be ***Low***, resulting in a ***Moderate*** residual impact significance. Propagation, if feasible, may be considered to replace lost individuals.

Regionally Rare IUCN Threatened Plants

Approximately 300 m east of the proposed Logistics Base footprint is the only known mainland New Guinea occurrence of the ***High*** sensitivity IUCN Endangered timber tree *Diospyros insularis*. The single known specimen will not be cleared during construction and is unlikely to be damaged by edge effects, as it stands less than 150 m from a larger natural clearing (i.e., the Purari River). Successfully avoiding the tree would reduce the impact to ***Low*** magnitude, resulting in a ***Moderate*** residual impact significance. Propagation, if feasible, may be considered to increase the population.

A population of the IUCN Critically Endangered timber tree *Diospyros lolinopsis* occurs in primary alluvial forest in the middle of the proposed export pipeline route. This is the only known site for this species in New Guinea's southern watershed. The potential loss of multiple clustered individuals for the proposed export corridor or impact to potentially remaining nearby stands from degradational processes, will lead to a ***High*** magnitude impact to this ***Very High*** sensitivity species resulting in a ***Major*** residual impact significance. Propagation, if feasible, may be considered to increase the population and reduce the impact magnitude.

Hunting-sensitive Fauna

For species that hunters specifically target, any increase in hunting activity due to Project-induced population influx represents an impact additional to that incurred from other mechanisms of change. The assessment of hunting-sensitive fauna considers the aggregate impact of both impacts as a direct impact of the Project and those incurred from indirect interactions with the Project, including induced impacts of population growth.

The residual impact significance for population influx is assessed as ***Minor*** for coastal regions and ***Moderate*** for villages in PRL-15. Hunting due to population influx is expected to be localized to forests surrounding villages and along access routes and is not expected to penetrate remote forest areas.

Species that are often captured but remain locally common, such as bandicoots (*Echymipera* sp.) and mound-building birds (Megapodiidae), or that may be inadvertently captured by dogs or snares, e.g., dasyurid marsupials, are not considered to be hunting-sensitive; they are assessed as widespread forest species.

The following sections discuss species currently targeted by hunters including a variety of IUCN Threatened and Near Threatened bird and mammal species, and the potential residual impacts to their populations should any potential hunting increase not be managed.

Terrestrial Species Present in the Project Area

A variety of mid-size to large-bodied birds and mammals that are specifically targeted by hunters occupy forest environments in the Project area:

- The grey *Dorcopsis*, southern cassowary, Papuan eagle and Pesquet's parrot occupy hill forest and alluvial forest in most ecological zones.

- Scheepmaker's crowned pigeon prefers primary forest on alluvial terrain, on the Delta Swamps and Plains and along watercourses in the Middle Purari Hills and Southeast Hills.
- The lowland tree kangaroo is present at low densities in hill forest in the Middle Purari Hills ecological zone, including in PRL-15.
- The giant bandicoot is provisionally considered present in alluvial and low elevation hill forest along the southern half of export pipeline corridor.

The impact magnitude for widespread and mobile species that are known to be common in the PAOI, such as the grey *Dorcopsis*, or for which there is no evidence of intensive hunting in the study area, for example Papuan eagle and Pesquet's parrot will be ***Minimal***. The residual impact significance to these ***High*** sensitivity species will be ***Minor***.

For species with low population densities, the loss of just a few individuals may have a disproportionate impact on their local population. Impacts to these species, although rarely encountered, will be ***Low***, resulting in a ***Minor*** residual impact significance to the ***Medium*** sensitivity southern cassowary and a ***Moderate*** impact significance to the ***High*** sensitivity lowland tree kangaroo, giant bandicoot and Scheepmaker's crowned pigeon.

Freshwater Turtles

Induced hunting presents the greatest potential threat to the ***High*** sensitivity pig-nosed turtle and striped New Guinea soft-shelled turtle. An increase in harvesting rates is possible given:

- A potential increase in non-landowners passing freely along major watercourses with nesting sites that are not constrained by the restricted access that protects other terrestrial species.
- A potential increase in local resident boat traffic. Most exploitation of pig-nosed turtles in Papua New Guinea occurs at the local level and is largely limited by the cost of fuel for outboard motors (Eisemberg et al., 2015).
- A potential increase in demand for eggs and adult turtles as a result of population growth.
- Improved accessibility to sales points.

Harvesting rates are already likely unsustainable (Eisemberg et al., 2011; 2015) and any increase in hunting pressure is precautionarily considered to threaten the viability of the local population.

Damage to nesting banks by boat-wash and dredging represents an additional, and potentially serious, impact to pig-nosed turtles. During the high-water season, the flows of the river conceal the nesting banks exposing them to potential damage from sedimentation and hydrological changes. Should the high-water season correspond with periods of high sediment load multiple nesting sites along the banks of main river channels and tributaries could be damaged, although controlling Project traffic would reduce the magnitude of impacts.

Impacts to the pig-nosed turtle nesting site at the Oyomo Creek outlet will be harder to mitigate, though the continued use of a nesting site at the mouth of Kuku Creek adjacent to the Herd Base facility indicates that the Oyomo Creek site may remain functional.

Nest sites of the striped New Guinea soft-shelled turtle are less susceptible to damage as they do not nest along the main Purari River channels, although they still may be exposed to the impacts of erosion from increased local boat traffic in tributaries from the Project and residents.

Other relevant impacts from loss of watercourses and wetlands, sedimentation of waterways, underwater noise and boat strike are considered to be less threatening.

The overall Project-related impact to the IUCN Threatened freshwater turtles is ***Low*** in magnitude, resulting in a ***Moderate*** residual impact significance for these ***High*** sensitivity species

Species Occupying Northern Margins of the Study Area

Hunting-sensitive fauna species restricted to primary hill forest in the Middle Purari Hills ecological zone include ***High*** sensitivity species such as the eastern long-beaked echidna, Goodfellow's tree kangaroo, ifola, dusky pademelon (*Thylogale brunii*), Salvadori's teal and the ***Very High*** sensitivity congregatory cave-roosting Bulmer's fruit bat. These species occur outside of Project areas and are remote from the nearest Pawaian villages in most cases. Direct impacts are unlikely; potential impacts are associated with induced population influx in the northern Pawaian village areas predominantly at Wabo and Ura; although, local residents reported that these species were not commonly captured. The magnitude of impacts to these species will be ***Minimal***, resulting in ***Minor*** residual impact significance.

Other Sensitive Fauna

Migratory and Congregatory Shorebirds

Nine Threatened and Near Threatened migratory shorebird species may seasonally visit the 65 km shorefront and the greater coastal region where they congregate at low tide to feed on exposed sand and mudflats, and at high tide to roost in nearby dryland habitats. Degradation and contamination of wetland habitats, disturbance from temporary noise and an increase in people, and increased hunting present the main potential impacts. These impacts will be temporary in most instances and are readily mitigated. Residual impacts to all species will be ***Minimal***, resulting in a ***Negligible*** or ***Minor*** residual impact significance to these ***High*** and ***Medium*** sensitive species.

Resident Marine Coastal Birds

Resident marine coastal birds include the Near Threatened beach stone-curlew (*Esacus magnirostris*) and nationally Protected eastern osprey (*Pandion cristatus*). These ***Medium*** sensitivity non-congregatory species are highly mobile and are uncommon. They are most susceptible to damage to or loss of breeding sites. As with migratory shorebirds the magnitude of impacts will be ***Minimal***, resulting in a ***Negligible*** residual impact significance.

Freshwater Wetland Birds

Three nationally Protected egret species (i.e., the great egret (*Ardea alba*), intermediate egret (*Egretta intermedia*) and little egret (*E. garzetta*)) occupy freshwater wetlands and the margins of larger watercourses across the study area. The Project footprint and degradation buffer largely avoids these locations; therefore, the impact magnitude of Project development will be ***Minimal*** resulting in a ***Negligible*** residual impact significance to these ***Medium*** sensitivity species.

Crocodiles

Hunting pressure to crocodiles is low and both species remain locally widespread and common in suitable habitat. Potential impacts from induced hunting, underwater noise, damage to nests, and contamination to the two locally occurring ***Medium*** sensitivity crocodile species will be ***Low*** in magnitude resulting in a ***Minor*** residual impact significance.

11.6.6 Summary of Residual Impacts to Terrestrial Biodiversity

Table 11.46 provides a summary of the assessment of residual impacts to terrestrial biodiversity including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the mitigation measures provided in Table 11.45.

The significance of all residual impacts is assessed to be ***Negligible*** to ***Minor***, except for ***Very High*** and ***High*** sensitivity species where the impact magnitude remains ***Medium*** or greater.

A ***Major*** residual impact significance has been determined for:

- *Begonia* sp. 5 – a ***Very High*** sensitivity new-to-science plant known from only five specimens in two isolated populations growing on permanently moist, shaded stream banks in foothill and well-drained alluvial forest; one along the northwest edge of the CPF footprint, the other approximately 650 m northwest.
- *Diospyros lolinopsis* and *Syzygium* sp. 4 – ***High*** sensitivity trees located in the proposed export pipeline corridor.

The following ***High*** sensitivity values have been assessed to have a ***Moderate*** residual impact significance:

- Primary alluvial forest – a locally and regionally restricted forest type that supports distinct flora and fauna communities.
- Lowland tree kangaroo, giant bandicoot and Scheepmaker's crowned pigeon – Hunting-sensitive fauna found in alluvial and hill forests.
- Pig-nosed turtle and striped New Guinea soft-shelled turtle – IUCN threatened freshwater turtles found in the Purari River and its tributaries.
- *Bulbophyllum* sp. 1 and *Oberonia* sp. 1 – Primary forest plants present only in the Middle Purari Hills ecological zone and adjacent well-drained alluvial terrain.
- *Archidendron* sp. 1, *Syzygium* sp. 1 and *Diospyros insularis* – new-to-science trees known from proposed CPF and Logistics Base.
- *Pseuduvaria* sp. 1 – a new-to-science tree located in the proposed export pipeline corridor.
- *Cophixalus* sp. 3 and *Oreophryne* sp. 2 –new-to-science microhylid frogs that are habitat specialists of moist stream banks.
- *Argiolestes tuberculiferus*, *Pyrrhargiolestes angulatus, Teinobasis* sp. 1, *Nososticta smilodon, Nososticta* sp. 1, *Rhyacocnemis* sp. 1, *Drepanosticta taurulus* and *Palaeosynthemis* sp. 1 – new-to-science or rare damselfly species requiring cool clear forest streams.

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Ecosystems							
Primary hill forest	Earthworks; vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operations; discharge of surface runoff; waste generation, storage and disposal	Habitat loss and fragmentation; habitat degradation; fire; introduction and spread of invasive alien species	PRL-15; export pipeline route	C, O, D	♦ EM001 ♦ EM002 ♦ EM003 ♦ EM004 ♦ EM005 ♦ EM011 ♦ EM012 ♦ EM018 ♦ EM041 ♦ EM078 ♦ EM018 ♦ EM024 ♦ EM025 ♦ EM026 ♦ EM027 ♦ EM028 ♦ EM029 ♦ EM030 ♦ EM036	Medium/Low	Minor
Primary alluvial forest			PRL-15; export pipeline route			High/Low	Moderate
Logged alluvial forest			PRL-15; export pipeline route			Medium/Low	Minor
Swamp forest; swamp woodland; low freshwater swamp vegetation			Export pipeline route			Medium/Low	Minor
Mangrove						High/Minimal	Minor
Riverine seral forest	Logistics and transport; Project employment and procurement	Habitat degradation; induced forest resource use and land clearing	River transport corridor			Medium/Minimal	Negligible
Protected Areas							
Crater Mountain Wildlife Management Area	Project employment and procurement	Induced hunting, forest resource use and land clearing	Pawaian villages (outside of Project areas)	C, O, D	See above	High/Minimal	Minor

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Focal Sites							
Caves	Quarries; earthworks	Habitat loss and fragmentation; loss of individuals and populations; disturbance, damage or destruction of feeding breeding nesting and roosting sites	PRL-15	C	♦ EM001 ♦ EM027 ♦ EM028	Very High/Minimal	Minor
Rock shelters						Medium/Minimal	Negligible
Large trees Large fig trees Hill forest pools	Vegetation clearing	Habitat loss and fragmentation; loss of individuals and populations; loss of focal features	PRL-15, export pipeline route	C	♦ EM001 ♦ EM018 ♦ EM024 ♦ EM025 ♦ EM026 ♦ EM027 ♦ EM028 ♦ EM041	Medium/Low	Minor
Forest Species: Primary Hill Forest Plants							
Bulbophyllum sp. 1	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operations; discharge of surface runoff	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	♦ EM001 ♦ EM002 ♦ EM004 ♦ EM013 ♦ EM018 ♦ EM023 ♦ EM024 ♦ EM025 ♦ EM026 ♦ EM027 ♦ EM028	High/Low	Moderate
Orophaea sp. 1; Begonia sp. 1; Ixora sp. 2; Maschalodesme sp. 1						Medium/Low	Minor

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Primary Hill Forest Plants (cont'd)							
Orophaea sp. 1; Begonia sp. 1; Ixora sp. 2; Maschalodesme sp. 1 (cont'd)	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operations; discharge of surface runoff	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	♦ EM030 ♦ EM031 ♦ EM033 ♦ EM041	Medium/Low	Minor
Begonia sp. 3; *B.* sp. 4; Genus 1 sp. 2; *Marsdenia venusta; Koompassia grandiflora; Myristica brachypoda; Syzygium sp. 3*						High/Minimal	Minor
Cyrtandra sp. 1; *C.* sp. 2; *Syzygium* sp. 2; *Ixora* sp. 1; *I.* sp. 3; *Psychotria diplococca* var. *tauriensis;* Genus 1 sp. 1; Genus 1 sp. 3						Medium/Minimal	Negligible
Forest Species: Disturbance Tolerant Hill Forest Plants							
Cyathocalyx lucidus; Mammea grandifolia; Ceratopetalum succirubrum; Archidendron forbesii; Intsia bijuga; Pterocarpus indicus; Flindersia pimenteliana; Guioa hospita	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	See above	High/Minimal	Minor

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Disturbance Tolerant Hill Forest Plants (cont'd)							
Pseuduvaria filipes; Cycas scratchleyana; Aglaia euryanthera; A. rimosa Myristica globose; Helicia amplifolia; H. latifolia; Flindersia amboinensis; F. schottiana	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation.	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	See above	Medium/Minimal	Negligible
Forest Species: Foothill Forest Plants							
Livistona sp. 1; *Cordyline minutiflora*; *Cyrtandra* sp. 3; *Barringtonia* sp. 1	Vegetation clearing operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation.	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	See above	Medium/Low	Minor
Forest Species: Primary Alluvial and Swamp Forest Plants							
Barringtonia sp. 2; *Psychotria purariensis*	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation.	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	See above	Medium/Low	Minor
Oberonia sp. 1						High/Low	Moderate

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Primary Alluvial and Swamp Forest Plants (cont'd)							
Syzygium sp. 5	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation.	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire.	PRL-15; export pipeline route	C, O, D	See above	High/Minimal	Minor
Species not recorded during Project surveys but known from nearby: *Cyrtandra externata; Ixora whitei*						High/Minimal	Minor
Avicennia rumphiana; *Bulbophyllum* sp. 2; *Glochidion delticola*; *Psychotria heterophylla*	Logistics and transport; Project employment and procurement	Loss of individuals; contamination of wetland habitat; habitat degradation; induced forest exploitation	River transport corridor	C, O, D	See above	High/Minimal	Minor
Forest Species: Hill Forest Fauna							
Goliath birdwing; paradise birdwing	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; construction works	Loss of habitat; loss of specialist feeding plants; invasive alien species; fire	PRL-15	C, O, D	♦ EM001 ♦ EM002 ♦ EM023 ♦ EM024 ♦ EM027 ♦ EM028 ♦ EM041	High/Low	Minor
Southern tailed birdwing			PAOI			Medium/Minimal	Negligible
Papuan free-tailed bat (*Otomops papuensis*); Papuan sheath-tailed bat (*Saccolaimus mixtus*)	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport;	Loss of individuals; damage or disturbance to breeding and roosting sites; fire; habitat loss and degradation; induced hunting	PRL-15; export pipeline route	C, O, D	♦ EM001 ♦ EM002 ♦ EM027 ♦ EM028 ♦ EM031	Medium/Minimal	Negligible

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Hill Forest Fauna (cont'd)							
Papuan free-tailed bat (*Otomops papuensis*); Papuan sheath-tailed bat (*Saccolaimus mixtus*) (cont'd)	quarries; Project employment and procurement	Loss of individuals; damage or disturbance to breeding and roosting sites; fire; habitat loss and degradation; induced hunting (cont'd)	PRL-15; export pipeline route	C, O, D	♦ EM046 ♦ EM047	Medium/Minimal	Negligible
New Guinea quoll (*Dasyurus albopunctatus*); Woolley's three-striped dasyure (*Myoictis leucura*)	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; Project employment and procurement	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire; induced hunting	PRL-15	C, O, D	♦ EM001 ♦ EM002 ♦ EM009 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	Medium/Low	Minor
Echymipera rufescens subsp.; Gurney's eagle (*Aquila gurneyi*); Doria's goshawk (*Megatriorchis doriae*); Blyth's hornbill; palm cockatoo; glossy-mantled manucode (*Manucodia ater*); crinkle-collared manucode (*M. chalybatus*); trumpet manucode (*Phonygammus keraudrenii*); magnificent riflebird (*Ptiloris magnificus*); magnificent bird-of-paradise (*Diphyllodes magnificus*)			PRL-15; export pipeline route			Medium/Minimal	Negligible

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Hill Forest Fauna (cont'd)							
King bird-of-paradise (*Cicinnurus regius*); Raggiana bird-of-paradise; yellow-eyed starling (*Aplonis mystacea*)	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; Project employment and procurement	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire; induced hunting	PRL-15; export pipeline route	C, O, D	See above	Medium/Minimal	Negligible
Gehyra sp. 1			Export pipeline route		♦ EM001 ♦ EM002 ♦ EM009 ♦ EM023 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	High/Minimal	Minor
Austrochaperina sp. 1; *Choerophryne crucifer*			PRL-15			Medium/Low	Minor
Callulops marmoratus; Cophixalus sp. 2*; Copiula* sp. 1*; Oreophryne* sp. 1;			PRL-15; export pipeline route			Medium/Minimal	Negligible

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest Species: Fauna - Alluvial and Foothill Forest							
Starry owlet-nightjar; *Stegonotus* sp. 1	Vegetation clearing operation of fixed and mobile plant and equipment; logistics and transport; construction works; Project employment and procurement	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire; induced hunting	PRL-15; export pipeline route	C, O, D	♦ EM001 ♦ EM002 ♦ EM009 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	High/Minimal	Minor
Oriomo bandicoot (*Echymipera oriomo*)						Medium/Low	Minor
Forest Species: Fauna Occupying Northern Margins of the Study Area							
Hydromys sp. 1; *Pseudohydromys* sp. 1	Logistics and transport; Project employment and procurement	Minor loss of habitat quality; zoonotic disease from invasive alien rodents	PAOI	C, O, D	♦ EM001 ♦ EM002 ♦ EM009 ♦ EM023 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	High/Minimal	Minor
Striated lorikeet; banded yellow robin						Medium/Minimal	Negligible

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest species: Fauna Dependent on Forest Streams, Forest Pools and Adjacent Riparian Habitats							
Cophixalus sp. 3; *Oreophryne* sp. 2; *Argiolestes tuberculiferus*; *Pyrrhargiolestes angulatus*; *Teinobasis* sp. 1; *Nososticta smilodon*; *N.* sp. 1; *Rhyacocnemis* sp. 1; *Drepanosticta taurulus*; *Palaeosynthemis* sp. 1	Vegetation clearing operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation	Loss of individuals or populations; degradation of remaining habitat; weed infestation; fire	PRL-15; export pipeline route	C, O, D	♦ EM001 ♦ EM002 ♦ EM004 ♦ EM009 ♦ EM018 ♦ EM023 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	High/Low	Moderate
Forest bittern; *Litoria exophthalmia*; *L. sauroni*; *L.* sp. 1; *Hylarana* sp. 1; *H.* sp. 2; *Metagrion trigonale*; *M.* sp. 1; *Teinobasis buwaldai*; *T. debeauxi*; *Selysioneura rhaphia*;						Medium/Low	Minor
Indolestes linsleyi; *Bironides ypsilon*; *Diplacina cyrene*; *Idiocnemis patriciae*; *Idiocnemis* sp. 1; *Nososticta chrismulleri*; *N. paraconifera; N. truncata*						Medium/Low	Minor

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Forest species: Fauna Dependent on Forest Streams, Forest Pools and Adjacent Riparian Habitats (cont'd)							
Odonates present in open and disturbed habitats: *Agyrtacantha* sp. 1; *Papuagrion* sp. 1					See above	Medium/Minimal	Negligible
Forest Species: Mangrove, Freshwater Swamp Forest and Alluvial Forest Fauna							
False water rat (*Xeromys myoides*)	Vegetation clearing operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation; waste generation storage and disposal; Project employment and procurement	Loss of individuals and habitat; contamination of wetland forest habitat; habitat degradation	All Project areas	C, O, D	See above	High/Minimal	Minor
Blue-black kingfisher (*Todirhamphus nigrocyaneus*); twelve-wired bird-of-paradise (*Seleucidis melanoleucus*)						Medium/Minimal	Negligible
New-to-science Plants with One of Few Known Populations in or near the Project Footprint							
Begonia sp. 5	Vegetation clearing operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation;	Loss of one of two known populations; degradation of remaining habitat; weed infestation; fire; threat to population viability	CPF	C, O, D	♦ EM001 ♦ EM013 ♦ EM018 ♦ EM024 ♦ EM025 ♦ EM026 ♦ EM027 ♦ EM028	Very High/Medium	Major
Archidendron sp. 1; *Syzygium* sp. 1		Loss of only known individual or one or more of few known individuals; degradation of remaining habitat; weed				High/Medium	Moderate

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
New-to-science Plants with One of Few Known Populations in or near the Project Footprint (cont'd)							
Archidendron sp. 1; *Syzygium* sp. 1 (cont'd)	waste generation storage and disposal; spoil disposal	infestation; fire; threat to population viability			♦ EM032 ♦ EM041	High/Medium	Moderate
Syzygium sp. 4	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation	Loss of only known individual or one or more of few known individuals; degradation of remaining habitat; weed infestation; fire	Export pipeline route	C, O, D	See above	High/High	Major
Pseuduvaria sp. 1						High/Low	Moderate
Ficus sp. 1; *Discocalyx* sp. 1						Medium/Low	Minor
Begonia sp. 2; *Medinilla* sp. 1; *Glochidion* sp. 1; *Lasianthus* sp. 1	Vegetation clearing; earthworks; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; construction works; pipeline operation; spoil disposal	Loss of individuals from among few known populations; degradation of remaining habitat; contamination of watercourses and associated riparian habitat; weed infestation; fire	Wellpads	C, O, D		High/Minimal	Minor
Regionally Rare IUCN Threatened Timber Trees							
Diospyros insularis	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; pipeline operation; spoil disposal	Loss of individuals from single known regional population; degradation of remaining habitat; weed infestation; fire	Logistics Base, CPF	C, O, D	See above	High/Low	Moderate

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Regionally Rare IUCN Threatened Timber Trees (cont'd)							
Diospyros lolinopsis	Vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport; onshore pipeline construction; pipeline operation		Export pipeline route	C, O, D	See above	Very High/High	Major
Hunting-sensitive Fauna in the Project Area							
Lowland tree kangaroo; giant bandicoot; Scheepmaker's crowned pigeon	Project employment and procurement; vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire; induced hunting	PRL-15, export pipeline route	C, O, D	♦ EM002 ♦ EM004 ♦ EM009 ♦ EM024 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033	High/Low	Moderate
Pesquet's parrot; Papuan eagle; grey dorcopsis						High/Minimal	Minor
Hunting-sensitive Fauna Occupying Northern Margins of the Study Area							
Pesquet's parrot; Papuan eagle; grey dorcopsis (cont'd)	Project employment and procurement; vegetation clearing; operation of fixed and mobile plant and equipment; logistics and transport	Loss of individuals and habitat; degradation of remaining habitat; weed infestation; fire; induced hunting	PRL-15, export pipeline route	C, O, D	♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	Medium/Low	Minor
Southern cassowary							

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Hunting-sensitive Fauna Occupying Northern Margins of the Study Area (cont'd)							
Pig-nosed turtle; striped New Guinea soft-shelled turtle	Project employment and procurement; dredging at Logistics Base; logistics and transport	Adult population reduction; nest failure; damage to or loss of river bank nest sites; induced hunting	PRL-15, river transport corridor	C, O, D	♦ EM001 ♦ EM004 ♦ EM013 ♦ EM014 ♦ EM022 ♦ EM024 ♦ EM027 ♦ EM028 ♦ EM031	High/Low	Moderate
Bulmer's fruit bat	Project employment and procurement	Loss of individuals from one of few regional colonies; induced hunting	PAOI	C, O, D	♦ EM001 ♦ EM004 ♦ EM009 ♦ EM024 ♦ EM027 ♦ EM028 ♦ EM031 ♦ EM033 ♦ EM034 ♦ EM035 ♦ EM046 ♦ EM047	Very High/Minimal	Moderate
Eastern long-beaked echidna; Goodfellow's tree kangaroo; ifola; dusky pademelon	Project employment and procurement	Loss of individuals; induced hunting				High/Minimal	Minor

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Migratory and Congregatory Shorebirds							
Far eastern curlew; great knot	Logistics and transport; Project employment and procurement	Loss of individuals; disturbance to feeding or roosting congregations impacting on energy reserves required for migration; induced hunting	River transport corridor	C, O, D	♦ EM019 ♦ EM027 ♦ EM028 ♦ EM046 ♦ EM047	High/Minimal	Minor
Asian dowitcher (*Limnodromus semipalmatus*); black-tailed godwit (*Limosa limosa*); bar-tailed godwit (*L. lapponica*); grey-tailed tattler (*Tringa brevipes*); red knot (*Calidris canutus*); red-necked stint (*C.ruficollis*); curlew sandpiper (*C. ferruginea*)						Medium/Minimal	Negligible
Resident Marine Coastal Birds							
Eastern osprey; beach stone-curlew	Logistics and transport; Project employment and procurement	Loss of individuals; disturbance to breeding sites; induced hunting	River transport corridor	C, O, D	See above	Medium/Minimal	Negligible
Freshwater Wetland Birds							
Great egret; intermediate egret; little egret	Logistics and transport; operation of fixed and mobile plant and equipment; construction works; Project employment and procurement	Disturbance at feeding or roosting sites; contamination of watercourses and associated riparian habitat; induced hunting	PRL-15; river transport corridor	C, O, D	See above	Medium/Minimal	Negligible

Table 11.46 – Summary of Assessment of Residual Impact Significance to Terrestrial Biodiversity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Crocodiles							
New Guinea freshwater crocodile; estuarine crocodile	Project employment and procurement; logistics and transport; waste generation storage and disposal	Loss of individuals; nest failure; damage to or loss of nest sites; induced hunting	PRL-15; river transport corridor	C, O, D	♦ EM014 ♦ EM022 ♦ EM023 ♦ EM024 ♦ EM027 ♦ EM028	Medium/Low	Minor

C = Construction, O = Operation, D = Decommissioning and closure.

11.7 References

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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 12: Impacts - Marine

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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12. Impacts: Marine

12.1 Marine Physical and Sediment Processes

12.1.1 Context

The offshore elements of the Papua LNG Project extend from Orokolo Bay at the northern end of the Gulf of Papua, along the continental shelf to Caution Bay (see Figure 4.7). Metocean processes and fluvial sediment inputs to the Gulf of Papua vary between the northwest monsoon season (December to March) and the southeast trade winds season (May to October). The southeast trade winds season typically has stronger winds and higher levels of wave-driven sediment resuspension than the northwest monsoon season. Rainfall and fluvial sediment delivery to the gulf is typically higher in the northwest monsoon season.

Fluvial sediments delivered to the gulf are deposited in shallow areas immediately offshore of rivers. Waves and currents remobilize sediments leading to high turbidity in Orokolo Bay, especially during the southeast trade winds season. Sediments in Orokolo Bay comprise muds and sands, and only a single rocky-reef, located in the southeastern part of the bay, is known to occur. The shoreline of the bay experiences high rates of sediment transport driven by incident southeasterly waves. This is causing a sediment lobe, located in the eastern part of the bay, to migrate westwards towards the Purari River mouth (see Figure 8.3).

The physical and climatic settings differ between Caution Bay and Orokolo Bay. Caution Bay receives fluvial sediment loads from the Vaihua River, which has a much smaller catchment and overall sediment load compared to the Purari River. There is, therefore, lower total fluvial sediment loads to Caution Bay compared to Orokolo Bay. Caution Bay is protected from waves by a barrier reef system between Vari Vari and Idihi islands and has a fringing nearshore reef. Due to the calmer conditions and lower fluvial sediment delivery, Caution Bay has lower turbidity and total suspended solid (TSS) concentrations than Orokolo Bay.

Substrates along the offshore export pipeline route generally consist of depositional, unconsolidated sediments, predominantly comprising silts and clays, in water 35 to 60 m deep. Wave climates in these offshore waters rarely reach wavelengths sufficient to mobilize sediments at this depth. Wave-induced bottom friction velocities are very low along the offshore export pipeline route.

12.1.2 Discipline-specific Impact Assessment Method

The significance assessment approach described in Chapter 3 was primarily used to characterize impacts relevant to physical and sediment processes. The magnitude and sensitivity descriptors used to assess impacts are presented in Tables 12.1 to 12.3.[1] The assessment is a function of the magnitude[2] of impact on a resource or receptor and the sensitivity of that resource or receptor. Together, they determine the significance of the residual impact, as shown in Table 12.4.

Numerical modeling of hydrodynamics and sediment transport was also undertaken to inform the impact assessment. The assessment is therefore a combination of the qualitative significance assessment approach and quantitative modeling. Further information on the modeling activities is provided in Part 4 of Volume 3.

1 These descriptors are also relevant to marine water quality, which is assessed in Section 12.2.
2 Magnitude is assessed considering combinations of (1) geographic extent and (2) the higher of severity and duration.

This modeling was used to simulate potential impact scenarios based on the proposed marine export pipeline works and construction methods. Whilst LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS, the modeling discussed here includes indicative information that will be refined as part of the downstream Papua LNG EIS.

Table 12.1 – Impact Magnitude Descriptors Relevant to Marine Physical and Sediment Processes, and Marine Water Quality

Geographic Extent of Impact*		Severity and Duration of Impact		
		Severity		Duration
5	Impact to any environmental feature that extends significantly beyond *subregion* (close to *regional*) scale.	5	Extreme impact such that: ♦ Intensity, frequency and duration of impact is well outside the range of natural variability; or ♦ One or more environmental values (social and biodiversity) are no longer supported.	Impact lasts >30 years
4	Impact to any environmental feature that extends beyond *subregion* (but not close to *regional*) scale.	4	Severe impact such that: ♦ Intensity, frequency and duration of impact is slightly outside the range of natural variability; or ♦ One or more environmental values (social and biodiversity) are adversely affected but supported in a highly modified condition.	Impact lasts 5 to 30 years
3	Impact to any environmental feature that extends beyond *localized* area but does not extend beyond *subregion*.	3	Moderate impact such that: ♦ Intensity, frequency and duration of impact is within the range of natural variability, similar to levels experienced during extreme events such as severe storms or tropical cyclones; or ♦ One or more environmental values (social and biodiversity) are adversely affected but still supported in a slightly to moderately modified condition.	Impact lasts <5 years
2	Impact to any environmental feature within a *localized* area.	2	Minor impact such that: ♦ Intensity, frequency and duration of impact is within the upper range of natural variability but below levels experienced during extreme events such as severe storms or tropical cyclones; and ♦ All environmental values (social and biodiversity) are maintained.	Impact lasts <1 year
1	Impact to any environmental feature within *highly localized* area.	1	Very minor to no impact such that: ♦ Intensity, frequency and duration of impact is within the average range of natural variability; and ♦ All environmental values (social and biodiversity) are maintained.	Impact lasts days to weeks

**Region* = Area greater than 20,000 km^2 (approximately 25% of the Gulf of Papua ecoregion (~75,000 km^2) and approximately 10% of the Southeast Papua New Guinea ecoregion (~225,000 km^2)).
Subregion = Area more than 2 km from the Project footprint but less than 20,000 km^2.
Localized = Area up to 2 km from the Project footprint.
Highly localized = Area up to 0.5 km from the Project footprint.

Table 12.2 – Impact Magnitude Matrix Relevant to Marine Physical and Sediment Processes, and Marine Water Quality

Severity/ Duration	Geographic Extent				
	1	2	3	4	5
1	Minimal	Low	Medium	Medium	High
2	Low	Low	Medium	High	High
3	Low	Medium	High	Very High	Very High
4	Medium	Medium	High	Very High	Very High
5	Medium	Medium	Very High	Very High	Very High

Table 12.3 – Receptor Sensitivity Descriptors Relevant to Marine Physical and Sediment Processes, and Marine Water Quality

Rating	Descriptor
Very High	♦ Environment is in a natural condition with no evidence of modification; all environmental benchmarks are met. ♦ Environment supports physical properties or processes that are considered rare or exceptional at a regional scale.
High	♦ Environment is in a near-natural condition with minimal human-induced modification; most environmental benchmarks are met. ♦ Environment supports physical properties that are considered rare or exceptional at a local scale, but well represented regionally.
Medium	♦ Environment is in a near-natural condition with some human-induced modification; most environmental benchmarks are met. ♦ Environment supports physical properties or processes that are well represented at the local scale and experience low inter-decadal variability from extreme events (e.g., cyclones, floods).
Low	♦ Environment is moderately degraded compared to equivalent areas or as measured by environmental benchmarks. ♦ Environment supports physical properties or processes that are resilient to change, experiencing extreme natural events (e.g., cyclones, floods) every few years.
Minimal	♦ Environment is highly degraded compared to equivalent areas or as measured by environmental benchmarks. ♦ Environment supports physical properties or processes that are very resilient to change, experiencing extreme natural events (e.g., cyclones, floods) every year.

Table 12.4 – Impact Significance Matrix Relevant to Marine Physical and Sediment Processes, and Marine Water Quality

Magnitude of Impact	Sensitivity of Receptor				
	Very High	High	Medium	Low	Minimal
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

A final pipeline alignment has not been decided in Caution Bay. The pipeline alignment will be finalized during the Project's front-end engineering design phase. For this impact assessment, two indicative alignments were modeled in Caution Bay with one to the south of the PNG LNG Gas Pipeline (base case) and the other to the north (alternative case). LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS, and the modeling in this EIS presents indicative information that will be refined as part of the downstream Papua LNG EIS.

The scenarios modeled for each shore crossing location and alignment were:

Orokolo Bay

- Base case alignment – northwest monsoon season.
- Base case alignment – southeast trade winds season.

Caution Bay

- Base case (southern) alignment – northwest monsoon season.
- Base case (southern) alignment – southeast trade winds season.
- Alternative case (northern) alignment – northwest monsoon season.
- Alternative case (northern) alignment – southeast trade winds season.

The Project has yet to determine the trenching method or method for dredge material management. It was assumed for the modeling and the impact assessment that a cutter suction dredge will be used. It is possible that a backhoe dredge may be used instead, but a cutter suction dredge would likely cause a higher plume release rate and therefore represents a conservative scenario.

It was estimated that trenching at both Orokolo Bay and Caution Bay would take less than five days (i.e., 4.75 days for Orokolo Bay and 1 to 2 days for Caution Bay), based on standard production rates for cutter suction dredges. When modeling, it was assumed that trenching would occur to -15 m lowest astronomical tide (LAT) and be completed in one week at each location; however, trenching is now planned to -20 m LAT. Other than the additional time required, this updated scenario does not significantly change the assessment of impacts to marine physical and sediment processes or marine biodiversity.

Modeling assumed that all the dredged material, discharged either in the water column or on the seabed, is subject to water current and wave-induced resuspension processes, which were explicitly modeled to provide conservatism to the impact assessments

The modeling outputs focused on identifying the impacts of sediment disturbed by the trenching, including sediment directly disturbed from the seafloor and sediment-laden water in the cutter suction dredge overflow. These impacts were measured as:

- Total suspended solids concentrations (mg/L) in water affected by the sediment disturbance, averaged over the depth of the water column.
- Extent of the area of TSS-affected water (the plume). The plume boundaries are based on different TSS thresholds, with the outer boundary identified to be the point at which the TSS concentration is less than 5 mg/L. As described in Section 12.3, a median TSS concentration of 5 mg/L is considered to be the threshold for moderate ecological impacts. Total suspended solids concentrations below this threshold are also considered non-discernible compared to the natural variability of background conditions.
- Extent of the area in which sediment disturbed by the trenching will deposit (i.e., the deposition extent). The deposition extent boundaries were identified to be the point at which deposition was below 200 mg/cm^2 (threshold for zone of influence described in Section 12.3) Both Orokolo Bay and Caution Bay experience frequent reworking of sediment and deposition from wave action. As such, deposition rates below 200 mg/cm^2 are considered unlikely to adversely affect sensitive receptors such as seagrass and coral, as rates below this threshold are considered to be within the range of natural variability and tolerance limits for these receptors (Erftemeijer et al., 2012).

12.1.3 Identification of Potential Impacts

Potential impacts to marine physical and sediment processes can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

12.1.3.1 Changes to Hydrodynamic and Morphological Processes

Pipeline Installation

The offshore export pipelines are not anticipated to alter hydrodynamic and morphological processes for the following reasons:

- At the shore crossing in Orokolo Bay, if sheet piling is used, sheet piles installed during pipeline trenching will be cut off between 0.5 and 1 m below the seabed following pipeline installation, resulting in no net change to coastal land or intertidal seabed levels. The physical presence of sheet piles will alter hydrodynamic conditions, i.e., patterns of physical forcing in the water such as currents and wave action, in a limited area in the shallow waters of Orokolo Bay during pipeline installation; however, these changed conditions will be highly temporary (i.e., weeks) and are expected to have insignificant impacts on coastal processes, i.e., patterns of coastal change, including sediment transport and deposition or scouring.[3]
- The offshore pipeline will be buried with a 1 m cover depth to the top when located in water shallower than 20 m [ED041]; therefore, there will be no net change to seabed levels and hence no change to hydrodynamic and morphological processes. The burial depth is also sufficient so that scour will not expose pipelines.

On this basis, no hydrodynamic and morphological impacts are expected due to pipeline excavation and burial, and this is not assessed further.

12.1.3.2 Sediment Mobilization

Pipeline Installation

Trenching for nearshore pipeline installation will mobilize sediment through the following processes:

- Direct physical disturbance of the seabed by the dredge.
- Discharge of sediment-laden overflow from the dredge, if a cutter suction dredge is used.

Sediments disturbed by trenching and overflow will be transported by waves and currents, and will eventually settle onto the seafloor. Deposited sediment may be available for subsequent resuspension by currents and waves.

Trenching activities will be undertaken in Orokolo and Caution bays. Impacts due to sediment mobilization may differ at each site due to differences in hydrodynamic and sediment processes.

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3 There is insufficient existing data to determine potential bed load transport rates from unusual events such as a significant storm. There is some uncertainty around the potential for sheetpiles to become exposed from such events in the long term (i.e., beyond the life of the Project); however, it is unlikely since this area is a prograding rather than an erosional environment, as discussed in Section 8.2.

Vessel Use

Vessels to be used by the Project include:

- Barges, which will be used to transport construction equipment, large plant and supplies to PRL-15 via the gulf, and the Purari River and its distributaries. The highest barge traffic numbers will occur during the construction phase.
- Pipelaying and support vessels, which will operate along the entire offshore export pipeline route. This vessel activity will occur during the construction phase.
- Trenching and support vessels, which will operate in waters up to -20 m LAT in Orokolo Bay and Caution Bay, and transiting to and from these areas. This will occur during the construction phase.

Propeller wash, anchoring and wake from these vessels can disturb the seabed and shoreline. Considering the environment and depths in which most work will occur, propeller wash and vessel wake are unlikely to cause any significant disturbance. The pipelaying vessel may cause some wash impacts, i.e., displacement of bed sediment, in the pipelaying footprint but these will be negligible compared to disturbance associated with the pipe trenching. Seabed disturbance from anchoring will also be minimal as the pipelaying vessel will use a dynamic positioning system (i.e., using propellers and thrusters rather than anchors) and the anchoring from other support vessels will be limited, occurring infrequently, being extremely localized and of negligible magnitude; therefore, impacts of vessel use on sedimentation and physical processes are not considered further. The potential scour impacts from vessels in the Purari River are discussed in Chapter 11.

12.1.3.3 Summary of Potential Impacts to Marine Physical and Sediment Processes

Potential impacts to marine physical and sediment processes due to the Project that have been considered in the residual impact assessment are as follows:

- Increased suspended sediment concentrations in the water column due to nearshore trenching for the pipeline.
- Increased sedimentation on the seabed due to nearshore trenching for the pipeline.

The residual risks of increases in suspended sediment and sedimentation occurring due to trenching are assessed in Section 12.1.5. The impacts on sensitive receptors, such as coral reef, seagrass and marine fauna, due to such increases in suspended sediment and sedimentation are specifically addressed in the marine biodiversity impact assessment in Section 12.3.

12.1.4 Proposed Mitigation and Management Measures

Table 12.5 describes mitigation and management measures manage to sediment mobilization during trenching. Mitigation and management in Caution Bay in the lease area for the PNG LNG project will be further aligned with the PNG LNG project and the downstream Papua LNG project.

Table 12.5 – Marine Physical and Sediment Processes Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Sediment mobilization from trenching causing an increase in suspended sediment in the water column and sedimentation on the seabed.	♦ Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species [EM037].	Water Management Plan

12.1.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to marine physical and sediment processes subject to the embedded design controls in Section 12.1.3 and the successful implementation of the mitigation and management measures in Section 12.1.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

12.1.5.1 Sediment Mobilization

The mitigation strategies for sediment mobilization relate to adapting trenching activities to respond to excessive sediment disturbance and generation. While this adaptive management approach may reduce the total impact compared to the pre-mitigation modeled scenario, the residual impact assessment presented below assumes no change in modeled concentrations or extents of plumes and sediment deposition, and therefore represents a conservative assessment.

Impacts are discussed for Orokolo Bay and Caution Bay based on: (i) plume impacts (combining plume concentration and plume extent results); and (ii) deposition impacts (focusing on the extent of deposition).

Orokolo Bay

Numerical modeling was undertaken to predict changes to: (i) TSS concentrations; and (ii) final net sediment deposition depth, from the proposed trenching works in Orokolo Bay (and Caution Bay). Refer to Part 4 of Volume 3 for details on the modeling.

Increase in Suspended Sediment in the Water Column

Plots of the predicted increase in 50th and 95th percentile TSS concentrations due to trenching during the northwest monsoon season and southeast trade winds season are shown in Figures 12.1 and 12.2, respectively. These concentrations are depth-averaged, i.e., average over the full depth of the water column, increments in concentration over background levels. The 50th percentile (i.e., median) concentration occurs 50% of the time and is therefore considered to represent typical conditions. The 95th percentile concentration, which is exceeded only 5% of the time, is considered to represent a short-term peak concentration.

During the northwest monsoon season, the plume from trenching generally extends in a southeasterly direction, with the typical 50th percentile concentration up to about 5 mg/L. The short-term peak increment in TSS (95th percentile) is up to approximately 100 mg/L within 500 m of trenching, but decreases to less than approximately 25 mg/L within 2 km. These peak concentrations are predicted to occur over a total period of five to six hours during a 4.75-day dredge campaign.

Similar impacts are predicted during the southeast trade winds season, except that the plume extends in a westerly direction.

These increases in median TSS concentrations represent a minimal increase above background levels in this area of Orokolo Bay (measured in the area to be 1 to 2 mg/L during the northwest monsoon season, and between 2 and 9 mg/L during the southeast trade wind season; as represented by results for sites M4, M8 and M12 described in Part 11 of Volume 2) and will be limited in duration and extent. The short-term peak increment in TSS also represents a localized impact of two to three hours. The magnitude of impact is therefore categorized to be ***Low***. Orokolo Bay in the area to be trenched has a ***Low*** sensitivity of sediment processes, as this area is relatively undisturbed but regularly receives high fluvial suspended sediment loads from the Purari and Vailala rivers. Combining these, the residual impact significance is ***Minor***.

DEPTH-AVERAGED TSS INCREASE IN OROKOLO BAY DURING NORTHWEST MONSOON SEASON

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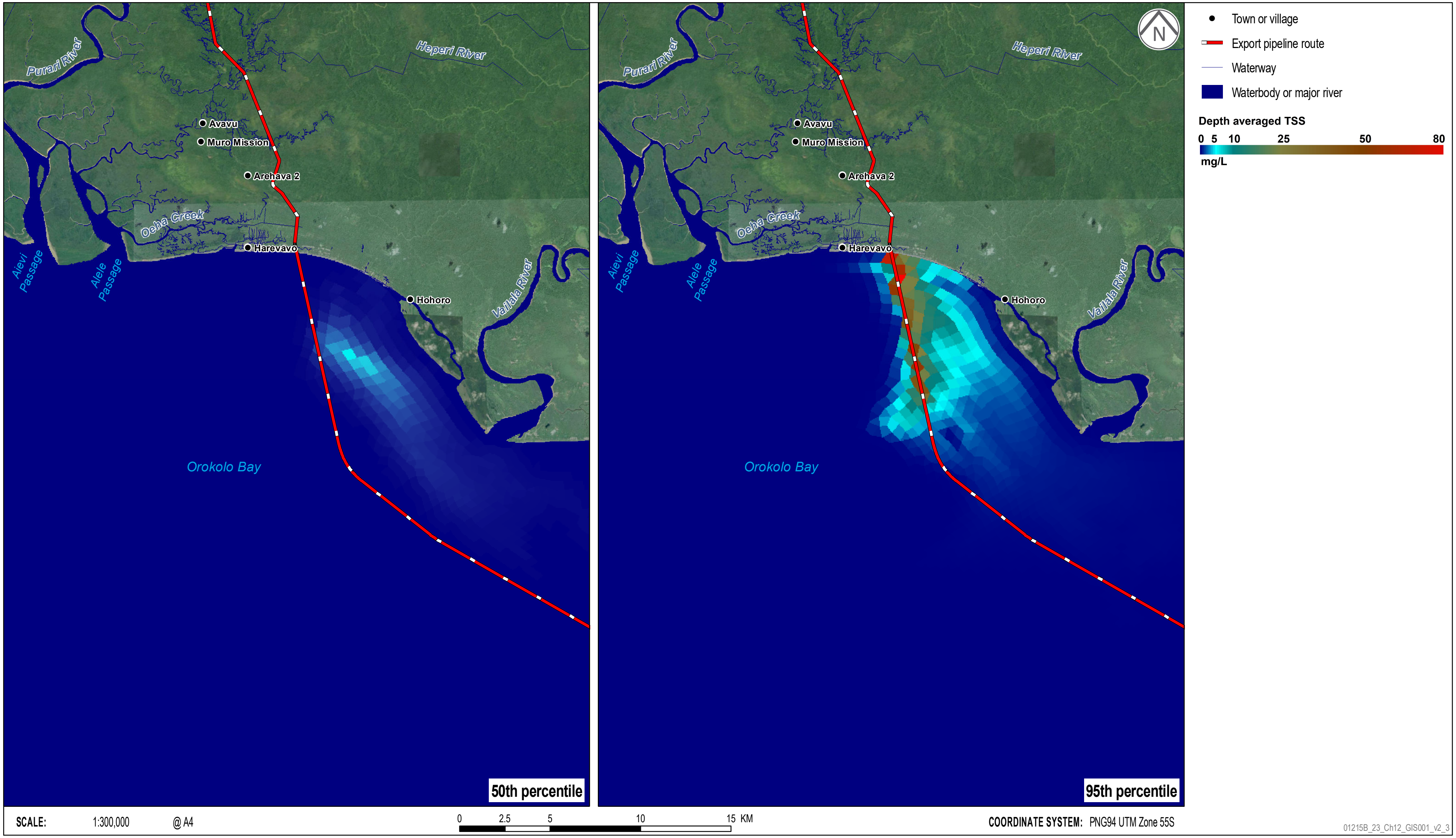
FIGURE 12.1



Source: Figure theme data from Part 4 of Volume 3.

DEPTH-AVERAGED TSS INCREASE IN OROKOLO BAY DURING SOUTHEAST TRADE WINDS SEASON

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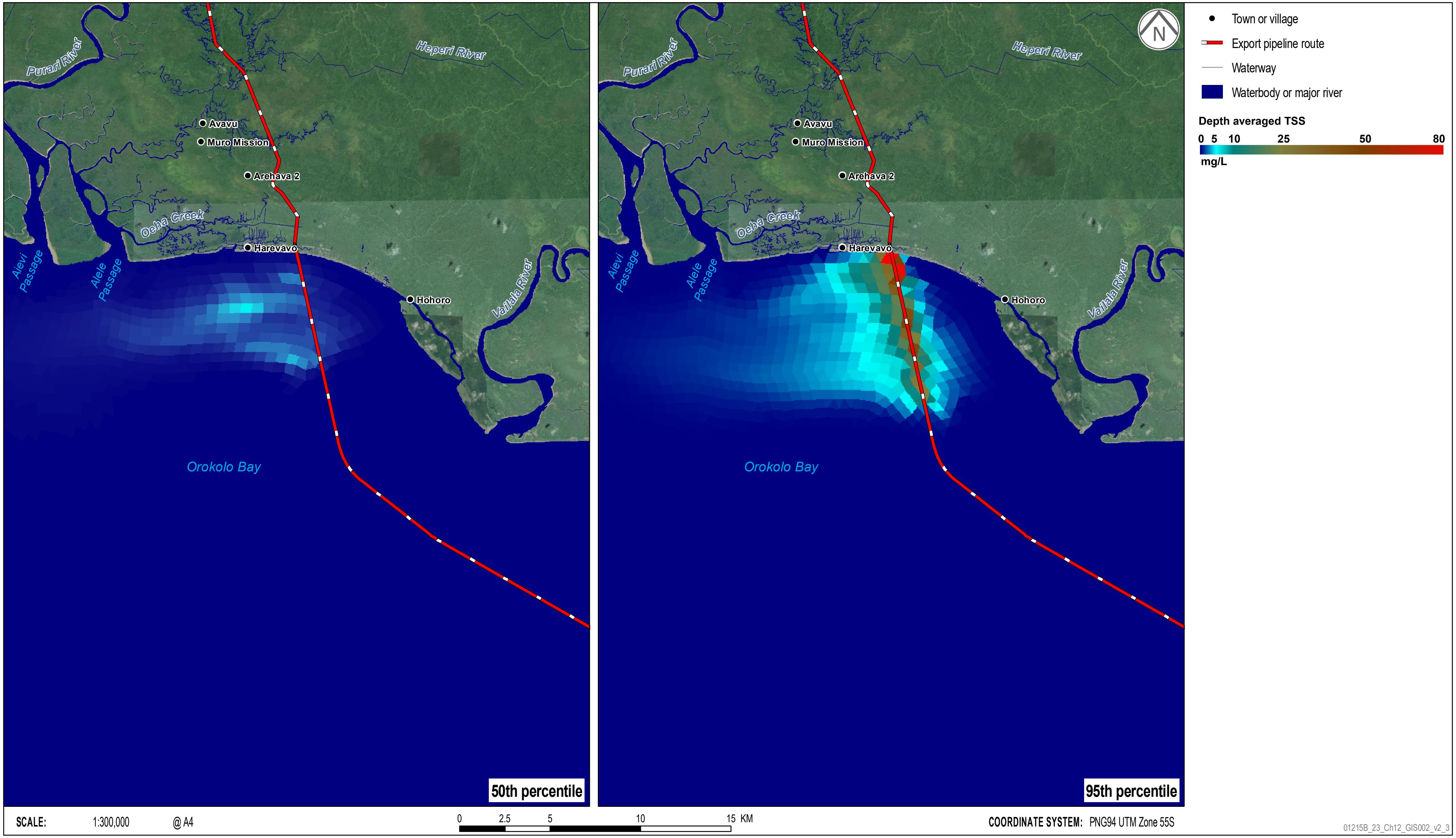
FIGURE 12.2



Source: Figure theme data from Part 4 of Volume 3.

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Increased Sedimentation on the Seabed

Final net sediment deposition depths for trenching occurring during the northwest monsoon season and southeast trade winds season are shown in Figure 12.3.

The modeled deposition extent above 200 mg/cm^2 is limited to within 500 m of the trenching during both the northwest monsoon and the southeast trade winds seasons. The model resolution for this deposition assessment uses a 500 m cell (i.e., all deposition occurs in the first cell of the model); hence the extent of deposition may be less. Maximum final sediment deposition rates for both seasons are 2,000 to 4,000 mg/cm^2 (Figure 12.3) in the deposition area. Sedimentation rates are negligible further than 500 m from the pipeline alignment.

Inshore sediments of Orokolo Bay are frequently re-worked by waves generated from the southeast trade winds, and deposits or high points of sediment will be rapidly remobilized and distributed over the sea floor. The geographic extent of impact will therefore be localized. The severity of impact will be within natural variability, considering the high fluvial inputs of sediment from the Purari and Vailala rivers, providing an overall impact magnitude rating of ***Low***. As described above, Orokolo Bay, in the area to be trenched, has a ***Low*** sensitivity with regard to sediment processes; therefore, the residual impact significance is assessed as ***Minor***.

Caution Bay

As indicated earlier, LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS, the related indicative information presented here will be refined as part of the downstream Papua LNG EIS.

Increase in Suspended Sediment in the Water Column

Plots of the predicted increase in 50th and 95th percentile TSS concentrations due to trenching during the northwest monsoon season and southeast trade winds season for the southern alignment scenario are shown in Figures 12.4 and 12.5, respectively. Plots for the alternative northern alignment scenario are shown in Figure 12.6 (northwest monsoon season) and Figure 12.7 (southeast trade winds season).

During the northwest monsoon season, the increases in median TSS concentrations in Caution Bay due to trenching are predicted to be 0.3 mg/L along the southern alignment and 0.6 mg/L along the northern alignment. During the southeast trade winds season, the increases in median TSS concentrations are slightly higher, with 1.7 and 4.5 mg/L expected for the southern and northern alignments, respectively. This relatively low level of suspended sediment is due to the high amount of sand expected in the material to be trenched. In the northwest monsoon season, this low-concentration plume extends south to Haidana Island due to the prevailing wind direction and resuspension associated with the wave climate. Within the southeast trade winds season, it remains contained in Caution Bay.

In comparison to these predicted increases, median TSS concentrations measured during baseline studies were less than 1 mg/L during the northwest monsoon season, and between 4 and 5 mg/L during the southeast trade winds season (see Part 11 of Volume 2). The predicted increase in the median TSS concentration from trenching represents a minimal increase in absolute TSS concentrations that will be short-term and of limited extent. A short-term peak increment in TSS concentration (i.e., 95th percentile concentration) of up to approximately 80 mg/L occurs; however, this is localized within 500 m of both pipeline alignments during both seasons. The magnitude of impact is therefore categorized to be ***Low.*** The Caution Bay marine environment is considered to have ***Medium*** sensitivity. The residual impact significance is therefore assessed to be ***Minor***.

FINAL NET DEPOSITION OF SEDIMENT MOBILIZED FROM TRENCHING IN OROKOLO BAY

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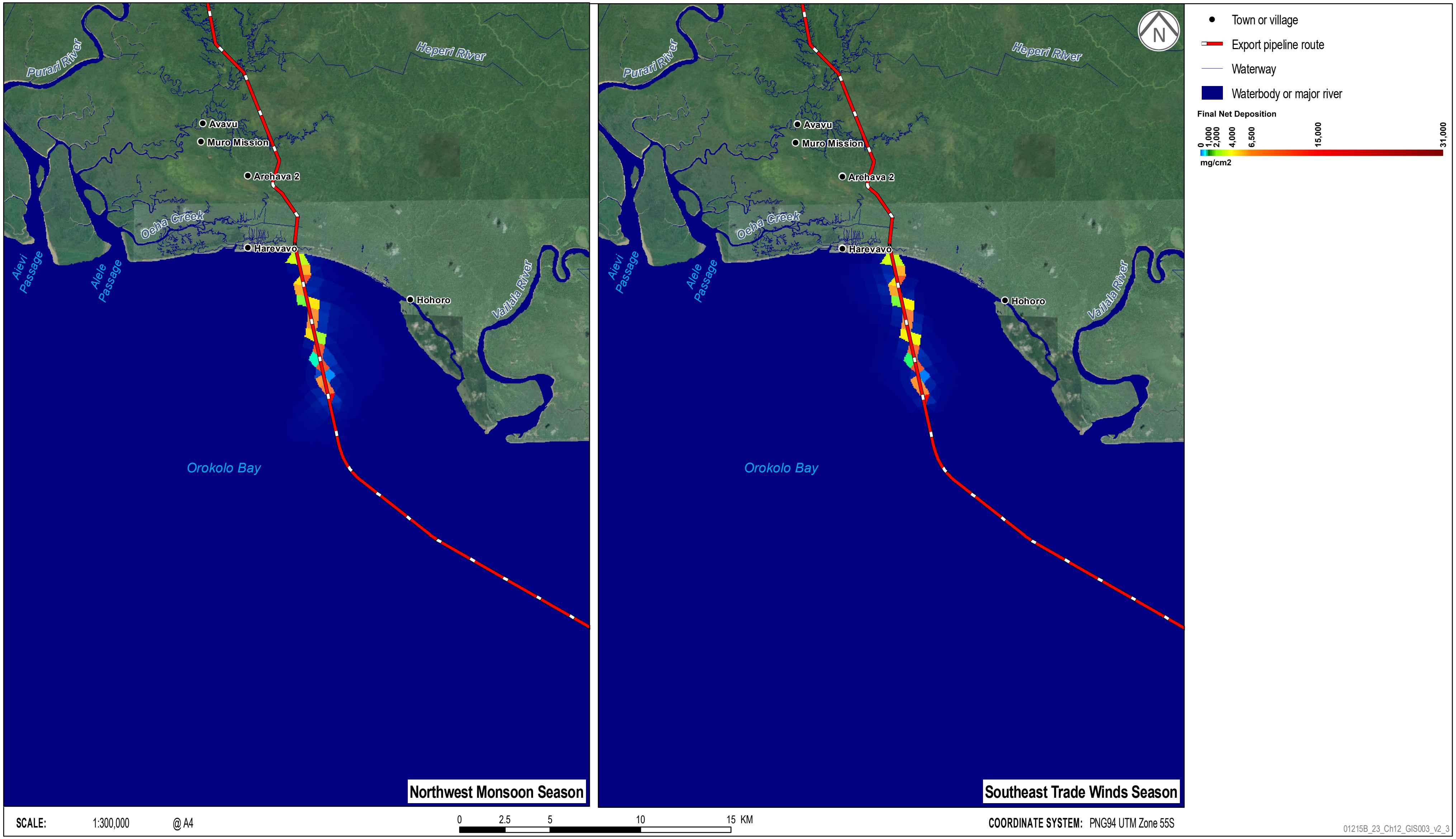
FIGURE 12.3



Source: Figure theme data from Part 4 of Volume 3.

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INDICATIVE DEPTH-AVERAGED TSS INCREASE IN CAUTION BAY DURING NORTHWEST MONSOON SEASON - SOUTHERN ALIGNMENT

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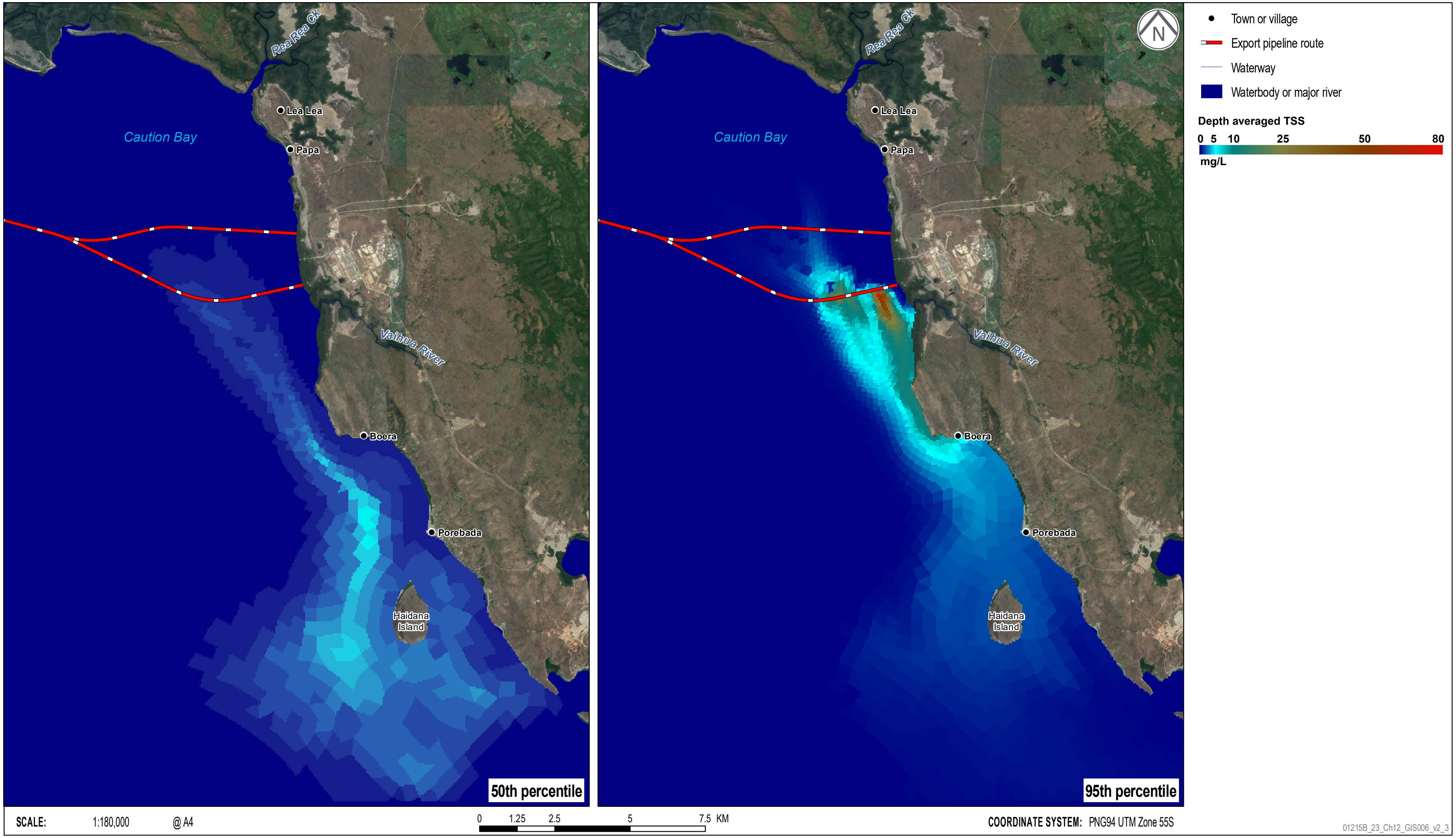
FIGURE 12.4



Source: Figure theme data from Part 4 of Volume 3.

INDICATIVE DEPTH-AVERAGED TSS INCREASE IN CAUTION BAY DURING SOUTHEAST TRADE WINDS SEASON - SOUTHERN ALIGNMENT

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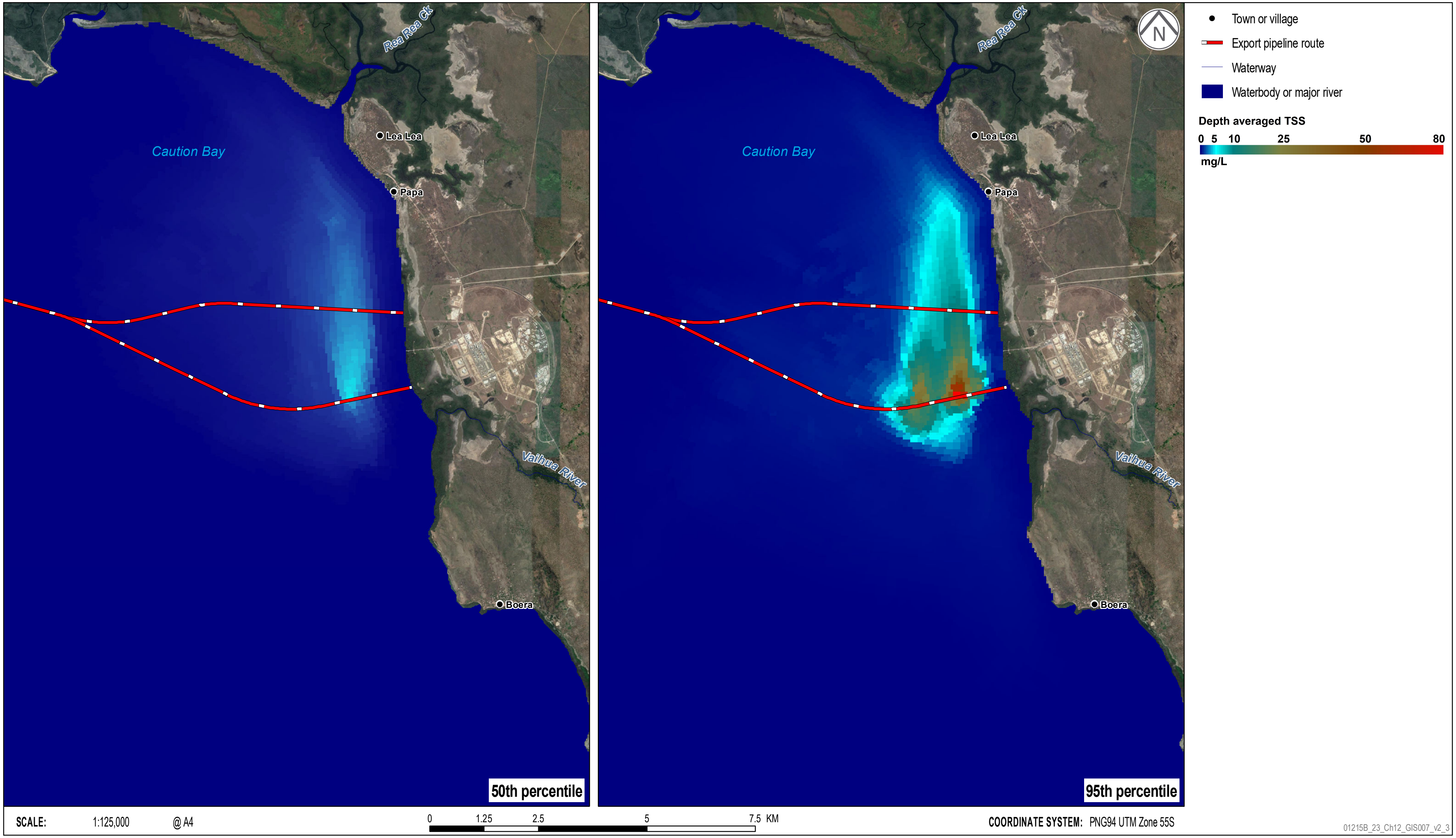
FIGURE 12.5



Source: Figure theme data from Part 4 of Volume 3.

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INDICATIVE DEPTH-AVERAGED TSS INCREASE IN CAUTION BAY DURING NORTHWEST MONSOON SEASON - NORTHERN ALIGNMENT

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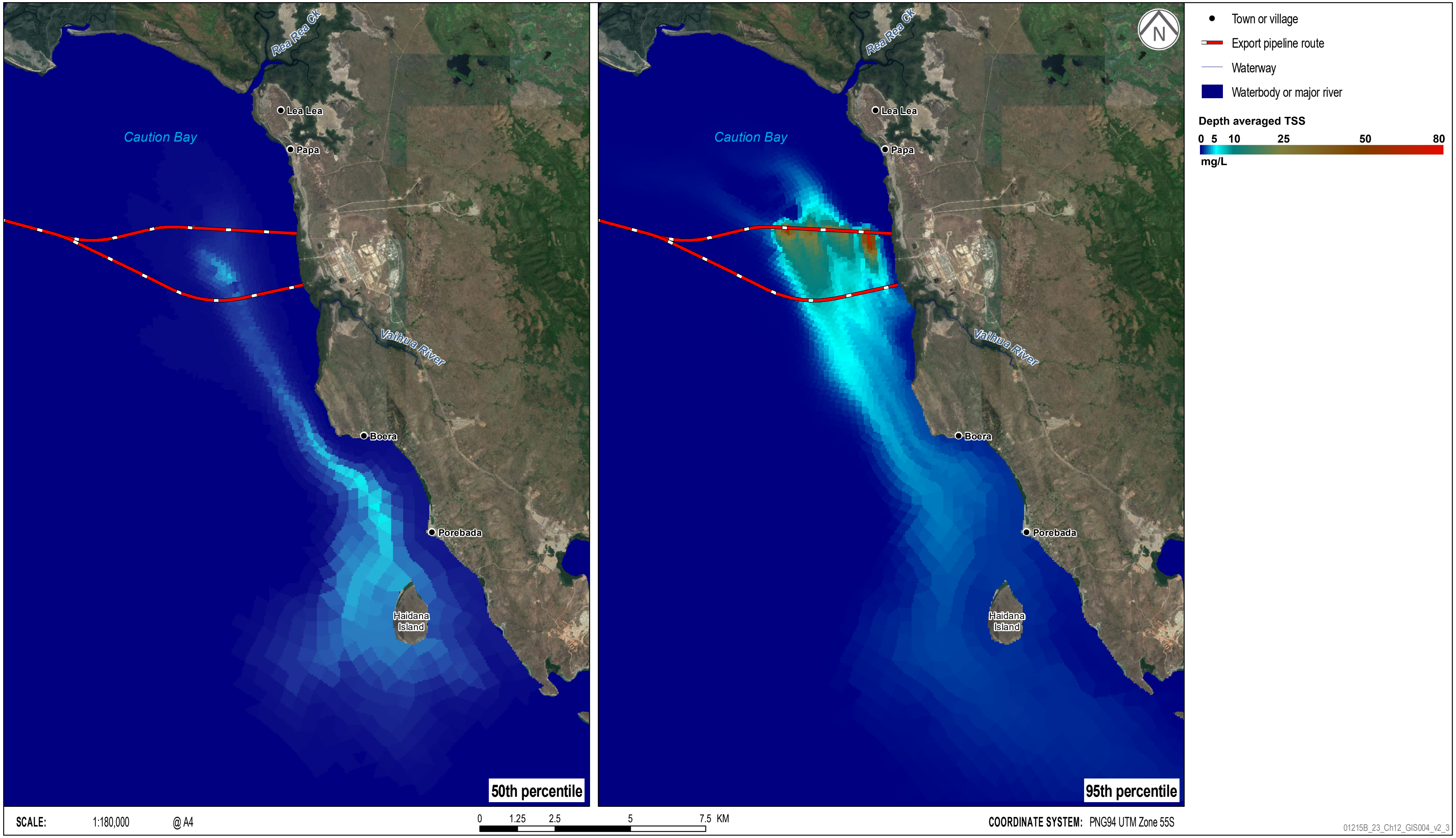
FIGURE 12.6



Source: Figure theme data from Part 4 of Volume 3.

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INDICATIVE DEPTH-AVERAGED TSS INCREASE IN CAUTION BAY DURING SOUTHEAST TRADE WINDS SEASON - NORTHERN ALIGNMENT

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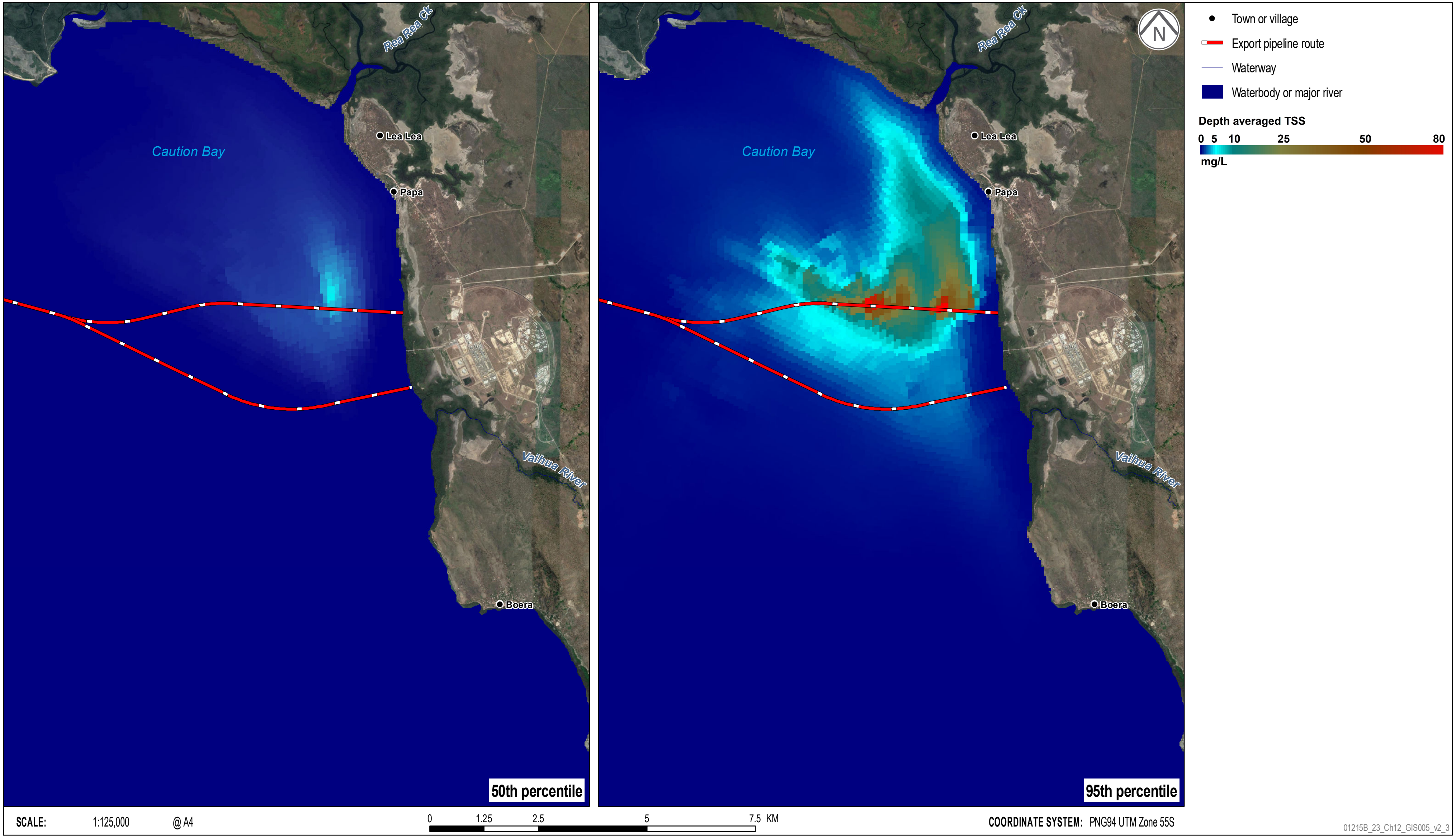
FIGURE 12.7



Source: Figure theme data from Part 4 of Volume 3.

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Increased Sedimentation on the Seabed

The extent of sediment deposition above 200 mg/cm^2 is predicted to be limited to within 500 m of the trenching for both pipeline alignments, as shown in Figures 12.8 (southern alignment) and 12.9 (northern alignment). Within 500 m of trenching activities, sedimentation rates are predicted to reach a peak of over 15,000 mg/cm^2 for both alignments in both seasons. As wave action naturally and rapidly reworks sediment, these modeled peak deposition rates are considered conservative, with the associated volume of sediment spread across a wider area, within the deposition extent. Outside of this higher impact area, the sediment rates rapidly attenuate to below 200 mg/cm^2.

Impacts to benthic communities in the localized area of sediment deposition may occur for up to five years, during which period wave action will rework and redistribute the deposited sediment. Environmental values would be supported in a slightly to moderately modified condition. The magnitude of impact is therefore categorized to be ***Low.***

The Caution Bay benthic environment is considered to have ***Medium*** sensitivity, based on existing levels of disturbance, with some fringing and nearshore reefs observed to be in poor condition due to fishing practices and suspension of sediment from strong winds and waves (see Section 8.5.2). The residual impact significance is therefore assessed to be ***Minor***.

12.1.6 Summary of Residual Impacts to Marine Physical and Sediment Processes

A summary of the residual impact assessment of marine physical and sediment processes is provided in Table 12.6, including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the mitigation measures provided in Table 12.5.

Residual impacts are assessed to be ***Minor***.

INDICATIVE FINAL NET DEPOSITION OF SEDIMENT MOBILIZED FROM TRENCHING OF CAUTION BAY - SOUTHERN ALIGNMENT

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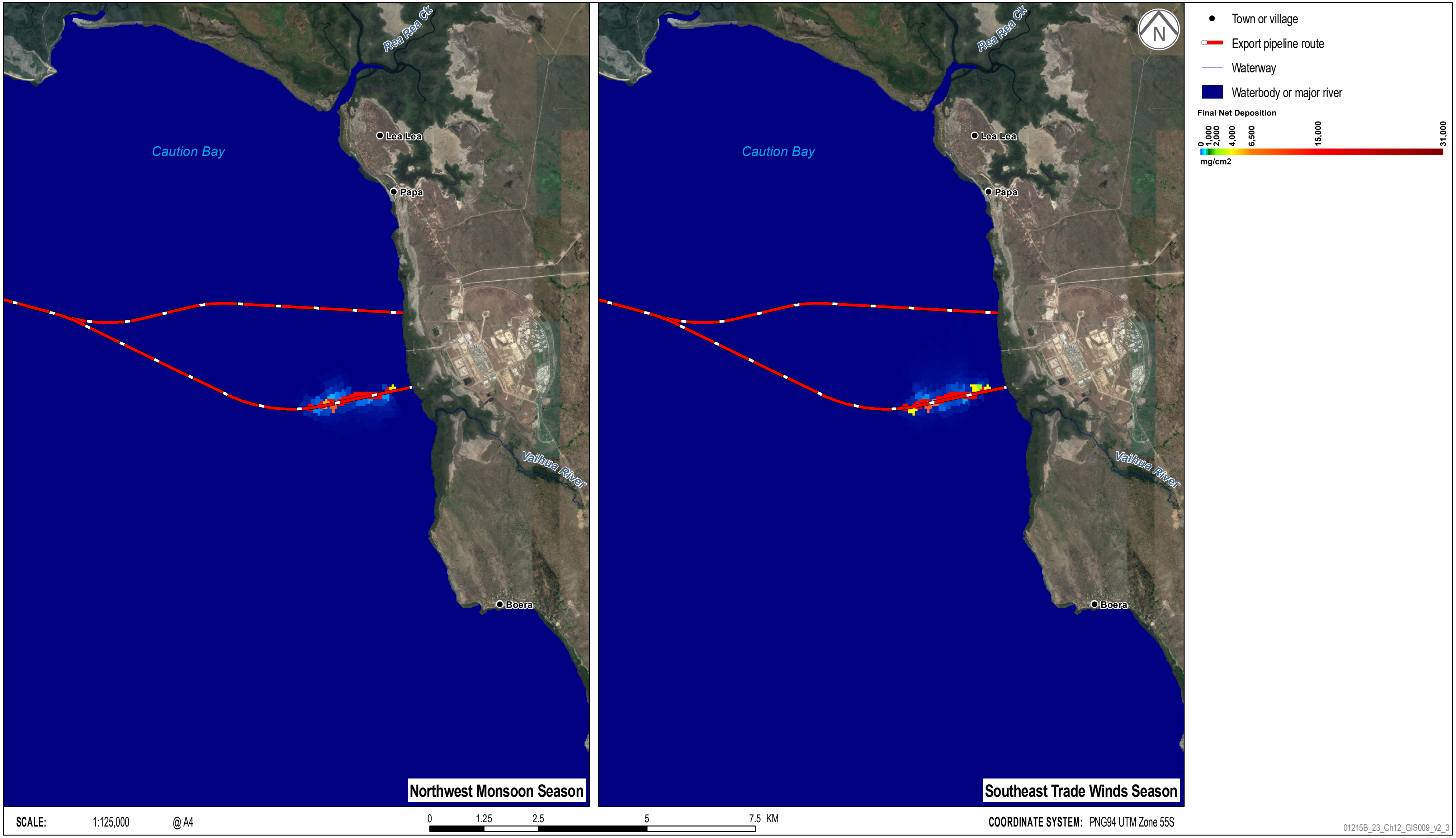
FIGURE 12.8



Source: Figure theme data from Part 4 of Volume 3.

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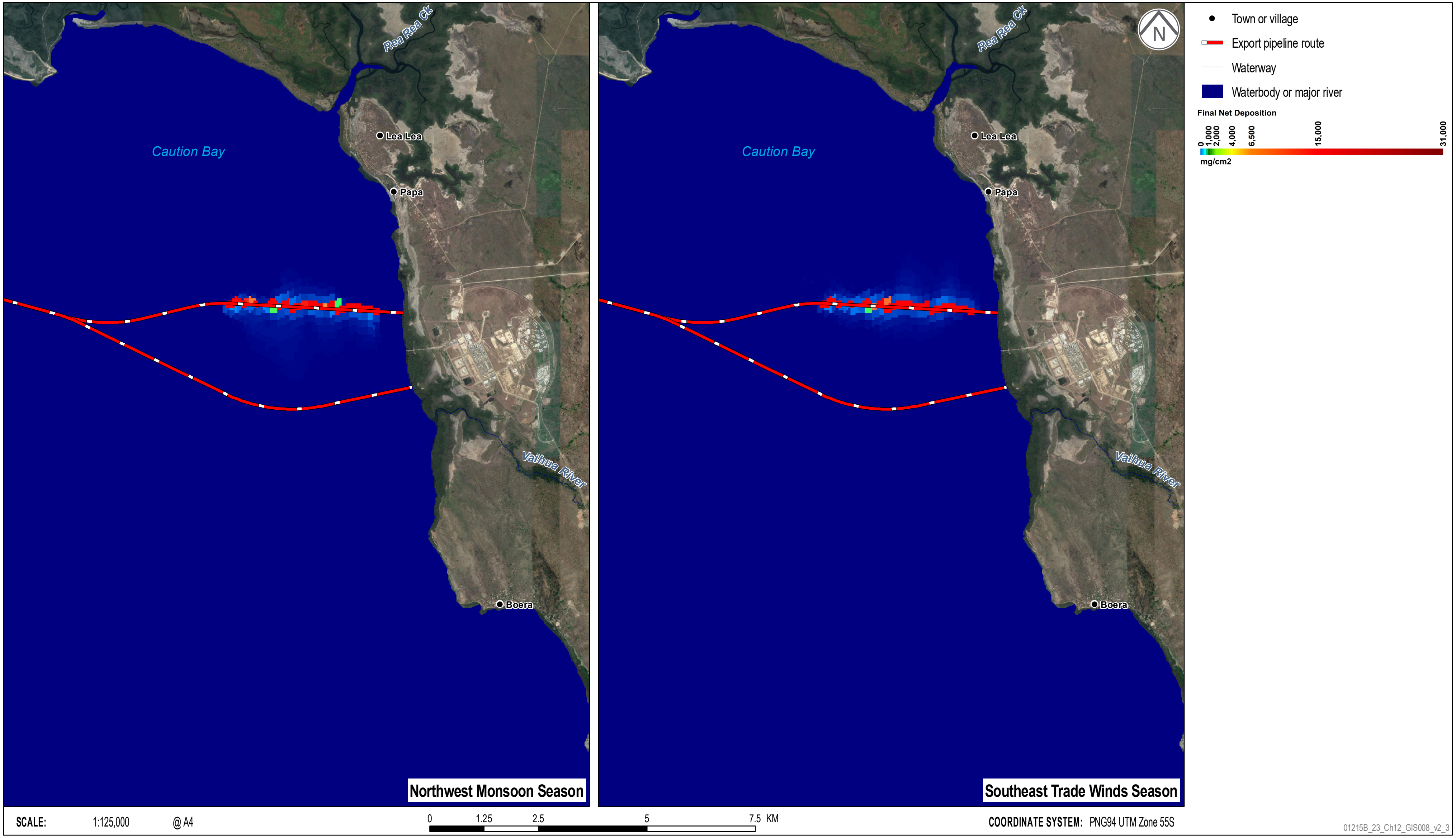
INDICATIVE FINAL NET DEPOSITION OF SEDIMENT MOBILIZED FROM TRENCHING OF CAUTION BAY - NORTHERN ALIGNMENT

Papua LNG Project | Environmental Impact Statement

FIGURE 12.9



Source: Figure theme data from Part 4 of Volume 3.

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Table 12.6 – Summary of Assessment of Residual Impact Significance – Marine Physical and Sediment Processes

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/Magnitude	Significance
Mobilization of sediments	Offshore pipeline construction – trenching for the pipeline in Orokolo and Caution bays	Increased suspended sediment concentrations in the water column.	Orokolo Bay	C	♦ EM037	Low/Low	Minor
			Caution Bay	C		Medium/Low	Minor
		Increased sedimentation on the seabed.	Orokolo Bay	C		Low/Low	Minor
			Caution Bay	C		Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure.

12.2 Marine Water Quality

This section considers potential contamination of marine water quality resulting from planned discharges and accidental releases of hydrocarbons or chemicals. Impacts on marine water quality due to increased levels of suspended sediment due to Project activities are described in Section 12.1. Associated impacts on sensitive receptors, i.e., marine fauna, due to deterioration of water quality are specifically addressed in the marine biodiversity impact assessment In Section 12.3.

12.2.1 Context

The marine waters of the PAOI are in a largely undisturbed condition; however, there are several existing sources of potential water quality contamination, including:

- Commercial shipping activities, which are potential sources of sewage and hydrocarbons. The PNG LNG Facilities in Caution Bay are the main shipping area in the marine PAOI. Major shipping lanes exist through the marine PAOI.
- Small craft (potential source of sewage and hydrocarbons), especially fishing vessels.
- Stormwater runoff and point source discharges, as occur in Caution Bay.
- Inputs from rivers and streams.

Despite these existing potential sources of contamination in the PAOI, ambient nutrient, metal, metalloid and hydrocarbon concentrations all meet water quality guidelines for the protection of aquatic ecosystems (see Section 8.4).

12.2.2 Discipline-specific Impact Assessment Method

The significance assessment approach described in Chapter 3 was used to characterize impacts to marine water quality. The magnitude and sensitivity descriptors used to assess impacts to marine water quality are the same as used for the assessment of impacts to marine physical and sediment processes (see Section 12.1.2).

Consideration was also given to the following standards and guidelines, as relevant to water quality:

- *Papua New Guinea Environment (Water Quality Criteria) Regulation 2002 (Water Quality Regulation),* applicable to ambient waters for the protection of aquatic ecosystems.
- Emission limit values for discharge water quality provided by:
  - TOTAL General Specifications, Environmental Requirements for Projects Design and E&P Activities (GS EP ENV 001).
  - International Finance Corporation Environmental, Health and Safety guidelines (IFC, 2007, 2015).
  - International Convention for the Prevention of Pollution from Ships 1973, as amended by the Protocol of 1978 (MARPOL 73/78).

12.2.3 Identification of Potential Impacts

Potential impacts to marine water quality processes can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

12.2.3.1 Planned Wastewater Discharges

Planned discharges to the marine waters of the PAOI have the potential to contaminate marine waters. Controlled Project-related discharges to the marine environment may include:

- Hydrotest waters.
- Sewage, grey water, ballast and bilge discharges from Project vessels.

As described in Section 4.10.6, pipeline hydrotesting will be undertaken to confirm the weld integrity following pipeline installation. Hydrotest water will contain a small amount of an oxygen scavenger, such as sodium bisulfite, to inhibit corrosion, and a biocide to prevent bacteria developing.

The hydrotest water discharge location will be defined during FEED and options may include the Purari River, Orokolo Bay or Caution Bay. The total volume of the offshore export pipelines is 220,000 m^3 and the hydrotest water volume will be similar to the pipeline volume. The hydrotest water discharge rate will depend on the dewatering train capacity but would typically be 15 to 23 m^3/minute. Consequently, discharge could take six to ten days from one or more discharge lines. Discharge will be undertaken according to applicable requirements.

Project vessels will discharge ballast waters, domestic wastewaters (i.e., sewage and grey water) and bilge waters. These wastewater discharges may contain elevated nutrient levels, which can degrade the water quality of receiving waters. Sewage discharges may also contain pathogens including *Escherichia coli* (*E. coli*), Salmonella and fecal coliforms. Bilge waters can be expected to contain high hydrocarbon concentrations.

The following embedded design controls address these potential impacts:

- Chemical use will be minimized, and selection of chemicals will be made considering lowest toxicity, lowest bioaccumulation potential, highest biodegradation and bans or phase-outs [ED006].
- Ballast waters, liquid effluents and waste from vessels will be managed according to MARPOL 73/78 requirements [ED022].

12.2.3.2 Accidental Contaminant Releases

The assessment relates only to spills or leaks that are typically incidental (but controllable) as part of construction and operation of large projects. Major accidental spills from unplanned events (e.g., bunker rupture from vessel collisions or groundings, or pipeline rupture) are considered in Chapter 18.

Hydraulic fluids, lubricants, oil, petrol, diesel and miscellaneous chemicals will be used in the Project construction and operation phases and could be accidentally spilt or leaked into the marine environment from Project vessels, e.g., during vessel refueling. The volumes of such spills are typically small, particularly in the context of the large dilution factor of the marine environment.

Condensate or gas leaks may also potentially occur if there are faulty joins in the offshore export pipeline. The potential for such leaks to occur will be avoided by the hydrotesting that will be undertaken prior to commissioning the pipeline.

Contaminants released from accidental releases have the potential to degrade water quality, with the potential for environmental harm dependent on various factors including:

- Contaminant type and volume.
- Sensitivities of the receiving environment, with nearshore environments containing coral, mangroves, seagrass and other high value habitats being more sensitive than open waters remote from sensitive receptors.
- The dispersal characteristics of the receiving waters.

Aside from accidental leaks from the offshore export pipeline, spills and leaks are more likely to occur during the construction phase rather than the operations phase, as larger volumes of equipment and materials will be used and more activities will occur in the marine environment during this phase.

The following embedded design controls address these impacts:

- Minimization of chemical use and selection of chemicals considering lowest toxicity, lowest bioaccumulation potential, highest biodegradation and bans or phase-outs [ED006].
- Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as:
  - Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan.
  - Building infrastructure on impervious surfaces where required
  - Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials.
  - Installing interceptor pits or similar to collect contaminated surface water runoff and treat where required.
  - Installing tanks above ground with impermeable liners and bunds around tanks.
  - Regularly inspect and maintain the containers, storage and transfer infrastructure to prevent/control spills or leaks.
  - Installing readily accessible spill kits and training staff in their use.
  - Appropriately treating and disposing of any accidentally contaminated soils. [ED003].
- Management of ballast waters, liquid effluents and waste from vessels according to MARPOL 73/78 requirements [ED022].
- The gathering and reinjection system, wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational controls (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring) [ED011].
- Hydrotesting will be undertaken to confirm weld integrity [ED012].

12.2.3.3 Summary of Potential Impacts to Marine Water Quality

Potential impacts on marine water quality due to Project activities that have been considered in the residual impact assessment are as follows:

- Deterioration in marine water quality due to planned wastewater discharges, including hydrotest water, domestic wastewater and bilge water.
- Deterioration in marine water quality due to accidental releases of hydrocarbons and chemicals.

12.2.4 Proposed Mitigation and Management Measures

Table 12.7 describes mitigation and management measures to further reduce impacts marine water quality from planned wastewater discharges and accidental contaminant releases. Mitigation and management in Caution Bay in the lease area for the PNG LNG Project will be further aligned with the PNG LNG Project and the downstream Papua LNG Project.

Table 12.7 – Marine Water Quality Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Deterioration in marine water quality due to planned wastewater discharges	♦ Sewage effluents from Project facilities will be treated to meet the environment (waste discharge) permit before discharge, in accordance with applicable standards. [EM008]. ♦ Hydrotest water management will consider: – The definition of volume and discharge rates and discharge locations. – Chemical additive selection, according to requirements defined in embedded design controls. – Reusing hydrotest water to minimize the discharge volume. – Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. – Monitoring hydrotest water discharges to the environment against applicable limits. [EM015]	Water Management Plan
Deterioration in marine water quality due to accidental releases of hydrocarbons and chemicals	♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site Contingency Plans, that will consider fire management measures – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018]. ♦ Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and *Marine Pollution (Ships and Installations) Act 2013* [EM019].	Emergency Response Plan

12.2.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to marine water quality subject to the embedded design controls in Section 12.2.3 and the successful implementation of the mitigation and management measures in Section 12.2.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

12.2.5.1 Planned Discharges of Wastewaters

Hydrotest waters discharges will be monitored and managed according to applicable limits. Rapid dispersion of discharges would occur given the large assimilative capacity of the open waters of the gulf. The magnitude of any impact to water quality is therefore expected to be ***Minimal***, with minor impacts occurring over a localized area (i.e., up to 500 m) for a short duration and the aquatic ecosystem health is maintained.

The marine waters of the PAOI are considered to have a ***Medium*** sensitivity since; although, they are in a near-natural condition with environmental benchmarks met (e.g., complying with water quality criteria in *Papua New Guinea Environment (Water Quality Criteria) Regulation 2002 (Water Quality Regulation),* it is an environment that is well represented in the broader gulf and there is large assimilative capacity with regard to water quality. The residual impact significance is therefore ***Negligible.***

12.2.5.2 Accidental Releases

In the unlikely event that accidental spills do occur, impacts are likely to be localized due to low contaminant volumes typically released by incidental spills and leaks. Impacts to water quality are expected to be short-term (i.e., days to weeks) after applying appropriate spill prevention, containment and cleanup measures; however, the severity of the impacts to water quality may be moderate depending on the nature of the contaminant, having slight to moderate impacts on the environmental values of the impacted area. The magnitude of impact is therefore considered to be ***Low.***

Hydrotesting, monitoring and maintaining the offshore export pipelines will limit the occurrence and extent of any condensate or gas leaks. The condensate is hydrophobic, lighter than water and has high volatility, and therefore can be expected to diffuse and disperse up through the water column to evaporate into the atmosphere. Any gas leaks would also evolve to the atmosphere. Impacts to water quality are expected to be minor if a leak from a pipeline join was to occur, extending over a highly localized area and for a short period (much less than a year). The magnitude of impact from such leaks is therefore also considered to be ***Low.***

As described in Section 12.2.5.1, the marine waters of the PAOI are considered to have a ***Medium*** sensitivity; hence the residual impact significance for impacts on marine water quality due to accidental releases of contaminants is ***Minor.***

12.2.6 Summary of Residual Impacts to Marine Water Quality

A summary of the assessment of residual impacts related to marine water quality is provided in Table 12.8, including in which Project phase and location these impacts are expected to occur. The table should be read with the mitigation measures provided in Table 12.7.

Residual impacts to marine water quality due to planned wastewater discharges and accidental contaminant releases from Project activities are assessed to be ***Negligible*** or ***Minor.***

Table 12.8 – Summary of Assessment of Residual Impact Significance for Marine Water Quality

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Planned wastewater discharges	Controlled discharges of hydrotest water, vessel domestic wastewater and bilge water.	Deterioration in marine water quality	Orokolo Bay, offshore export pipeline route and Caution Bay	C, O	♦ EM008 ♦ EM015	Medium/Minimal	Negligible
Accidental releases of hydrocarbons and chemicals	Spill or leak of hydrocarbons and chemicals from vessels.	Deterioration in marine water quality	Orokolo Bay, offshore export pipeline route and Caution Bay	C, O, D	♦ EM018 ♦ EM019	Medium/Low	Minor
	Leaks of condensate or gas from pipeline joins.	Deterioration in marine water quality	Orokolo Bay, offshore export pipeline route and Caution Bay	O	None	Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure.

12.3 Marine Biodiversity

12.3.1 Context

The marine PAOI includes several marine ecosystem types and habitats. In order of largest to smallest spatial extent, these are:

- Pelagic (open water) environments.
- Unconsolidated sediment habitat (i.e., beach, nearshore coastal and offshore).
- Coral and rocky reefs.
- Seagrass meadows.

Most of the PAOI consists of unconsolidated soft sediment habitat comprising muds and sands. This includes most of Orokolo Bay and the offshore export pipeline route. Water depths extend to 100 m. Deeper offshore waters associated with the continental shelf provide pelagic habitat for oceanic fauna species.

There is a single rocky reef identified at Orokolo Bay, south of the Vailala River mouth. This reef supports a mixed assemblage of filter-feeding soft corals, sponges, ascidians and echinoderm species that are exposed to periodic high turbidity and low salinity conditions.

Coral reefs occur in Caution Bay. Reef types represented in Caution Bay are: (i) barrier reefs between Vari Vari and Idihi islands; (ii) fringing reefs which extend along the coast; and (iii) smaller patch reefs and atolls between the barrier reef and coast. The barrier reefs have higher coral cover than nearshore (fringing) reefs and are in an undisturbed condition (i.e., there is no evidence of anthropogenic impacts or natural disturbance). The most abundant hard coral genera for these reefs are *Acropora*, *Montipora* and *Porites*. Human disturbances, particularly fishing practices that use explosives, have adversely affected fringing reefs; however, they appear to be recovering, which is attributed to a reduction in these fishing practices.

Seagrass meadows occur in Caution Bay between the fringing reef and shoreline, and comprise *Enhalus acoroides*, *Syringodium isoetifolium* and *Cymodocea* spp. A large but sparse seagrass meadow also occurs in the northern embayment of the bay (east of Redscar Head), comprising *Halophila* spp.

The Caution Bay coastline has a strip of mangroves extending 7 km along the coast and up to 1 km wide, in the vicinity of the PNG LNG Facilities.

The PAOI supports habitat for a wide variety of marine and estuarine fauna species, including several sensitive marine species, i.e., threatened species, near threatened species, species of high fisheries significance or other listed species under Papua New Guinean legislation or the IUCN Red List.

Orokolo Bay supports the narrow sawfish (*Anoxypristis cuspidata*) which has been identified recently (based on villager catch), and other species (e.g., threatened sawfish and river shark species) may also occur there. Positive sighting of other fish species in this area include the Endangered winghead shark (*Eusphyra blochii*) and the endemic Papua seerfish (*Scomberomorus multiradiatus*), both known from the catches of Orokolo Bay villagers. Additionally, Orokolo Bay may support other threatened shark and ray species (e.g., *Carcharhinus leucas*, *Hemiscyllium hallstromi*, *Glaucostegus typus*, *Aetobatus narinari*, *Epinephelus fuscoguttatus*, *Scomberomorus commerson*). The migratory saltwater crocodile (*Crocodylus porosus*) is known to occur in the Purari River and is likely to be present in Orokolo Bay.

Coastal and oceanic shark and fish species are also likely to occur in Caution Bay, with the Near Threatened hardnose shark (*Carcharhinus macloti*) confirmed during Project baseline surveys. The seagrass and coral reef habitat in Caution Bay may also support threatened marine turtle species (*Chelonia mydas*, *Caretta caretta*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, *Natator depressus*), the Vulnerable reef manta ray (*Manta alfredi*) and the Near Threatened guinea’s sea krait (*Laticauda guineai*), although none of these species have been confirmed to be present. The most likely of the marine turtles to occur in Caution Bay is the Vulnerable green turtle, with a mapped aggregation area located north of Caution Bay.

Dolphin species occur across the Gulf of Papua, including species known to occur in nearshore waters. The most likely species in the PAOI consist of the migratory but not threatened common bottlenose (*Tursiops truncatus*), Indo-Pacific bottlenose (*T. aduncus*), spinner (*Stenella longirostris*), pantropical spotted (*S. attenuata*) and short-beaked common (*Delphinus delphis*) dolphins, the Near Threatened Australian snubfin (*Orcaella heinsohni*) and vulnerable Australian humpback (*Sousa sahulensis*) dolphins. Dugongs (*Dugong dugon*) could possibly occur but are unlikely based on lack of recent sightings in the gulf.

Important fishery species in the PAOI include the ornate rock lobster (*Panulirus ornatus*) which is part of the tropical rock lobster fishery and a known migratory species. The rock lobster migrates from Torres Strait through the Gulf of Papua to breeding grounds at Yule Island located east of the offshore export pipeline route, approximately 75 km northwest of Caution Bay (see Figure 8.27).

Other significant fishery species include prawns which are commercially harvested by the Gulf of Papua Prawn Fishery. Prawn species include banana, tiger and endeavor prawns, which occur throughout the water column from nearshore to the edge of the continental shelf. These species rely on mangroves as nursery habitat. Based on historical fishing records, sea cucumbers (bêche-de-mer) are expected to occur in nearshore habitats at Orokolo Bay and Caution Bay, and include a variety of IUCN listed threatened species. Overfishing has led to closure of the commercial bêche-de-mer fishery.

All these species differ in their habitat requirements. Seagrass and coral reef habitats represent preferred high value habitat for many species of turtle, dolphins, dugong, rays, fish and snakes. Turbid waters near the coastline and mangroves of Orokolo Bay and the Purari River delta represent potential high value habitat for sawfish, river sharks and crocodiles. Soft sediment habitats and pelagic waters also represent habitat or fauna movement corridors for species (e.g., lobsters, mackerel and rays) that prefer reef and seagrass habitats.

Few invasive or introduced species have been documented in Papua New Guinea; however, many of the reef-associated species of northern Australia and the Great Barrier Reef are common to Papua New Guinea. Current marine pests of northern Australia include the Asian green mussel (*Perna viridis*) and Caribbean tubeworm (*Hydroides sanctaecrucis*). *Acanthaster planci* (crown-of-thorns seastar), although native to the Indo-Pacific reefs, can be considered an invasive species when in high abundance and can devastate coral reefs.

12.3.2 Discipline-specific Impact Assessment Method

The significance assessment approach described in Chapter 3 was used to characterize impacts to marine biodiversity. Magnitude and sensitivity descriptors used to assess impacts to marine biodiversity are presented in Table 12.9 to 12.11. The assessment is a function of the magnitude[4]

4 Magnitude is assessed considering combinations of (1) geographic extent and (2) the higher of severity and duration.

of impact on a resource or receptor and the sensitivity of that resource or receptor. Together, they determine the significance of the residual impact as shown Table 12.12.

The impact assessment assumes that the pipeline will be trenched at water depths less than 20 m below lowest astronomical tide (LAT)[5] and that the trench disturbance corridor will be 6 m wide. Assessment of impacts considers potential direct and indirect impacts to habitats and species.

Table 12.9 – Impact Magnitude Descriptors Relevant to Marine Biodiversity

Geographic Extent of Impact*		Severity and Duration of Impact		
		Severity		Duration
5	Impact to ♦ >15% of an ecosystem’s or habitat type’s range in the region; or ♦ >10% of a species’ distribution in the subregion.	5	Impact to habitat, ecosystem or species that: ♦ Is very large or severe relative to natural variability; or ♦ Severely reduces ecosystem viability in the affected area; or ♦ Causes a significant change in the ecosystem community composition, including functional loss of keystone species and potentially leading to ecosystem collapse; or ♦ Causes a very large decline in a species population that threatens the viability of a subregional population and/or that may threaten the viability of the regional population.	Impact lasts >30 years
4	Impact to ♦ 5 to 15% of an ecosystem’s or habitat type’s range in the region; or ♦ 5 to 10% of a species’ distribution in the subregion.	4	Impact to habitat, ecosystem or species that: ♦ Is large relative to natural variability; or ♦ Reduces ecosystem viability in the affected area; or ♦ Causes a loss or decline of multiple species populations that alters the composition and may reduce the viability of ecosystem communities or keystone populations; or ♦ Causes a large decline in a species population that may threaten the viability of a subregional population.	Impact lasts 5 to 30 years
3	Impact to: ♦ <5% of an ecosystem’s or habitat type’s range in a region; or ♦ 1 to 5% of a species’ distribution in a subregion.	3	Impact to habitat, ecosystem or species that: ♦ Is moderate and readily detectable with respect to natural variability; or ♦ May reduce ecosystem viability in the affected area; or ♦ Causes a decline of multiple species populations, with moderate changes to community composition that is unlikely to reduce the viability of ecosystem communities or keystone populations; or ♦ Causes a moderate decline in the population of a species that is unlikely to threaten the viability of a subregional population.	Impact lasts <5 years
2	Impact to: ♦ <1% of a species’ distribution in a subregion ♦ Any environmental feature in a localized area.	2	Impact to habitat, ecosystem or species that: ♦ Is low and marginally detectable with respect to natural variability, and readily able to regenerate on remaining habitat; or ♦ Causes a minor decline in one or more species populations; although with no detectable change in the composition or viability of ecosystem communities and populations; or ♦ Causes a minor decline that does not threaten the viability of a subregional population.	Impact lasts <1 year

5 Trenching to a water depth of -15 m LAT was adopted for sediment plume modeling studies to assess impacts due to trenching (see Section 12.1), based on information available during the modeling. The extension of trenching to a water depth of -20 m LAT is not expected to cause additional sedimentation impacts to high-value habitat such as seagrass and corals, as these are not found along this extended section of the alignment. The modeling outputs are considered sufficient to assess impacts due to sediment plumes and sedimentation due to trenching.

Table 12.9 – Impact Magnitude Descriptors Relevant to Marine Biodiversity (cont'd)

<table>
<tr><th colspan="2" rowspan="2">Geographic Extent of Impact*</th><th colspan="3">Severity and Duration of Impact</th></tr>
<tr><th colspan="2">Severity</th><th>Duration</th></tr>
<tr><td>1</td><td>Impact to any environmental feature in a highly localized area.</td><td>1</td><td>Impact to habitat, ecosystem or species that:
♦ Is very low and undetectable with respect to natural variability; or
♦ Causes no measurable decline in a species population.</td><td>Impact lasts days to weeks</td></tr>
</table>

Region = Area greater than 20,000 km^2 (being approximately 25% of the Gulf of Papua ecoregion (~75,000 km^2) and approximately 10% of the Southeast Papua New Guinea ecoregion (~225,000 km^2)).
Subregion = Area more than 2 km from the Project footprint but less than 20,000 km^2.
Localized = Area up to 2 km from the Project footprint.
Highly localized = Area up to 0.5 km from the Project footprint.

Table 12.10 – Impact Magnitude Matrix Relevant to Marine Biodiversity

Severity/ Duration	Geographic Extent				
	1	**2**	**3**	**4**	**5**
1	Minimal	Low	Medium	Medium	High
2	Low	Low	Medium	High	High
3	Low	Medium	High	Very High	Very High
4	Medium	Medium	High	Very High	Very High
5	Medium	Medium	Very High	Very High	Very High

Table 12.11 – Receptor Sensitivity Descriptors Relevant to Marine Biodiversity

Rating	Descriptor – Ecosystems and Habitats	Descriptor – Species
Very High	♦ Ecosystem or habitat supports IUCN Critically Endangered species (or equivalent based on expert opinion). ♦ Ecosystem or habitat is critical to the survival of a species. ♦ Ecosystem or habitat is unique or very rare locally and regionally.	♦ IUCN Critically Endangered species. ♦ Lower-listed IUCN species whose true conservation status is likely to be equivalent to IUCN Critically Endangered at the national or global scale, according to expert opinion. ♦ Endemic or restricted-range species with very low abundance in the area of occurrence.
High	♦ Ecosystem or habitat supports high or regionally important concentrations of conservation-listed species (or equivalent based on expert opinion) or endemic or restricted-range species. ♦ Ecosystem or habitat supports a unique assemblage or high proportion of habitat specialist species. ♦ Ecosystem or habitat is of local or regional importance for migratory species. ♦ Ecosystem or habitat is in a protected area. ♦ Ecosystem or habitat is unmodified. ♦ Ecosystem or habitat is rare locally and regionally with limited connectivity to comparable ecosystems or habitats.	♦ IUCN Vulnerable or Endangered species. ♦ Lower-listed IUCN species whose true conservation status is likely to be equivalent to IUCN Vulnerable or Endangered at the national or global scale, according to expert opinion. ♦ Endemic or restricted-range species with low abundance in the area of occurrence. ♦ Species that are highly adapted habitat specialists.
Medium	♦ Ecosystem or habitat supports viable assemblages of native flora and fauna species that are largely unaltered from their original composition; conservation-listed species may be present. ♦ Ecosystem or habitat has not been significantly modified in terms of primary ecological functions and composition.	♦ Species Protected under the *Fauna (Protection and Control) Act 1966.* ♦ CITES Appendix I species. ♦ IUCN Near Threatened species. ♦ IUCN Data Deficient, Not Evaluated or Least Concern species whose true conservation status is likely to be equivalent to IUCN Near

Table 12.11 – Receptor Sensitivity Descriptors Relevant to Marine Biodiversity (cont'd)

Rating	Descriptor – Ecosystems and Habitats	Descriptor – Species
Medium (cont'd)	♦ Ecosystem or habitat has several local and regional equivalents with some connectivity to comparable ecosystems or habitats.	Threatened at the national or global scale according to expert opinion. ♦ Endemic or restricted-range species with moderate to high abundance in the area of occurrence. ♦ Species that are habitat specialists but able to occur in other marginal habitats. ♦ Fish or macrocrustacean species of fisheries significance.
Low	♦ Ecosystem or habitat supports viable assemblages of some native species, but flora and fauna communities are significantly altered from their original composition found elsewhere locally; invasive species may be present. ♦ Ecosystem or habitat is subject to some degradation. ♦ Ecosystem or habitat is common locally and regionally with moderate connectivity to other comparable ecosystems or habitats.	♦ CITES Appendix II species. ♦ IUCN Least Concern species. ♦ IUCN Data Deficient or Not Evaluated species considered common or widespread according to expert opinion.
Minimal	♦ Ecosystem or habitat supports few or no native species, or invasive species are prevalent. ♦ Ecosystem or habitat is highly degraded. ♦ Ecosystem or habitat is common and widespread locally, regionally and nationally, and has high connectivity to other comparable ecosystems or habitats.	♦ Native species well adapted to habitat loss or degradation. ♦ Invasive species.

Table 12.12 – Impact Significance Assessment Matrix Relevant to Marine Biodiversity

Magnitude of Impact	Sensitivity of Receptor				
	Very High	**High**	**Medium**	**Low**	**Minimal**
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

Areas of direct habitat loss or disturbance have been calculated based on mapped areas of sensitive receptor habitat, i.e., coral reef and seagrass. These sensitive habitat types are limited to Caution Bay in the PAOI. The offshore export pipeline route intersects several unsurveyed areas in Caution Bay. Any reefs in these areas have been excluded in calculations except where habitat can be inferred based on adjacent surveyed areas. LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS, however indicative information is presented here; that will be refined as part of the downstream Papua LNG EIS.

The impact assessment also considers results from numerical modeling undertaken to predict increases in suspended sediment concentrations and sedimentation on the seabed due to the proposed trenching works (Section 12.1).

Ecological impacts associated with Project-generated TSS and sedimentation due to trenching were assessed using the outputs from the predictive numerical model to present impact predictions as 'zones of impact'. The 'zones of impact' approach is recognized as good international industry practice in dredging environmental assessments and is commonly used in environmental assessments of dredging projects in Australia, based on approaches described in dredging environmental assessment guidelines produced by the Western Australia Environmental Protection Agency (WA EPA, 2016). This approach provides additional quantitative data to assess the geographic extent and severity of impacts according to the descriptors in Table 12.9.

The zones adopted for the assessment are illustrated in Figure 12.10 and include the following:

- Zone of high impact: Predicted mortality of ecological receptors with recovery time greater than 24 months.
- Zone of moderate impact: Predicted degradation, harm or injury to ecological receptors or mortality with recovery or recolonization between six months (lower end of range) to 24 months (upper end of range).
- Zone of influence: Extent of detectable[6] plume, but no predicted ecological impacts.

The recovery times outlined for the various zones should are indicative only; life history parameters and ecological responses to pressures are unknown for all species, making recovery times difficult to accurately predict.

Deriving the impact zones requires selecting thresholds related to the increase in TSS and sediment deposition due to trenching. TSS threshold values used in the impact assessment are based on thresholds developed for low turbidity offshore waters in Western Australia (DHI, 2010) and Queensland (AECOM and BMT WBM, 2016). These threshold values are presented in Tables 12.13 and 12.14.

Considering the short duration of the trenching campaign, the most appropriate thresholds for impact assessment are the median case (50th percentile) thresholds for the increase in TSS (as higher thresholds represent extremely short duration spikes) and the final sediment deposition case. These values are shown in bold in Tables 12.13 and 12.14.

Table 12.13 – Impact Thresholds for Total Suspended Solids

Impact Zone	Total Suspended Solids (mg/L) Thresholds Above Background			
	20th Percentile	50th Percentile	80th Percentile	95th Percentile
Zone of high impact	5	**10**	25	NA
Zone of moderate impact	2	**5**	10	NA
Zone of influence	NA	**1**	5	10

Note: Threshold values are based on thresholds developed for low turbidity offshore waters in Western Australia (DHI, 2010) and Queensland (AECOM and BMT WBM, 2016). Values are increases above background levels. NA: Not applicable; threshold is not reached for the length of time necessary to cause an impact.

6 Detectable plume means being detectable above background conditions by instrumentation deployed in the water column.

CONCEPT DESIGN OF IMPACT ZONES

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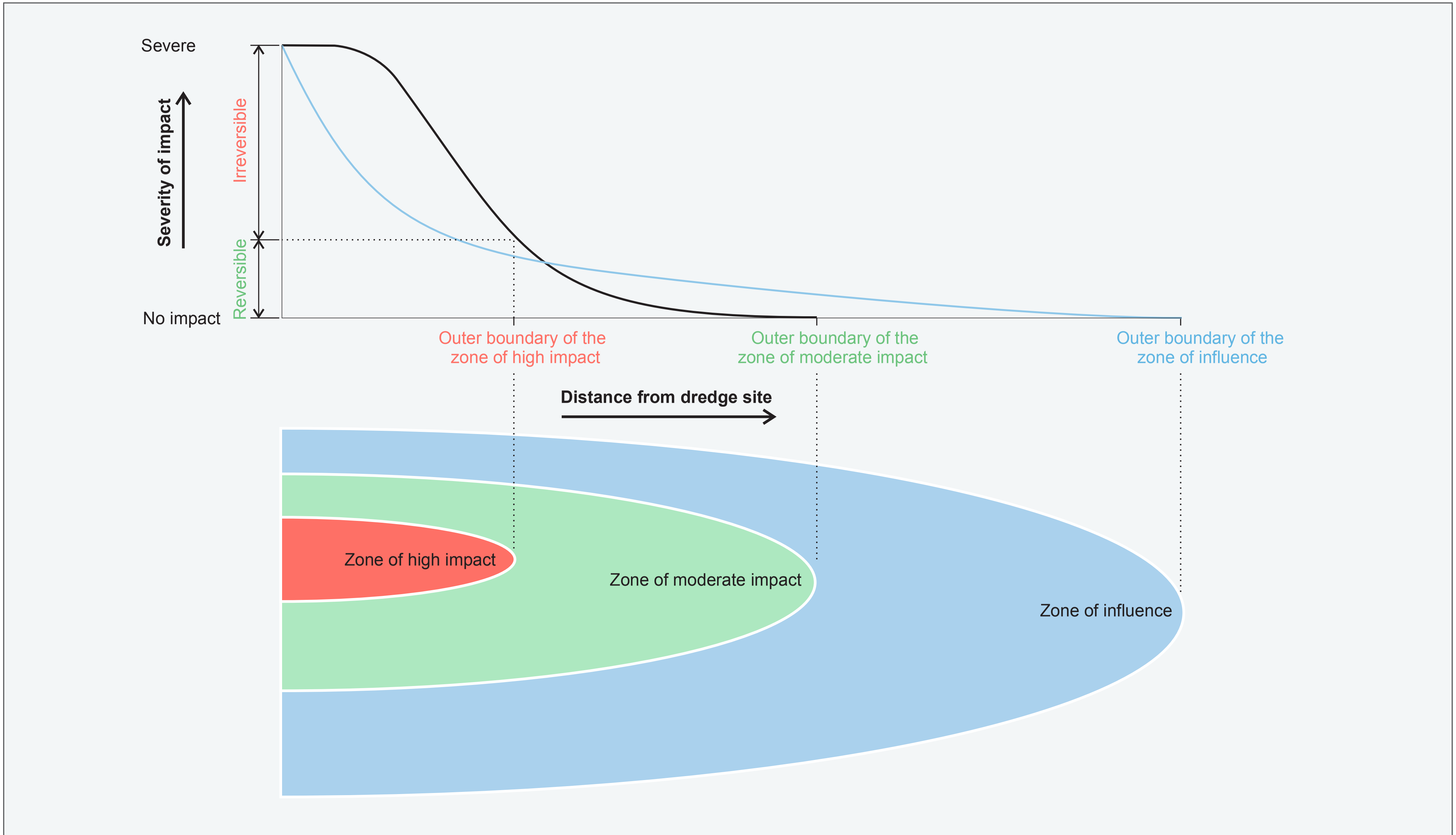
FIGURE 12.10



Source: WA EPA, 2016

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Table 12.14 – Impact Thresholds for Sediment Deposition

Impact Zone	50th Percentile i.e., 15 days per month ($mg/cm^2/day$)	95th Percentile i.e., 1.5 days per month ($mg/cm^2/day$)	Final Deposition (mg/cm^2)
Zone of high impact	>70	>700	**>700**
Zone of moderate impact	20 to 70	200 to 700	**200 to 700**
Zone of influence	3 to 20	30 to 200	**30 to 200**

Note: Threshold values are based on thresholds developed for low turbidity offshore waters in Western Australia (DHI, 2010) and Queensland (AECOM and BMT WBM, 2016). Values are increases above background levels.

12.3.3 Identification of Potential Impacts

Potential impacts to marine biodiversity can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

12.3.3.1 Loss or Disturbance of Benthic Habitat and Marine Fauna from Trenching and Pipelaying

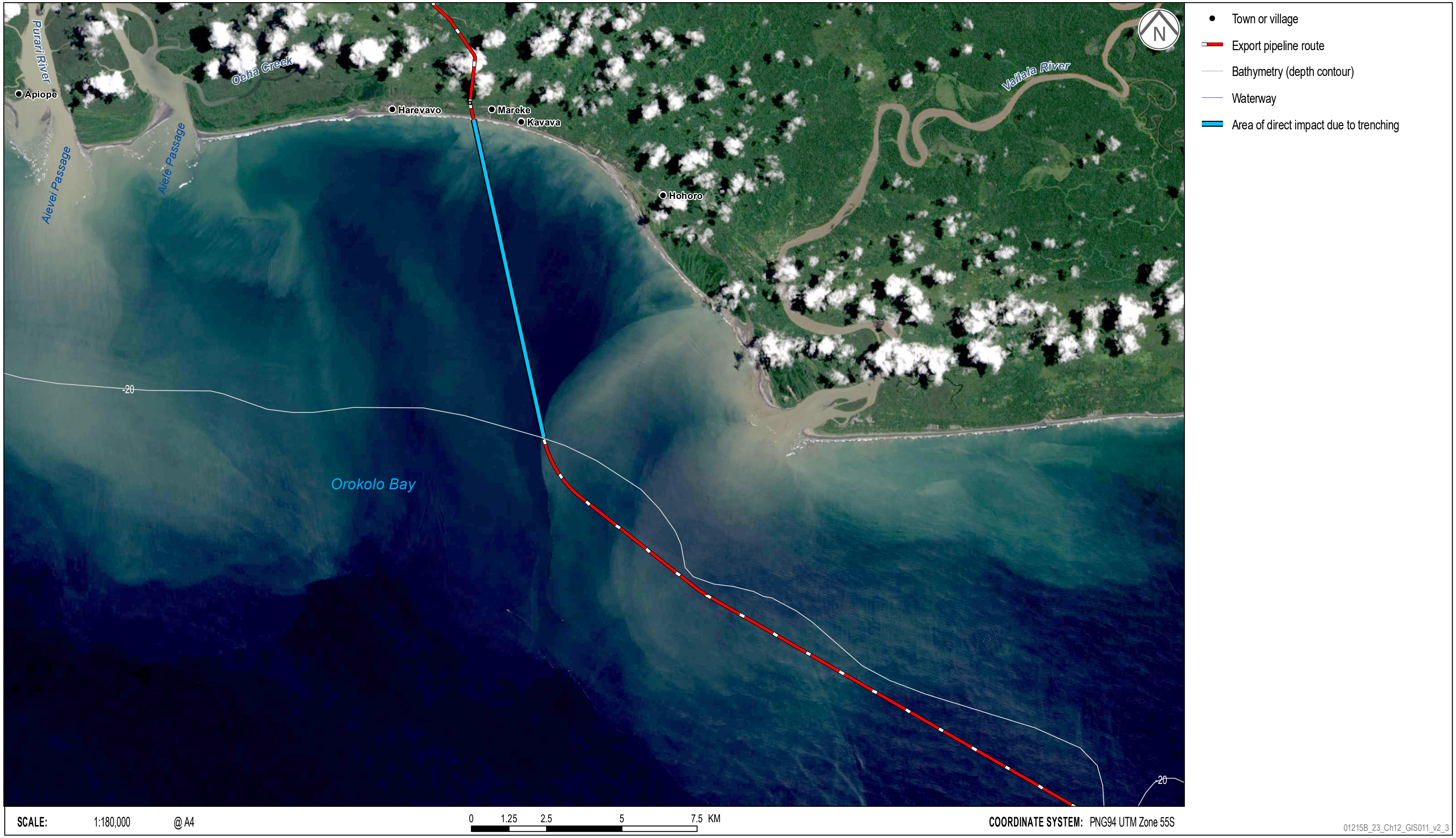
Benthic Habitat

Trenching and pipelaying will directly remove or bury benthic habitat. Figures 12.11 and 12.12 show the extent and location of benthic habitats directly disturbed by pipeline trenching in Orokolo Bay and Caution Bay, respectively. Habitats directly disturbed by trenching are soft sediments in Orokolo Bay and soft sediments, coral reef and seagrass meadows in Caution Bay. Caution Bay (Figure 12.12) benthic habitats are shown based on sidescan sonar transect readings, interpolated acoustic habitat mapping and historical nearshore habitat mapping (see Section 8.5). The actual extent of impacts due to removing or burying benthic habitat may differ slightly from mapped amounts for this area following more detailed survey of a finalized route. No changes to predicted impacts are expected in Orokolo Bay due to the absence of sensitive benthic habitats (i.e., seagrass and coral reef) in this area.

The areas of benthic habitat removal due to trenching are described in Table 12.15, based on a trench width of 6 m. Habitats directly disturbed by trenching are unconsolidated sediments in Orokolo Bay and unconsolidated sediments, coral reef and seagrass meadows in Caution Bay. Trenching is not proposed to occur in waters deeper than -20 m LAT, where the pipeline will be laid on the seafloor. Pipelaying in these waters deeper than -20 m LAT between Orokolo Bay and Caution Bay will also cause the direct loss of unconsolidated soft sediment habitat for benthic fauna in addition to that shown in Table 12.15, which considers habitat loss from trenching only. Losses of this habitat type will be the highest of all marine habitats found in the PAOI; however, this habitat type is also the most widespread in the PAOI and more broadly in the Gulf of Papua and is considered a low value habitat. The impact to unconsolidated soft sediment habitat due to pipelaying is therefore considered insignificant and is not further assessed in the residual risk assessment. The residual impacts to the high value seagrass and coral reef habitats, and marine fauna, are assessed in Section 12.3.5.

OROKOLO BAY PIPELINE ALIGNMENT AND AREAS OF DIRECT IMPACT

FIGURE 12.11



Source: Figure theme data from Part 4 of Volume 3.

CAUTION BAY PIPELINE ALIGNMENT AND AREAS OF DIRECT IMPACT

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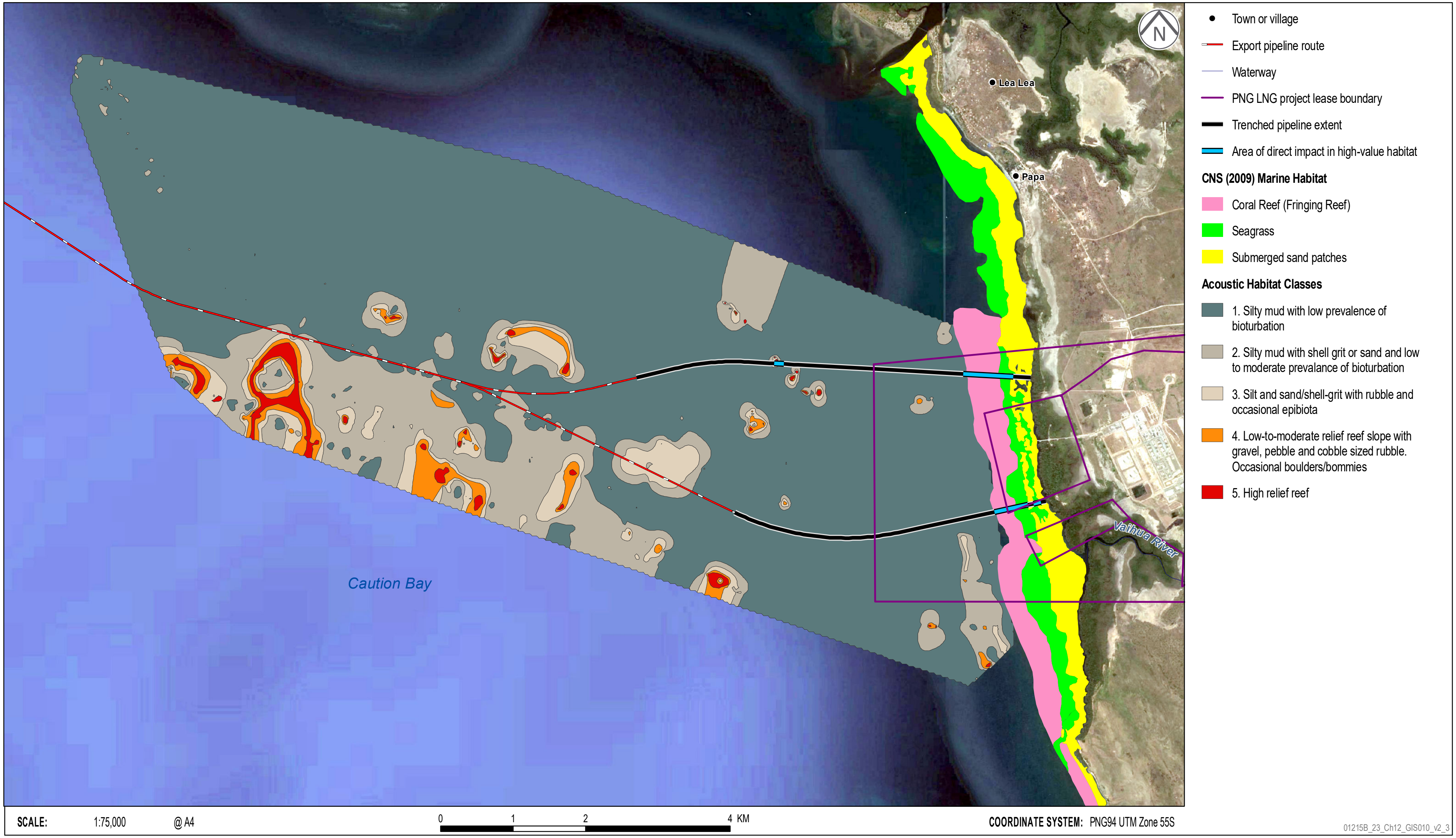
FIGURE 12.12



Source: Figure theme data from Part 4 of Volume 3.

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Table 12.15 – Benthic Habitat Directly Removed by Trenching

Benthic Habitat Type	Orokolo Bay	Caution Bay	
		Southern Alignment	Northern Alignment
Seagrass (High-value Habitat)			
Linear distance (m)	0	300	200
Area of disturbance (m^2)	0	1,800	1,200
Total area of seagrass habitat in Caution Bay (m^2)	0	2,175,000	
Approximate loss of seagrass habitat in Caution Bay (%)	0	0.08	0.06
Coral Reef (High-value Habitat)			
Nearshore fringing reef linear distance (m)	0	280	500
Isolated bombora linear distance (m)	0	0	200
Area of coral reef disturbance (m^2)	0	1,680	4,200
Total area of coral reef habitat (fringing and bombora reefs) in Caution Bay (m^2)	0	5,140,000	
Approximate loss of coral reef habitat in Caution Bay (%)	0	0.03	0.08
Unconsolidated Sediment (Low-value Habitat)			
Seabed – linear distance (m)	10,800	3,820	4,600
Seabed – total area (m^2)	64,800	22,920	27,600
Approximate loss of unconsolidated sediment habitat (%)	<1	<1	<1
Total Habitat Loss (m^2)	**64,800**	**26,400**	**33,000**

Marine Fauna

Trenching will cause the mortality of small invertebrates such as mollusks, worms, and crustaceans living in or on the seabed. Trenching in Caution Bay is also likely to directly remove larger sessile invertebrates such as soft corals and sponges. Highly motile fauna such as fishes and mobile invertebrates, such as lobsters, are expected to be able to evade the dredge.

Indirect impacts may also potentially occur to other marine fauna, due to changes to benthic habitats and assemblages in the trenching footprint causing localized changes to food and habitat resource availability. These impacts could include increased feeding competition and associated health issues for species that depend on benthic fauna for feeding. The occurrence of flow-on effects to other fauna groups (e.g., fish, turtles and dugongs) largely depends on:

- The spatial scale of the impact relative to the total area of habitat available. The total extent of habitat removed is very small relative to the extent of available habitat, even at localized spatial scales (i.e., in Orokolo and Caution bays) (see Table 12.15). None of the affected areas are known or expected to support unique or otherwise critical food or habitat resources at a local scale, based on habitat assessments.
- Recovery timeframes for habitat and food resources. Soft sediment benthic fauna are expected to commence recovery within weeks (see case studies in Wilber and Clarke, 2007), while some seagrass species could take years to recover following disturbance (see Cabaco et al., 2008). Coral recolonization is expected to take five to 10 years (Erftemeijer et al., 2012).

Mobile fauna are predicted to temporarily avoid disturbed areas during the recovery period. This is expected to cause highly localized changes in foraging patterns until such times as benthic communities recolonize the disturbed area. It is highly unlikely that detectable flow-on effects to local fauna populations outside the disturbance footprint will occur, given the small extent of habitat disturbance relative to available habitat.

Pipelines will be laid on the seafloor in waters deeper than -20 m LAT, directly smothering benthic fauna under the pipeline. It is expected that fish, sea turtles and other motile organisms would have the capacity to evade the pipeline. It is possible some motile benthic fauna could evade the pipeline placement, but it is expected that infauna directly in the pipeline footprint will be lost, with benthic fauna recovering within months for most benthic communities. This impact to benthic fauna from pipeline installation is considered insignificant given the widespread availability of similar habitats that support similar benthic faunal assemblages in the Gulf of Papua, and this impact is not further assessed in the residual impact assessment.

12.3.3.2 Pipeline Barrier to Marine Fauna Movements

Over time, the pipelines are expected to settle in areas of soft unconsolidated sediments, but the pipeline is likely to protrude above the seafloor up to a height of 40 inches, excluding the concrete collar. Benthic fauna are the species most likely to interact with the exposed pipeline.

The pipelines are not expected to affect fish, ray and sawfish movements, as they are strong swimmers.

Prawns migrate seasonally out of the Purari River delta into the coastal zone and subsequently out to the deeper waters of the continental shelf during the northwest monsoon season from December to March. Penaeid prawns are the primary species of this area and are known to be active swimmers (Zhang et al., 2006; Kenyon et al., 2004; Watson and Turnbull, 1993). The export pipeline route leaves the shoreline east of the Purari River delta perpendicular to the coast, and is therefore unlikely to present a barrier to prawns migrating from inshore waters to the deeper waters of the gulf. Additionally, these prawns are expected to swim over the pipeline if encountered. As such, the pipeline is unlikely to restrict prawn movements and is not considered further in the residual impact assessment.

The ornate rock lobster (*Panulirus ornatus*) regularly migrates from the Torres Strait through the Gulf of Papua to the Yule Island spawning grounds (see Section 8.6.2.2). The route for this migration crosses the export pipeline route and the existing PNG LNG Gas Pipeline. Lobsters walk along the seafloor and have relatively weak swimming ability, except over short distances and in short bursts. The pipelines may therefore present a physical obstruction of the migration to spawning grounds near Yule Island (see Figure 8.27). This may impact the population by decreasing the number of migrating lobsters reaching the spawning area and successfully spawning, thereby potentially decreasing larval supply and recruitment.

The ornate rock lobster also has important artisanal value in the Cape Suckling to Yule Island region and commercial significance in the Torres Strait. Any potential decline in future lobster populations may therefore also reduce ecosystem service provision, which is assessed in Chapter 16.

12.3.3.3 Sediment Mobilization from Trenching

Trenching for pipeline installation will temporarily increase suspended sediment concentrations and sediment deposition rates, as described and assessed in Section 12.1. The ecological impacts depend on the sensitivity of the environments and associated fauna and characteristics (i.e., intensity, duration and frequency) of turbid plumes. As noted in Section 12.3.2, modeling of sedimentation deposition was undertaken from trenching to the -15 m LAT mark rather than to the -20 m LAT mark; however, this altered scenario is not expected to cause additional impacts to high-sensitivity habitat (i.e., seagrass and coral reef) due to the absence of such habitat between the area modeled and the -20 m LAT mark. The model results are therefore considered acceptable for assessing impacts from sedimentation due to trenching.

Orokolo Bay

The modeled plumes for Orokolo Bay will not interact with any receptors sensitive to elevated suspended sediment levels, as the nearest reef is over 3 km from the trenching. Due to the high existing TSS levels and sediment deposition rates in Orokolo Bay, resident biota (including prawns) are highly tolerant to sediment disturbance and; therefore, are not expected to be impacted by the trenching. Section 8.5.4 describes the habitat of Orokolo Bay to have a moderate sensitivity; however, this rating was due to the highly turbid waters potentially providing preferential feeding habitat for some vulnerable species. Considering that these species have a tolerance or preference for highly turbid environments, biodiversity impacts at Orokolo Bay are not expected due to sediment mobilization and are not considered further in the residual impact assessment.

Caution Bay

Caution Bay has low turbidity levels and contains species that are sensitive to suspended sediments and sediment deposition. The main sensitive ecological receptors in Caution Bay are species that require light for nutrition, such as algae, seagrass and hermatypic corals. A decrease in health or an increase in mortality of these species may potentially occur due to reduced light penetration and sedimentation where trenching occurs close to coral reef or seagrass beds, or where currents carry mobilized sediment over these areas.

Potential impacts on aquatic biota due to increased suspended sediment and sedimentation levels include:

- Increased turbidity reducing light in the water column, thus reducing the productivity of phytoplankton and benthic microalgae.
- Increased turbidity reducing water clarity and the ability to detect prey.
- Physiological stress from high sediment concentrations, e.g., blocking of respiratory or feeding structures.
- Smothering and burial of sedentary species such as benthic microalgae and benthic invertebrates, including corals.

12.3.3.4 Planned Wastewater Discharges and Accidental Contaminant Releases

Contaminants may enter the environment from planned discharges of treated hydrotest water, domestic wastewaters and bilge water. Hazardous substances, including hydrocarbons and liquid wastes, may also be accidentally spilled or leaked from Project vessels. Condensate or gas leaks may also potentially occur if there are faulty joins in offshore pipelines.

The assessment undertaken in Section 12.3.5 relates only to spills or leaks that are typically incidental (but controllable) as part of construction and operation of large projects. Major accidental spills from unplanned events (e.g., bunker rupture from vessel collisions or groundings, or pipeline rupture) are considered in Chapter 18.

The potential impacts to marine biota from accidental contaminant releases depend on several factors, including the extent of contamination, duration of exposure and contaminant type. Oils and petroleum hydrocarbons are less dense than water and are biodegradable. The most toxic oil fractions to aquatic biota are lighter fractions that contain higher proportions of aromatic hydrocarbons; however, exposure of aquatic organisms in the water column to such fractions is usually limited due to their high volatility. Conversely, fauna that inhabit the surface layer would be exposed to hydrocarbons and exposed to toxicity effects. Apart from direct toxic effects to aquatic biota, oils and hydrocarbons can also cause tainting of fish flesh, loss of invertebrates and food sources, and an increase in algal growth (ANZECC/ARMCANZ, 2000). Hydrocarbons present on the surface layer of the water column may also coat surface swimming marine fauna, potentially affecting the insulating ability of fur-bearing mammals and the water repellency of bird's feathers.

As discussed in Section 12.2.3, the following embedded design controls address these impacts:

- Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as:
  - Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan.
  - Building infrastructure on impervious surfaces where required.
  - Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials.
  - Installing interceptor pits or similar to collect contaminated surface water runoff and treat where required.
  - Installing tanks above ground with impermeable liners and bunds around tanks.
  - Regularly inspect and maintain the containers, storage and transfer infrastructure to prevent/control spills or leaks.
  - Installing readily accessible spill kits and training staff in their use.
  - Appropriately treating and disposing of any accidentally contaminated soils. [ED003].
- Chemical use will be minimized, and selection of chemicals will be made considering lowest toxicity, lowest bioaccumulation potential, highest biodegradation and bans or phase-outs [ED006].
- Ballast waters, liquid effluents and waste from vessels will be managed according to MARPOL 73/78 requirements [ED022].

12.3.3.5 Vessels Striking Fauna

Vessels operating in marine waters may strike marine fauna. This is especially the case for mobile megafauna that swim near the surface or frequent the surface to breath, such as whales, dolphins, dugongs, crocodiles and turtles. Fish practice avoidance behavior around vessels and are unlikely to be injured due to vessel strike.

Vessel strike risk depends on many factors including the fauna type and abundance, vessel type, vessel speed and location. Slow moving fauna, such as turtles, near the water surface may be unable to evade fast moving watercraft such as support vessels. Large vessels, e.g., pipelaying vessels, barges and dredges, are slow-moving and may provide marine fauna time to evade the approaching vessel. They also typically have large powerful propellers and a lower draft, and, as such, present a risk to slow moving fauna throughout the upper parts of the water column. Interactions may occur in the offshore export pipeline footprint and shipping lanes between Port Moresby and the Purari River delta.

During trenching, it is possible for the suction at the dredge head to entrain fauna, potentially causing fauna injury or mortality. Of the marine megafauna potentially present in the PAOI, turtles are the group most likely to be affected. Turtles are highly mobile and will tend to avoid the dredge, typically returning to the surface to breath every few minutes; however, they can remain underwater for as long as two hours without breathing when they are resting. There are recorded incidences of turtles being injured by suction type dredges (Reine and Clarke, 1998). Other megafauna species (e.g., cetaceans and dugong) are not considered to be prone to dredge entrainment and will not be impacted by such interactions. The dredge may also entrain benthic fauna and demersal fish and mortality for these fauna is expected.

Assessment of impacts to marine fauna associated with underwater noise generated by vessels is undertaken separately in Section 12.4.

12.3.3.6 Spread of Marine Pests, Diseases and Pathogens

The dredge and other vessels could translocate marine pests from their port of origin to Port Moresby, the Gulf of Papua and to the Purari River system during all Project stages. There are two key vectors for translocating marine pests: Biofouling of the vessel hull or releasing pests into the marine environment in ballast waters (Hewitt and Campbell, 2010).

Vessel hulls and dredge plant can provide habitat for biofouling marine pest species. In particular, dredges and associated construction equipment can provide complex habitats that may be difficult to clean and inspect (Hewitt and Campbell, 2010).

Ballast water is typically discharged from each ship as it enters port, at the port anchorage areas, and at the berths as it is loaded. Most vessels discharge only a small percentage of their ballast water in outer approach channels to conform to navigational requirements. Most ballast water is discharged alongside the wharf to balance the trim of the vessel and stresses in the vessel’s hull, as materials are loaded.

If conditions are suitable, introduced marine species can survive and establish a reproductive population in the host environment and can become invasive whereby they outcompete native species and multiply into pest proportions. Introduced species can replace native species through direct competition for resources (i.e., food and space) or, indirectly, by flow-on effects through ecosystem or food web changes. The environmental impacts due to the introduction of exotic marine pests can be significant. Marine pests, once established, can be difficult to eradicate and can have serious and permanent consequences for the marine environment, marine productivity and public health (see Chapter 8).

There is little information on the present status of invasive marine species in Papua New Guinea or the wider Pacific Island Countries and Territories. Raaymakers (2006) notes that introduced species of concern in the region include the barnacle (*Chthamalus proteus*), several macro-algae species, harmful planktonic algae species and the black striped mussel (*Mytilopsis sallei*). Asian green mussel (*Perna viridis*), which have a natural range within South East Asia, also represent a key potential risk species for tropical environments in Australia (Hayes et al., 2005) and Papua New Guinea.

Ships originating from colder, temperate waters have a lower risk of establishing marine pest populations than those originating from tropical ports, because foreign organisms from temperate ports are generally considered to be less likely to survive or proliferate in the warmer tropical waters.

Diseases and pathogens are not commonly spread in the marine environment but, when translocation does occur, the same vectors as marine pests generally spread them. Antifouling techniques and appropriate ballast water exchanges to manage marine pests will therefore also address risks associated with diseases and pathogens.

The following embedded design control addresses these potential impacts:

- Ballast waters, liquid effluents and waste from vessels will be managed according to the MARPOL 73/78 requirements [ED022].

12.3.3.7 Summary of Potential Impacts to Marine Biodiversity

Potential Project impacts to marine biodiversity that have been considered in the residual impact assessment are as follows:

- Loss or disturbance of benthic habitat and marine fauna from trenching and pipelaying.
- Pipeline presenting a barrier to marine fauna movements.
- Sediment mobilization from trenching, causing impacts to aquatic biota due to increased levels of suspended sediment and sedimentation on the seabed.
- Planned wastewater discharges or contaminant releases reducing water quality, with potential acute or chronic toxicity effects on aquatic fauna.
- Project vessels striking fauna.
- Project vessels and equipment spreading marine pests, diseases and pathogens

12.3.4 Proposed Mitigation and Management Measures

Table 12.16 describes mitigation and management measures to further reduce impacts to marine biodiversity. Mitigation and management in Caution Bay in the lease area for the PNG LNG Project will be further aligned with the PNG LNG Project and downstream Papua LNG Project.

Table 12.16 – Marine Biodiversity Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Direct loss of benthic habitat and loss of or injury to marine fauna from trenching and pipelaying	♦ Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species [EM037].	-
Pipeline barrier to marine fauna movements	♦ Where required, implement adaptive management, including appropriate monitoring, to minimize the project's impacts on lobster migration [EM038].	Biodiversity Action Plan
Sediment mobilization from trenching	♦ Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species [EM037].	Water Management Plan
Contaminant releases	♦ Sewage effluents from Project facilities will be treated to meet the environment (waste discharge) permit before discharge, in accordance with applicable standards. [EM008]. ♦ Hydrotest water management will consider: – The definition of volume and discharge rates and discharge locations. – Chemical additive selection, according to requirements defined in embedded design controls.	Water Management Plan; Hazardous Materials Management Plan

Table 12.16 – Marine Biodiversity Mitigation Strategies and Management Plans (cont’d)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Contaminant releases (cont’d)	– Reusing hydrotest water to minimize the discharge volume. – Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. – Monitoring hydrotest water discharges to the environment against applicable limits. [EM015] ♦ An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: – Site Contingency Plans, that will consider fire management measures – An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. – A Blow Out Contingency Plan including well blowout control and contingency measures [EM018]. ♦ Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and Marine Pollution (Ships and Installations) Act 2013 [EM019].	Water Management Plan; Hazardous Materials Management Plan
Vessels striking fauna	♦ Implement lower speeds past aquatic fauna when observed in the water [EM022]. ♦ All Project personnel, workers, contractors and 3rd party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028].	Traffic and Transport Management Plan; Biodiversity Action Plan
Spread of marine pests, diseases and pathogens	♦ Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: – Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna. – A quarantine management program for moving people, equipment and supplies in accordance with PNG law. – Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna. [EM023]. ♦ All Project personnel, workers, contractors and 3rd party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking.	Biodiversity Action Plan

Table 12.16 – Marine Biodiversity Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Spread of marine pests, diseases and pathogens (cont'd)	– Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028].	Biodiversity Action Plan

Note: A dash (-) denotes no management plan is required.

12.3.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to marine biodiversity subject to the embedded design controls in Section 12.3.3 and the successful implementation of the mitigation and management measures in Section 12.3.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

As indicated earlier, LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS; the related indicative information presented here will be refined as part of the downstream Papua LNG EIS.

12.3.5.1 Loss or Disturbance of Benthic Habitat and Marine Fauna from Trenching and Pipelaying

Trenching and pipelaying will cause direct impacts to benthic habitats and biota that is unavoidable. Route selection will be refined during FEED to minimize impacts to high value habitats, wherever practicable. The residual impacts to seagrass and coral reef habitats and marine fauna are assessed below. As described in Section 12.3.3, the impact to unconsolidated sediment habitat due to pipeline installation is considered insignificant.

Seagrass

The direct loss of seagrass habitat due to trenching in Caution Bay is estimated to be 0.08% of the total seagrass habitat for the southern alignment and 0.06% of the total seagrass habitat for the northern alignment (see Table 12.15).

Seagrass species recorded in Caution Bay are *Enhalus acoroides, Syringodium isoetifolium, Cymodocea* spp. and *Halophila* spp. (see Section 8.5). These species have a range of adaptations that allow for rapid recovery following disturbance (Table 12.17) including the ability to reproduce both sexually and asexually. Where some shoots or roots remain intact, vegetative growth through rhizomes can allow recovery in a relatively short time frame (Carruthers et al., 2002; Unsworth et al., 2015). It is expected that recovery will take up to 10 years[7], depending on the level of initial impact and ambient environmental conditions during the recovery period.

7 Considering *Enhalus acoroides* which has the longest recovery time

Table 12.17 – Sensitivity to Disturbance of Seagrass Species Found in the PAOI

Species	Sensitivity to Disturbance
Cymodocea serrulata	♦ High light requirement. ♦ Large growing species with large energy reserves (rhizomes) and the capacity to endure short-term changes in turbidity. ♦ Low to moderate growth and reproductive output (compared to *Halophila*), high rhizome persistence. ♦ Recovery longer than *Halophila*. ♦ Classified as an intermediate taxon that can tolerate moderate levels of disturbance and is able to rapidly recover following disturbance.
Enhalus acoroides	♦ High light requirement. ♦ Large growing species with large energy reserves and a high capacity to endure short-term changes in turbidity. ♦ Low growth and reproductive output (compared to *Halophila* and *Cymodocea*). ♦ Recovery longer than *Halophila.* ♦ Can tolerate moderate levels of disturbance, but takes up to 10 years to fully recover.
Syringodium isoetifolium	♦ Small stores of energy reserves. ♦ Rapidly declines when conditions become unfavorable for growth. ♦ Reproduces from seed and vegetative growth. ♦ Fast growth and high reproductive output. ♦ Classified as an opportunistic species that can tolerate high levels of disturbance.
Halophila spp.	♦ Small energy reserves. ♦ Rapidly declines when conditions become unfavorable for growth. ♦ Reproduces from seed and vegetative growth. ♦ Colonizing growth strategy. ♦ Fast growth and high reproductive output. ♦ Classified as an ephemeral genus that can tolerate high levels of disturbance.

Sources: Collier and Waycott (2009); Carruthers et al., (2002); Unsworth et al., (2015); Duarte et al., (1997).

Trenching across seagrass meadows is expected to cause short-term loss of less than 0.1% of seagrass habitat in Caution Bay with recolonization expected to occur in one to five years. *Halophila* species will rapidly recolonize, with slower growing species such as *Enhalus acoroides*, recolonizing in subsequent years. Impacts are therefore temporary and highly localized, and will not cause long-term impacts to other marine components outside of the disturbance footprint; therefore, the magnitude of the impact will be ***Low***. These meadows have a ***Medium*** sensitivity, as they are in near natural condition; although, local and commercial fishing, and the development of the PNG LNG project have removed some seagrass meadow patches in the past. This provides a residual impact significance of ***Minor***.

Reefs

The direct loss of nearshore fringing coral reef due to trenching in Caution Bay is estimated to be 0.03% of the total coral habitat for the southern alignment (see Table 12.15). For the alternative northern alignment, the loss of fringing coral reef habitat is estimated to be 0.08% of the total coral habitat.

The trench footprint through the fringing reef will be backfilled using the excavated material, which is expected to largely consist of unconsolidated coral rubble that differs from the existing reef habitat. This represents a long-term change to habitat conditions, with recovery (e.g., cementation of reef substrates) possibly measured in tens of decades (Erftemeijer et al., 2012). Damage to or loss of large coral heads, if present in the alignment, would be permanent as these features are several hundred years old.

The recovery timeframes of reef assemblages will vary among species. It is expected that there will be a successional change to a benthic assemblage, with initial colonization by an algae-dominated assemblage, and the eventual recolonization by reef fauna (i.e., hard corals, hydroids and sponges) (Pearson, 1981; Done, 1992). The reef assemblage in the footprint may differ from that prior to trenching due to the expected change in substrate types and their stability. The timeframe for establishing a relatively diverse and abundant benthic assemblage may be five to 10 years (Erftemeijer et al., 2012).

Although impacts would be limited to the trenching footprint and are therefore highly localized, the impact magnitude is ***Medium*** based on the recovery times for corals. As for seagrass, these reefs have a ***Medium*** sensitivity as local and commercial fishing, and the development of the PNG LNG project have removed or damaged coral patches in the past. This provides a residual impact significance rating of ***Moderate***.

Marine Fauna

Direct injury to or loss of benthic invertebrates from trenching in Orokolo and Caution bays will be highly localized and temporary, as surrounding fauna are likely to recolonize the sediment within weeks after the trench has been filled. These impacts will not threaten the viability of subregional populations and the impact magnitude is considered ***Low***. The sensitivity of benthic invertebrate is ***Minimal*** since they are species well adapted to habitat loss and there are widespread similar benthic faunal assemblages. The residual impact significance is therefore ***Negligible.***

The offshore export pipeline route through Caution Bay will pass through reef and seagrass habitat supporting marine species with significant conservation status including marine turtles, dugong and some fish; however, these species have not been sighted in Caution Bay during marine surveys for the Project, or the PNG LNG project, to date and local populations are likely to be very small if they are present. The total extent of habitat disturbance is very small relative to the extent of available habitat, even at a localized spatial scale (i.e., less than 0.1% of available habitat in Caution Bay). None of the affected areas are known or expected to support unique or otherwise critical food or habitat resources at a localized scale, based on habitat assessments.

This small and temporary reduction in foraging habitat for fish, marine turtles and dugong is unlikely to cause a measurable reduction in the species populations. The impact magnitude for all species is therefore ***Minimal***. Sensitivity ratings vary depending upon the relevant species. Table 12.18 provides the residual impact significance ratings per species, considering the different sensitivities.

Table 12.18 – Impact Significance Ratings for Habitat Loss or Disturbance for Relevant Species

Species	Likely Abundance	Status*	Sensitivity	Magnitude	Significance
Loggerhead turtle (*Caretta caretta*)	Low	VU, App I	High	Minimal	***Minor***
Green turtle (C*helonia mydas*)	Low to medium	EN, App I	High	Minimal	***Minor***
Leatherback turtle (*Dermochelys coriacea*)	Very low (if present)	CR[#], P, App I	Very High	Minimal	***Minor***
Hawksbill turtle (*Eretmochelys imbricata*)	Low to medium	CR, App I	Very High	Minimal	***Minor***

Table 12.18 – Impact Significance Ratings for Habitat Loss or Disturbance for Relevant Species (cont'd)

Species	Likely Abundance	Status*	Sensitivity	Magnitude	Significance
Olive ridley turtle (*Lepidochelys olivacea*)	Low	VU, App I	High	Minimal	***Minor***
Flatback turtle (*Natator depressus*)	Low	App I	Medium	Minimal	***Negligible***
Dugong (*Dugong dugon*)	Very low (if present)	VU, P, App I	High	Minimal	***Minor***
Spotted eagle-ray (*Aetobatus narinari*)	Low	NT	Medium	Minimal	***Negligible***
Brown marbled grouper (*Epinephelus fuscoguttatus*)	Low to medium	NT	Medium	Minimal	***Negligible***
Non-threatened fish species	Medium to high	Not IUCN listed or protected in PNG	Minimal to Low	Minimal	***Negligible***

* Status consists of IUCN Red List listing (CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened), National Status (P: Protected) and CITES Appendix I Listing (App I). Only the status relevant to sensitivity. is provided. [#] West Pacific population.

12.3.5.2 Pipeline Barrier to Marine Fauna Movement

The export pipelines may potentially obstruct the ornate rock lobster migration across the gulf to spawning grounds at Yule Island, as described in Section 12.3.3.2.

Dennis et al. (1996) demonstrated that lobsters can cross a 26-inch diameter pipeline to access a food source in experiments conducted in test tanks. The diameter of the existing PNG LNG Gas Pipeline is 34 inches and there is no evidence to indicate it has presented a barrier to lobster migration to Yule Island causing impacts on lobster populations, with the National Fisheries Authority not receiving any reports of negative impacts to lobster catches following its installation (Kasu, pers. com., 2019).

Uncertainty remains regarding the ability of ornate rock lobsters to traverse a 40-inch diameter pipeline, which is the diameter of the proposed gas export pipeline excluding the thickness of the concrete collar. Martec (2004) found that some American lobsters (*Homarus americanus*, a temperate lobster species in a different family but potentially with similar mobility) were unable to traverse a 32-inch pipeline with a rough coating in a test tank. Of the eight lobsters in the test, five were able to traverse a fully exposed pipeline and three were able to traverse a pipeline that was three-quarters exposed. In the same tests, nine of 10 lobsters were unable to traverse a 48-inch pipeline with a rough coating when fully exposed, and 13 of 16 lobsters when three-quarters exposed. Martec (2004) concluded that pipe diameter, burial and roughness determined the ability for *H. americanus* to traverse a pipeline to access a food source and a threshold diameter for this species may be between 32 and 48 inches.

The residual impact of the export pipelines, in particular the 40-inch diameter gas pipeline coated with a rough concrete collar, to the ornate rock lobster is therefore uncertain. Disruption of the ornate rock lobster migration may possibly occur. This could cause a decline in the number of migrating lobsters arriving at spawning sites in the Yule Island area. This has the potential to cause in a decline in the subregional population of the species, but is unlikely to threaten the viability of the regional population, which is also supported by spawning grounds elsewhere in the gulf including Parama Island near the mouth of the Fly River (see Section 8.6.2). The magnitude of impact is therefore assessed to be ***High***.

As the ornate rock lobster is of fisheries significance, it has a ***Medium*** sensitivity. Overall, the potential for the pipelines to be a barrier to lobster migration is therefore assessed to have a ***Moderate*** residual impact significance.

The pipeline is not expected to negatively affect prawn movements (see Section 12.3.3.2).

12.3.5.3 Sediment Mobilization from Trenching

Orokolo Bay

Plume and sedimentation impacts to marine biodiversity are not expected at Orokolo Bay due to the lack of sensitive receptors and the high adaptation levels of local marine biota to naturally occurring high levels of suspended sediment and sedimentation (see Section 12.3.3).

Caution Bay

Trenching for pipeline installation, which will occur in water depths less than -20 m LAT, will temporarily increase suspended sediment concentrations and sediment deposition rates, as described and assessed in Section 12.1. Comparison of modeling results for the predicted increase in suspended sediment and sedimentation to the impact thresholds provided in Tables 12.13 and 12.14 shows the following:

- The median (50th percentile) TSS concentration for both alignments during both seasons exceeds the threshold for the zone of influence (1 mg/L) and reaches, but does not exceed, the threshold for the zone of moderate impacts (5 mg/L) (see Figures 12.4 to 12.7). Thus, while there will be changes in TSS concentrations, these will be insufficient to degrade, harm or injure ecological receptors (Section 12.3.2).
- Final sediment deposition for both alignments during both seasons exceeds the threshold for the zone of high impact (700 mg/cm^3) up to 500 m from the trenching alignment (see Figure 12.8 and 12.9). This represents an area in which most sensitive receptors will die, with recovery by recolonization taking longer than 24 months (Section 12.3.2). Beyond this extent, there is an immediate drop-off in deposition and sedimentation rates to levels below the zone of influence threshold (<30 mg/cm^3), where there are no ecological impacts.

Table 12.19 shows the resulting areas of impact (i.e., those in the zone of high impact due to sediment deposition), based on the previously mapped extent of seagrass and coral habitats in Caution Bay (see Section 8.5.2 and Figure 8.21) and modeled sedimentation results (see Figure 12.8 and 12.9). This shows that the highest impact scenario with respect to coral reef habitat is the northern alignment with around 85,000 m^2 disturbed for both seasons. This is a potential loss of around 2% of total coral reef habitat found in Caution Bay due to smothering from deposition. The scenario with the lowest impact to coral habitat is the southern alignment, with trenching conducted during the northwest monsoon season (i.e., a potential loss of 1% of the total coral reef habitat). Impacts to seagrass habitat are not predicted to occur due to the narrower extent of mapped seagrass along the northern alignment. The area of impact on seagrass habitat along the southern alignment is approximately the same for either season (8,000 to 9,000 m^2, representing 0.4% of total seagrass in Caution Bay).

Table 12.19 – High-value Benthic Habitat Disturbed by Sedimentation During Trenching

Benthic Habitat Type	Caution Bay – Southern Alignment		Caution Bay – Northern Alignment	
	m^2	%	m^2	%
Northwest Monsoon Season				
Seagrass	8,000	0.4	0.0	0.0
Coral reef	44,000	1.0	85,000	2.0

Table 12.19 – High-value Benthic Habitat Disturbed by Sedimentation During Trenching (cont'd)

Benthic Habitat Type	Caution Bay – Southern Alignment		Caution Bay – Northern Alignment	
	m^2	%	m^2	%
Southeast Trade Winds Season				
Seagrass	9,000	0.4	0.00	0.0
Coral reef	67,000	1.6	84,300	1.9

Areas represent areal extent of seagrass and coral reef in the zone of high impact (mortality with recolonization time greater than 24 months) due to sediment deposition.

In summary, sediment deposition will adversely impact marine biodiversity in Caution Bay; however, increased suspended sediment levels are not expected to have adverse impacts. The zone of high impact is predicted to adversely affect less than 1% of seagrass habitat and 2% of fringing coral reef habitat in Caution Bay causing mortality in this zone. Impacts on fringing coral reefs and seagrasses will be temporary as wave action is expected to naturally and rapidly rework sediment deposited in the zone of impact. The magnitude of impact is dependent upon their ability to recover.

In seagrass meadows, some species such as *Halophila* species can recolonize in one to five years while slower growing species such as *Enhalus acoroides* may take up to 10 years to fully recover (Rollon et al., 1999). Sedimentation impacts to coral reefs are expected to last five to 10 years before plating and branching coral species recover. Impacts to large ancient coral heads (where they occur) could take hundreds of years to recover. The magnitude of impacts to these habitats is as follows:

- Seagrass impacts will be highly localized within 500 m of the trenching alignment and recolonization is expected to take between one to five years, with some species (e.g., *Halophila* spp.) recolonizing more rapidly than others (e.g., *Enhalus acoroides*). Therefore, the impact will be of ***Low*** magnitude.
- Fringing coral reefs impacts will be highly localized and large relative to natural variability and could take up to 10 years to recover equivalent habitat values; therefore, the impact will be of ***Medium*** magnitude. Impacts on coral heads habitat, if present on the fringing coral reefs, will also be highly localized and large relative to natural variability but could take hundreds of years to recover. The magnitude of impact is, however, similarly assessed to be ***Medium***.

Seagrass habitats in Caution Bay are considered to have a ***Medium*** sensitivity since they support seagrass species with moderate vulnerability, including *Enhalus acoroides* (see Section 8.5.4), and are in near natural condition providing habitat for marine fauna but with some minor historical and ongoing disturbance. Overall, the impact on seagrass due to sediment mobilization from trenching is therefore assessed to have a ***Minor*** residual impact significance.

Notwithstanding the high sensitivity rating given to coral reef habitats in general in Section 8.5.4, fringing and nearshore reefs in Caution Bay have been observed to be in poor condition, which is attributed to high intensity fishing and the suspension of sediment from strong winds and waves, although recovery in condition is occurring (see Section 8.5.2). The sensitivity of fringing reef in Caution Bay is therefore assessed to be ***Medium*** for the impact assessment, i.e., habitat is not significantly modified in terms of primary ecological function and composition, supports viable assemblages of native flora and fauna species and conservation-listed species may be present. The impact on fringing coral reef due to sediment mobilization from trenching is therefore assessed to have a ***Moderate*** residual impact significance.

The seagrass and reef habitats may support marine species with significant conservation status including marine turtles, dugong, and some fish. Impacts on these habitats will create small reductions in foraging habitat for fish, marine turtles, and dugong but are unlikely to cause a measurable reduction in the species populations. The magnitude of impact from sediment mobilization for marine species is therefore ***Minimal***. The residual significance of impact for various fauna due to sediment mobilization is the same as described in Table 12.18 for habitat loss or disturbance, given that the magnitude of impact is the same.

12.3.5.4 Planned Wastewater Discharges and Accidental Contaminant Releases

Assessment of the impacts on marine water quality of planned wastewater discharges and accidental contaminant releases is undertaken in Section 12.2. Embedded design controls and mitigation measures will be in place to: (i) prevent and minimize the occurrence of accidental contaminant spills or leaks; (ii) respond appropriately should a spill occur. Given the expected low volumes of any contaminant release assessed in this Chapter, the assimilation factor inherent in the marine environment, and taking into account the proposed embedded controls and mitigation and response measures (see Section 12.3.3 and Table 12.2.4), the residual impact significance of contamination in marine waterways was assessed as ***Negligible*** for planned wastewater discharges (see Section 12.2.5.1). The residual impact significance for accidental contaminant releases causing a deterioration of water quality was assessed as ***Minor*** (see Section 12.2.5.2).

The release of low volumes of contaminants is most likely to have insignificant impacts on habitats but may affect individual animals. The susceptibility of marine fauna to the potential physical or toxic effects of contaminants will depend on factors such as the fauna type, contaminant type, length of exposure and the contaminant concentration. When appropriately detected and managed, accidental spills and leaks would have a highly localized impact, and are unlikely to cause a measurable decline in marine fauna populations. The magnitude of the impact is therefore assessed as ***Minimal***.

Contaminants accidentally released into the marine environment have the potential to affect any marine fauna exposed to the release. The overall significance of impact for various fauna due to contaminant release is shown in Table 12.20 considering their different sensitivities.

Table 12.20 – Impact Significance Ratings for Contaminant Release for Various Species

Species	Likely Abundance	Status	Sensitivity	Magnitude	Significance
Loggerhead turtle (*Caretta caretta*)	Low	VU, App I	High	Minimal	***Minor***
Green turtle (C*helonia mydas*)	Low to medium	EN, App I	High	Minimal	***Minor***
Leatherback turtle (*Dermochelys coriacea*)	Very low (if present)	CR#, P, App I	Very High	Minimal	***Minor***
Hawksbill turtle (*Eretmochelys imbricata*)	Low to medium	CR, App I	Very High	Minimal	***Minor***
Olive ridley turtle (*Lepidochelys olivacea*)	Low	VU, App I	High	Minimal	***Minor***
Flatback turtle (*Natator depressus*)	Low	App I	Medium	Minimal	***Negligible***
Dugong (*Dugong dugon*)	Very low (if present)	VU, P, App I	High	Minimal	***Minor***
Australian snubfin dolphin (*Orcaella heinsohni*)	Low	EN, App I	High	Minimal	***Minor***

Table 12.20 – Impact Significance Ratings for Contaminant Release for Various Species (cont'd)

Species	Likely Abundance	Status	Sensitivity	Magnitude	Significance
Australian humpback dolphin (*Sousa sahulensis*)	Low	VU, App I	High	Minimal	***Minor***
Spotted eagle-ray (*Aetobatus narinari*)	Low to medium	NT	Medium	Minimal	***Negligible***
Brown marbled grouper (*Epinephelus fuscoguttatus*)	Low to medium	NT	Medium	Minimal	***Negligible***
Non-threatened marine fauna (includes fish, macrocrustaceans and dolphins)	Low to high	Not IUCN listed or protected in PNG	Minimal to Low	Minimal	***Negligible***

* Status consists of IUCN Red List listing (CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened), National Status (P: Protected) and CITES Appendix I Listing (App I). Only the status relevant to sensitivity is provided. # West Pacific population.

12.3.5.5 Vessels Striking Fauna

Implementing a protocol to minimize interactions with marine fauna, including lower speeds past aquatic fauna when observed in the water will reduce the risk of Project vessels striking fauna. The risk of strike may be higher in Caution Bay than elsewhere due to the greater possibility of fauna (especially marine turtles) being present in shallower waters with coral reef and seagrass habitats. The magnitude of impacts across the PAOI for all species is considered ***Minimal,*** as the possible injury or death of individuals is unlikely to cause a measurable decline in fauna populations.

The species most likely to be at risk are large marine fauna that can occur at the surface, namely dolphins, marine turtles and dugongs. The sensitivity of these species differs, leading to variable impact significance as shown in Table 12.21.

Table 12.21 – Impact Significance Ratings for Vessel Strike for Relevant Species

Species	Status	Sensitivity	Magnitude	Significance
Loggerhead turtle (*Caretta caretta*)	VU, App I	High	Minimal	***Minor***
Green turtle (*Cheloni mydas*)	EN, App I	High	Minimal	***Minor***
Leatherback turtle (*Dermochelys coriacea*)	CR#, P, App I	Very High	Minimal	***Minor***
Hawksbill turtle (*Eretmochelys imbricata*)	CR, App I	Very High	Minimal	***Minor***
Olive ridley turtle (*Lepidochelys olivacea*)	VU, App I	High	Minimal	***Minor***
Flatback turtle (*Natator depressus*)	App I	Medium	Minimal	***Negligible***
Dugong (*Dugong dugon*)	VU, P, App I	High	Minimal	***Minor***
Australian snubfin dolphin (*Orcaella heinsohni*)	EN, App I	High	Minimal	***Minor***
Australian humpback dolphin (*Sousa sahulensis*)	VU, App I	High	Minimal	***Minor***
Non-threatened dolphins (*Delphinus delphis, Stenella attenuate, Tursiops aduncus* and *Tursiops truncates*)	Not IUCN listed or protected in PNG	Low	Minimal	***Negligible***

* Status consists of IUCN Red List listing (CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened), National Status (P: Protected) and CITES Appendix I Listing (App I). Only the status relevant to sensitivity is provided. # West Pacific population.

12.3.5.6 Spread of Marine Pests, Diseases and Pathogens

A quarantine management program for moving people, equipment and supplies will be developed and implemented during Project construction and operation in accordance with PNG law. Biosecurity measures detailed in these procedures, including compliance with the *Marine Pollution [Ballast Water Control Act] Act 2013,* will minimize the risk of marine pests, diseases and pathogens being introduced into marine waters from either the discharge of ballast water or via the hulls of vessels. Vessels will transit the gulf to PRL-15 during all Project[8] phases; however, most vessels will be based locally and so have a much lower risk of introducing marine pests, diseases and pathogens compared to vessels arriving from overseas. Given the short-term duration of construction and the small number of vessels required (up to four barges per day during the peak period in Year 2) during all Project phases, introduction of marine pests, diseases and pathogens is unlikely to occur; however, any impacts would be expected to be localized and not threaten the viability of a sub-regional species population. The magnitude of impact is therefore assessed as ***Low***.

The existing environment has a ***Medium*** sensitivity as it is in a near-natural condition but with some minor human-induced modification and an ongoing risk of marine pest introduction (e.g., international shipping traffic). This provides a residual impact significance rating that is ***Minor***.

12.3.6 Summary of Residual Impacts to Marine Biodiversity

Table 12.22 provides a summary of the assessment of residual impacts to marine biodiversity, including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the mitigation measures provided in Table 12.16.

All residual impacts are assessed to be ***Negligible*** to ***Minor***, except for the following:

- Direct loss or decline in the health of fringing coral reef habitat in Caution Bay due to: i) direct trenching and ii) indirect sedimentation, associated with trenching for the pipeline installation, which are assessed to have a ***Moderate*** residual impact rating. The impacts to this habitat will be localized and, although pipelaying will be a short-term activity (e.g., less than one week), moderate impacts are expected due to the long recovery periods required for coral reefs to re-establish (i.e., more than five years).
- Decline in ornate rock lobster spawning and abundance due to possible obstruction of their migration across the gulf to spawning grounds at Yule Island. This is assessed to have ***Moderate*** residual impact rating; however, there is some uncertainty regarding these impacts and further assessments are to be undertaken and appropriate management measures developed if required.

8 This assessment excludes LNG tankers exporting gas from the PNG LNG Facilities, which are not considered in this environmental impact assessment.

Table 12.22 – Summary of Assessment of Residual Impact Significance – Marine Biodiversity

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Loss or disturbance of habitat and benthic biota	Trenching in water depths <-20 m LAT and pipelaying	Direct loss of seagrass habitat	Caution Bay	C	♦ EM037	Medium/Low	Minor
		Direct loss of coral reef habitat	Caution Bay			Medium/Medium	Moderate
		Direct mortality or injury of benthic invertebrates	Orokolo Bay and Caution Bay			Minimal/Low	Negligible
		Indirect impacts to marine fauna due to habitat loss (e.g., decrease in heath due to a reduction in food resources) – leatherback turtles and hawksbill turtles	Caution Bay			Very High/Minimal	Minor
		Indirect impacts to marine fauna due to habitat loss (e.g., decrease in heath due to a reduction in food resources)– loggerhead turtles, green turtles, olive ridley turtle and dugongs				High/Minimal	Minor
		Indirect impacts to marine fauna due to habitat loss (e.g., decrease in heath due to a reduction in food resources)– flatback turtles, spotted eagle-rays and brown marbled groupers				Medium/Minimal	Negligible
		Indirect impacts to marine fauna due to habitat loss (e.g., decrease in heath due to a reduction in food resources)– non-listed fish species				Minimal to Low/Minimal	Negligible
Barrier to marine fauna movement	Offshore pipeline	Disruption to ornate rock lobster migration to spawning grounds and possible associated impact on population	Offshore export pipeline route	O, D	♦ EM038	Medium/High	Moderate

Table 12.22 – Summary of Assessment of Residual Impact Significance – Marine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Sediment mobilization	Trenching in water depths <-20 m LAT	Smothering of seagrass from sedimentation	Caution Bay	C	♦ EM037	Medium/Low	Minor
		Smothering of coral from sedimentation				Medium/Medium	Moderate
		Habitat loss or disturbance to marine fauna from sedimentation – leatherback turtles and hawksbill turtles				Very High/Minimal	Minor
		Habitat loss or disturbance to marine fauna from sedimentation – loggerhead turtles, green turtles, olive ridley turtle and dugongs				High/Minimal	Minor
		Habitat loss or disturbance to marine fauna from sedimentation – flatback turtle, spotted eagle-rays and brown marbled groupers				Medium/Minimal	Negligible
		Habitat loss or disturbance to marine fauna – non-threatened fish species				Minimal to Low/Minimal	Negligible
Contaminant release	Planned wastewater discharges and accidental contaminant releases	Acute and chronic toxicity impacts to aquatic fauna individuals – leatherback turtles and hawksbill turtles	Orokolo Bay, offshore export pipeline route, Caution Bay and logistics supply route	C, O, D	♦ EM008 ♦ EM015 ♦ EM018 ♦ EM019	Very High/Minimal	Minor
		Acute and chronic toxicity impacts to aquatic fauna individuals – loggerhead turtles, green turtles, olive ridley turtles, dugongs, Australian snubfin dolphins and Australian humpback dolphins	Orokolo Bay, offshore export pipeline route and Caution Bay	C, O, D		High/Minimal	Minor

Table 12.22 – Summary of Assessment of Residual Impact Significance – Marine Biodiversity (cont'd)

Impacting Process	Activity and Potential Impact		Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Contaminant release (cont'd)	Planned wastewater discharges and accidental contaminant releases	Acute and chronic toxicity impacts to aquatic fauna individuals – flatback turtles, spotted eagle-rays and brown marbled groupers	Orokolo Bay, offshore export pipeline route and Caution Bay	C, O, D	♦ EM008 ♦ EM015 ♦ EM018 ♦ EM019	Medium/Minimal	Negligible
		Acute and chronic toxicity impacts to aquatic fauna individuals – non-threatened marine fauna				Minimal to Low/Minimal	Negligible
Fauna strike	Project vessel operations	Marine fauna mortality or injury from vessel strikes – leatherback turtles and hawksbill turtles	Orokolo Bay, offshore export pipeline route, Caution Bay and logistics supply route	C, O, D	♦ EM022 ♦ EM028	Very High/Minimal	Minor
		Marine fauna mortality or injury from vessel strikes – loggerhead turtles, green turtles, olive ridley turtles, dugongs, Australian snubfin dolphins and Australian humpback dolphins				High/Minimal	Minor
		Marine fauna mortality or injury from vessel strikes – flatback turtles				Medium/Minimal	Negligible
		Marine fauna mortality or injury from vessel strikes – non-threatened dolphin species				Low/Minimal	Negligible
Spread of marine pests, diseases and pathogens	Project vessel operations	Introduction of pests and diseases that cause mortality and replacement of native fauna	Orokolo Bay, offshore export pipeline route, Caution Bay and logistics supply route	C, O, D	♦ EM023 ♦ EM028	Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure

12.4 Underwater Noise

The assessment of the residual impacts of underwater noise addresses marine, estuarine and freshwater environments and has been placed in this chapter so that it can be treated as one integrated assessment for the aquatic environment.

12.4.1 Context

The PAOI includes a variety of underwater acoustic environments including rivers, estuaries and nearshore and offshore marine waters. Table 12.23 presents a summary of existing underwater sound levels and the key contributing sound sources at representative assessment locations in the riverine environments of PRL-15 and the river transport corridors, and the nearshore and offshore marine segments of the export pipeline corridor. Further description of these noise sources is provided in Section 8.7 and the assessment locations are shown in Figure 8.29.

Table 12.23 – Summary of Existing Underwater Noise Levels and Key Noise Sources

Project Area	Assessment Location	Water Depth (m)	Key Noise Sources	Baseline Noise (dB re 1µPa$_{rms}$*)	
				Mean	Range
Offshore export pipeline route	1 (Caution Bay)	30	Soniferous fish, snapping shrimp, commercial shipping traffic including LNG carriers and tugboats.	110	90 to161
	2 (south of Kerema)	80	Wind, waves, snapping shrimp, barges and trawlers.	105	75 to 127
	3 (south of Ihu)	50			
	4 (Orokolo Bay)	12	Wind, waves, rainfall, soniferous fish, snapping shrimp, marine mammals, barges and community vessels.	110	85 to 163
River transport corridors (Purari River delta)	5 (Aievi Passage)	6	Rainfall, soniferous fish, marine mammals, barges and community vessels.	110	75 to 175
	6 (Port Romilly)	8			
PRL-15	7 (Purari River)	6	Wind, rainfall, soniferous fish, barges and community vessels.	120	75 to 170

* Received sound pressure level and root mean square (rms).

Freshwater and marine fauna considered to be sensitive to potential impacts from underwater noise, and known or expected to occur in the PAOI, are marine and freshwater fish, freshwater turtles, freshwater and estuarine crocodiles, cetaceans, dugongs and sea turtles.

12.4.2 Discipline-specific Impact Assessment Method

The significance assessment approach described in Chapter 3 was primarily used to assess the impacts of underwater noise to aquatic fauna. This approach is based on determining significance through a combination of magnitude (of the impact) and sensitivity (of the receptor). The discipline-specific criteria used to categorize magnitude and sensitivity of underwater noise impacts are described in Section 12.4.2.1 and Section 12.4.2.2, respectively.

Assessment of the sensitivity of receptors and magnitude of impacts also considers whether acoustic thresholds for impacts, where available, are exceeded based on calculating underwater noise attenuation with distance from Project noise sources (see Part 1 of Volume 3). The impact assessment is therefore a combination of the qualitative significance assessment approach and the semi-quantitative modeling.

12.4.2.1 Magnitude of Impact

The magnitude of the impact for underwater noise is a combination of the geographical extent of radiated noise, intensity (severity) and its duration. In aquatic environments, impacts have the potential to be widespread, e.g., low frequency noise propagation, but with a differing level of significance based on the intensity and duration of the impact.

Magnitude has been categorized as per the descriptors in Table 12.24. Further description of the various impacts that underwater noise may have on marine fauna is provided in Section 12.4.3.

Table 12.24 – Criteria for the Magnitude of Impacts

Magnitude	Description
Very high	♦ Aquatic fauna exposed to very high levels of impulsive continuous or intermittent noise. ♦ Aquatic fauna exposed to very high levels of non-impulsive, continuous or intermittent noise. ♦ Fatality or trauma causing rupture of swim bladder and non-auditory bleeding and substantial hemorrhaging of eyes and tissues (e.g., kidney or liver). ♦ Permanent hearing loss via a permanent threshold shift that is irreversible. ♦ All aquatic fauna permanently displaced vertically or horizontally from the sound field for the duration of the noise-generating activity. ♦ High level of auditory masking of biologically important sounds (e.g., vocalization) in non-injurious sound field.
High	♦ Aquatic fauna exposed to high levels of impulsive, continuous or intermittent noise. ♦ Aquatic fauna exposed to high level of non-impulsive, continuous broadband noise. ♦ Permanent hearing loss via a permanent threshold shift that is irreversible. ♦ Noise-sensitive aquatic fauna that are temporarily displaced vertical or horizontally from the sound field for the duration of the noise-generating activity. ♦ Medium level of auditory masking of biologically important sounds (e.g., vocalization).
Medium	♦ Aquatic fauna exposed to moderate levels of impulsive continuous or intermittent noise. ♦ Aquatic fauna exposed to moderate level of non-impulsive, continuous broadband noise that is tolerated. ♦ Temporary hearing loss via a temporary threshold shift that is reversible within a few days. ♦ Noise-sensitive aquatic fauna that are temporarily displaced vertically or horizontally from the sound field but return to previously occupied areas during the noise-generating activity. ♦ Low level of auditory masking of biologically important sounds (e.g., vocalization).
Low	♦ Aquatic fauna exposed to low levels of non-impulsive, continuous broadband noise. ♦ Temporary hearing loss via a temporary threshold shift that is reversible within a few hours. ♦ Aquatic fauna not displaced vertically or horizontally from the sound field during the noise-generating activity through habituation. ♦ Temporary hearing loss via a temporary threshold shift that is reversible within a few hours. ♦ Auditory masking is weak except near the noise source.
Minimal	♦ Aquatic fauna exposed to low levels of non-impulsive, continuous or intermittent noise. ♦ Aquatic fauna remain in the sound field during the noise-generating activity through habituation or perceiving the sound field as non-threatening. ♦ Temporary hearing loss via a temporary threshold shift that is reversible within a few minutes. ♦ Auditory masking absent but may occur near the noise source. ♦ Aquatic animal is unlikely to approach a high intensity noise source due to the detection of an underwater noise gradient or is exposed for a very short period that is insufficient to cause auditory damage.

12.4.2.2 Sensitivity of Receptors

Table 12.25 shows the descriptors used to categorize the sensitivity of receptors to underwater noise. This differs to the approach used to assess the sensitivity of aquatic biodiversity in Sections 11.5 and 12.3, which is largely based on IUCN Red List threatened species status. Instead, categorization is based on species sensitivity with specific regard to underwater noise. The difference in approach is illustrated by considering the largetooth sawfish (*Pristis pristis*) and the northern river shark (*Glyphis garricki*). Both these species are classified as Critically Endangered under the IUCN Red List and therefore have a sensitivity of Very High in the freshwater and marine biodiversity impact assessments (Sections 11.5 and 12.3). Considering sensitivity to underwater noise, these two fish are cartilaginous fish species, which are only sensitive to particle motion and vibration and not to sound pressure (Myrberg, 2001); therefore, the former approach giving a sensitivity rating of Very High is inappropriate for underwater noise since these fish do not hear or sense sound pressure and therefore have a ***Low*** sensitivity.

Table 12.25 presents sensitivity criteria for noise-sensitive aquatic fauna used in the impact assessment whereby sensitivity relates solely to sensitivity to underwater noise. The acoustic threshold criteria, behavioral responses, modification of vocalization and distribution apply to a range of aquatic fauna, including cetaceans, sea turtles, freshwater turtles, crocodiles and dugongs. Additional emphasis is placed on fish sensitivity in the descriptors, as they are the most abundant sensitive receptors in the PAOI likely to be exposed to underwater noise. Other abundant faunal groups include zooplankton, micronekton (e.g., larval stages of fish and decapods) and invertebrates, which do not respond to sound pressure but rather to particle motion and vibration. Most zooplankton studies relate to the effects of very high-energy impulsive noise from marine geophysical surveys using air guns (e.g., McCauley et al., 2017) with fewer studies for non-impulsive noise sources. A lack of acoustic damage or disturbance threshold criteria exists for both impulsive and non-impulsive noise impacts to zooplankton and micronekton, and threshold criteria for particle motion or vibration do not exist; therefore, water column zooplankton and micronekton, and benthic invertebrates have not been considered further in this assessment.

Table 12.25 – Criteria for the Sensitivity of a Receptor

Sensitivity	Description
Very High	♦ Acoustic threshold criteria for acoustic damage (tissue or gas-filled organs) are exceeded. ♦ Acoustic threshold criteria for onset of permanent threshold shift are exceeded causing permanent hearing loss due to auditory cell death or nerve damage that is irreversible.
High	♦ Acoustic threshold criteria for onset of permanent threshold shift are not exceeded. ♦ Acoustic threshold criteria for onset of temporary threshold shift are exceeded. ♦ Acoustic threshold criteria for disruptive behavioral disturbances* are exceeded. ♦ Highly noise-sensitive fish with a swim bladder connected to their ear or gas-containing spheres (prootic bullae) (e.g., sardines, anchovies, freshwater herrings and catfish). ♦ Group 4[#] fish that hear sounds below 1,000 Hz in a similar manner to fish in Group 1 see below) but their hearing range extends up to at least 4 kHz and some species are able to detect sounds to over 180 kHz. ♦ Major changes in locomotion speed, direction or dive profile and major avoidance of sound sources and major shift in individual or group distribution (aggregation or separation). ♦ Prolonged cessation or modification of vocal behavior.
Medium	♦ Acoustic threshold criteria for onset of permanent threshold shift and temporary threshold shift or behavioral disturbance are not exceeded. ♦ Moderately noise-sensitive fish with a swim bladder close to their ear and a type of structure mechanically coupled to the inner ear (e.g., marine catfish and sciaenids [croakers and drummers]).

Table 12.25 – Criteria for the Sensitivity of a Receptor (cont'd)

Sensitivity	Description
Medium (cont'd)	♦ Group 3# fish that hear sounds to 3,000 Hz or more, and their hearing sensitivity (which is pressure driven), is better than in fish of Groups 1 and 2 (see below). ♦ Moderate changes in locomotion speed, direction or dive profile and moderate avoidance of sound sources (temporary vertical and lateral displacement) and moderate shift within group distribution (aggregation or separation). ♦ Minor cessation or modification of vocal behavior.
Low	♦ Acoustic threshold criteria for onset of permanent threshold shift and temporary threshold shift or behavioral disturbance are not exceeded. ♦ Potentially noise-sensitive fish with a swim bladder distant from their ear but have no known structures in the auditory system that would enhance hearing of sound pressure (e.g., wide range of fish species including some tuna with swim bladders which includes yellowfin tuna). ♦ Group 2# fish that hear sounds from below 50 Hz and up to 800 to 1,000 Hz (though several probably only detect sounds to 600 to 800 Hz). ♦ Minor but temporary avoidance of anthropogenic sound sources. ♦ Brief but minor shift within group distribution (aggregation or separation). ♦ Minor changes in locomotion speed, direction or dive profile but no avoidance of sound sources, and temporary orientation behavior within sound fields during noise-generating activity. ♦ Brief or minor cessation or modification of vocal behavior during noise-generating activity.
Minimal	♦ Acoustic threshold criteria for onset of permanent threshold shift and temporary threshold shift or behavioral disturbance are not exceeded. ♦ Noise-insensitive fish that do not have a swim bladder or other gas-filled organ and respond to particle motion or vibration only (e.g., sharks and skates, mackerels and most tuna), flatfish and other bottom living fish, and also include fish eggs and larvae. ♦ Group 1# fish are likely to use only particle motion for sound detection and the highest sound frequency detected is likely to be no greater than 400 Hz, with poor sensitivity compared to fish with swim bladders. ♦ Insensitivity to underwater noise at or just above ambient background noise levels; that is within natural variability of baseline noise. ♦ Brief and temporary orientation response to sound field during noise-generating activities. ♦ No significant cessation or modification of vocal behavior. ♦ Zero sensitivity if an aquatic animal is not present within a sound field.

* Disruptive behavioral disturbance includes changes in social interaction, feeding, movement, separation distance between mother and infant, and temporary or permanent habitat abandonment.
# Classification of fish hearing group sensitivities by Popper (2012).

12.4.2.3 Impact Significance

The significance of an impact on a receptor is determined by combining the likely magnitude of the impact on that receptor shown in Table 12.24 with its sensitivity shown in Table 12.25 via the significance assessment matrix shown in Table 12.26.

Table 12.26 – Impact Significance Matrix Relevant to Underwater Noise

Magnitude of Impact	Sensitivity of Receptor				
	Very High	**High**	**Medium**	**Low**	**Minimal**
Very High	Severe	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

12.4.2.4 Spatial and Temporal Scope

The spatial scope of the underwater noise impact assessment is centered on the navigable Purari River transport corridor in PRL-15 and the Purari River delta (i.e., estuaries and distributaries), and the marine section of the proposed export pipeline route from nearshore Orokolo Bay to the offshore Gulf of Papua to a nearshore point immediately to the west of Caution Bay, which is the lowest astronomical tide (LAT) mark.

The temporal scope covers underwater noise generated during the construction, operations and decommissioning Project phases.

12.4.2.5 Assessment Criteria

No explicit underwater noise acoustic threshold criteria or guidelines exist for aquatic fauna in Papua New Guinea; therefore, a literature search was conducted to collate overseas underwater noise level criteria to protect noise-sensitive aquatic fauna. The assessment criteria adopted in this impact assessment are based on peer-reviewed and widely accepted literature. When acoustic threshold criteria for aquatic fauna were unavailable, a literature review was undertaken to identify the distances at which noise-sensitive aquatic fauna may show behavioral reaction to various identified noise sources and the received sound pressure or sound exposure levels that initiated the reaction.

Desktop modeling and assessment of underwater noise was undertaken to inform the impact assessment (see Part 1 of Volume 3). Project-related underwater noise was assessed at representative locations in the riverine environments of PRL-15 and the river transport corridors, and the nearshore and offshore marine segments of the offshore export pipeline route described in Section 12.4.1 and shown in Figure 8.29.

Tables 12.27 to 12.32 summarize the acoustic threshold criteria adopted for the underwater noise impact assessment and identify the literature source for the adopted criteria. Part 1 of Volume 3 provides further detail regarding the source information for the criteria. Further explanation of the technical units and terms used to describe underwater noise levels in Table 12.27 to 12.32 is provided in Section 8.7.

Table 12.27 – Adopted Acoustic Threshold Criteria for Cetacean Behavioral Disturbance for All Noise Sources

Acoustic Impact	Acoustic Threshold Criterion (dB re 1μPar_{ms})
Potential high-level behavioral reaction to impulsive noise and potential permanent physiological auditory damage (i.e., irreversible reduction in hearing sensitivity).	180
Potential moderate-level behavioral reaction to impulsive noise and potential temporary physiological auditory damage (i.e., reversible reduction in hearing sensitivity with full recovery after exposure).	160
Potential moderate-level behavioral reaction to non-impulsive, continuous broadband noise but with no physiological auditory damage.	120

Source: McCauley et al. (2000); Environment Australia (2001); Southall et al., (2007); DEWHA (2008); NMFS (2018).

Table 12.28 – Adopted Non-impulsive Noise Acoustic Threshold Criteria for Cetaceans

Hearing Group	Hearing Range (Frequency)	Non-impulsive Sound Exposure Level (dB re 1 μPa²•s)	
		Permanent Threshold Shift	Temporary Threshold Shift
Low frequency cetaceans (baleen whales)	7 Hz to 35 kHz	199	179
Mid frequency cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz	198	178
High frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	275 Hz to 160 kHz	173	153

Source: NMFS (2018); Finneran (2016).

Table 12.29 – Adopted Impulsive Noise Acoustic Threshold Criteria for Cetaceans

Hearing Group	Hearing Range (Frequency)	Permanent Threshold Shift		Temporary Threshold Shift	
		Sound Exposure Level	Peak Sound Pressure Level (SPL_{pk})	Sound Exposure Level	Peak Sound Pressure Level (SPL_{pk})
		dB re 1μPa²•s	dB re $1μPa_{rms}$	dB re 1μPa²•s	dB re $1μPa_{rms}$
Low frequency	7 Hz to 35 kHz	183	219	168	213
Mid frequency	150 Hz to 160 kHz	185	230	170	224
High frequency	275 Hz to 160 kHz	155	202	140	196

Source: NMFS (2018). SEL threshold criteria include a marine mammal auditory weighting (Finneran, 2016).

Table 12.30 – Adopted Acoustic Threshold Criteria for Fish

Acoustic Impact	Acoustic Threshold Criterion
Fish injury thresholds and onset of permanent threshold shift (bony fish)	Received peak sound pressure level of 206 dB re 1 $μPa_{pk}$ rms
	Cumulative sound exposure level of 203 dB re 1 μPa²•s
Behavioral disturbance (bony and cartilaginous fish)	150 dB re 1 $μPa_{rms}$

Source: Halvorsen et al. (2012a, 2012b); Casper et al. (2012a, 2012b); Casper et al. (2013 a, 2013b); WSDOT (2019).

Table 12.31 – Summary of Adopted Acoustic Threshold Criteria for Turtles and Crocodiles

Acoustic Impact	Acoustic Threshold Criterion
Physical injury and onset of permanent threshold shift	Received peak sound pressure level of 208 dB re 1 $μPa_{pk}$
Behavioral disturbance (increased swimming speed and behavior becomes increasingly erratic with avoidance probable)	Received average sound pressure level of 175 dB re 1 $μPa_{rms}$

Source: Gavrilov et al. (2016); Popper et al. (2006); McCauley et al. (2000).

Table 12.32 – Summary of Adopted Acoustic Threshold Criteria for Dugongs

Acoustic Impact	Acoustic Threshold Criterion	
	Peak Sound Pressure Level (dB re 1 μPa$_{pk}$)	Weighted Sound Exposure Level (dB re 1 μPa^2•s)
Impulsive Noise		
Physical injury and onset of permanent threshold shift	226	190
Non-injurious and onset of temporary threshold shift	220	175
Non-impulsive Noise		
Behavioral disturbance (increased swimming speed and behavior becomes increasingly erratic with avoidance probable)	220	175

Source: Impulsive noise criteria by Finneran, 2016). Non-impulsive noise criterion by McPherson et al. (2017).
* Unit is dB re 1 μPa$_{rms}$. – Denotes not applicable.

12.4.3 Identification of Potential Impacts

Potential impacts to underwater noise can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. Specific embedded design controls are identified throughout this section where they address potential impacts.

12.4.3.1 Potential Impacts of Underwater Noise

The potential impacts of underwater noise on aquatic fauna will vary depending on a range of factors including the noise sensitivity of the aquatic fauna, characteristics of the noise source (e.g., impulsive or non-impulsive continuous noise), noise propagation and transmission loss, and river, estuary or sea bathymetry and bottom substrate composition.

The response or potential impacts associated with underwater noise to aquatic fauna may be broadly categorized into the following five categories, which increase in severity from the lowest to the highest: i) audibility; ii) auditory masking; iii) behavioral response; iv) physiological impacts; and v) trauma or fatality. Further detail regarding the five categories of potential impacts to aquatic fauna is provided in the following sections.

Figure 12.13 summarizes the theoretical impact zones for these impact categories relative to an underwater noise source (represented by a black dot), which is located in the center. Received noise levels at the edge of these zones have been calculated on the estimated noise source levels due to Project activities and sound transmission loss. These calculations are provided in Part 1 of Volume 3. The calculated noise levels were then compared to the acoustic threshold criteria (see Section 12.4.2) to assess the residual impacts of underwater noise (see Section 12.4.5).

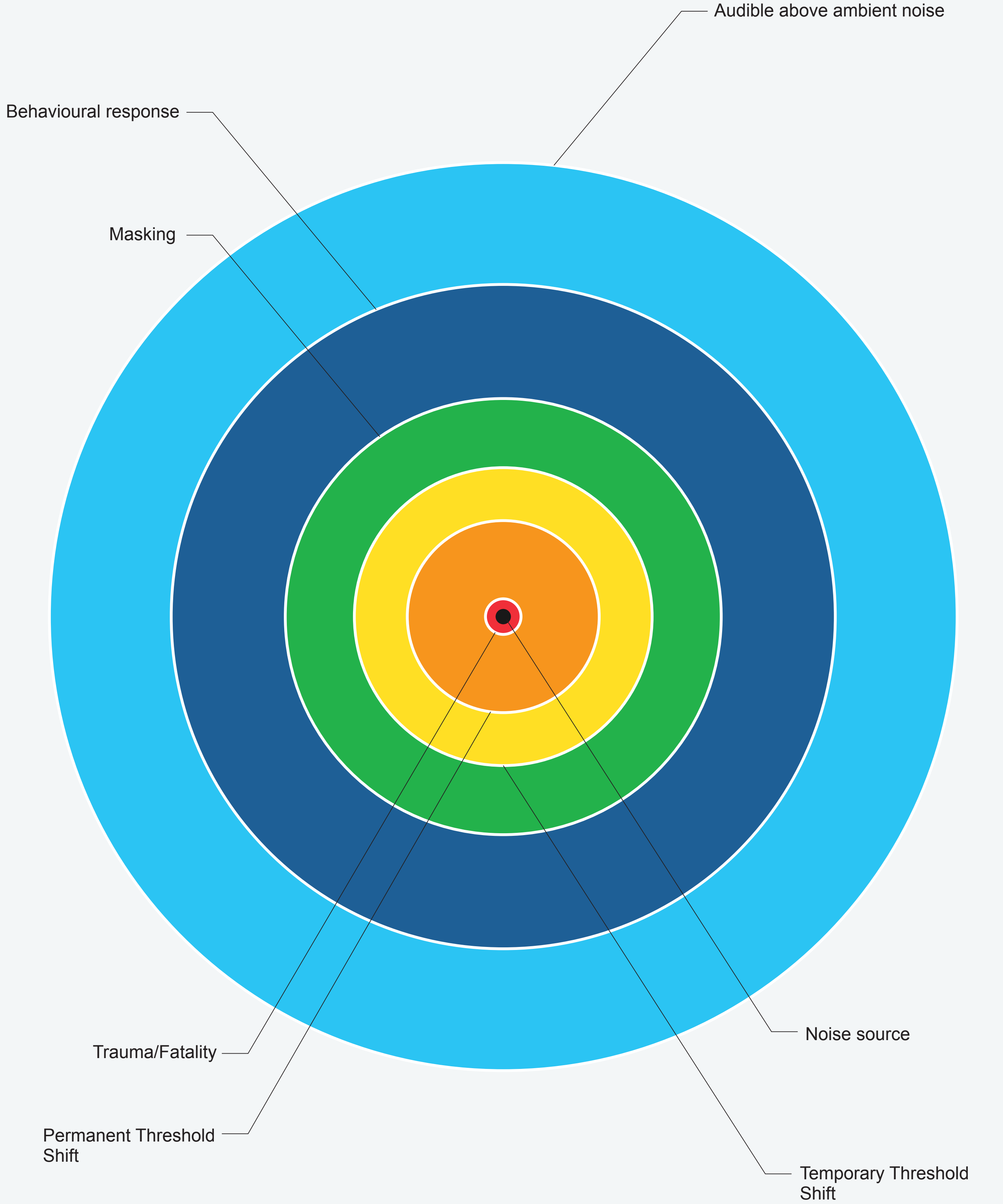
Audibility

Project-generated underwater noise is at a level that can be perceived by aquatic fauna but will depend on ambient background noise. The distances of audible detection of Project-generated noise by aquatic fauna will be larger when there is low ambient noise and smaller under high ambient noise conditions.

POTENTIAL UNDERWATER NOISE IMPACT ZONES SURROUNDING A NOISE SOURCE

Papua LNG Project | Environmental Impact Statement

FIGURE 12.13



Note: The widths of the theoretical impact zones are illustrative only and have no significance.

Adapted from Richardson et al. (1995).

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Auditory Masking

Project-generated underwater noise has the potential to mask communication amongst those aquatic fauna that produce sound for social cohesion, reproductive displays and territorial defense. Auditory masking occurs when anthropogenic noise prevents an aquatic animal from hearing these sounds. Masking of biologically important sounds may interfere with communication and social interaction and cause behavioral changes.

Behavioral Response

Behavioral responses of aquatic fauna to underwater noise include changes in vocalization, resting, diving and breathing patterns, changes in mother-infant spatial relationships, and potential avoidance of a noise source (NRC, 2003). Potential behavioral impacts can be categorized as disruptive or non-disruptive. Disruptive behavioral impacts include substantial changes in behavior of aquatic animals exposed to a sound. This may include long-term changes in behavior and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns. Potential non-disruptive impacts relate mainly to temporary behavioral responses to increased underwater noise, with aquatic fauna showing subtle behavioral changes (e.g., increased swimming, breathing or diving rates).

Physiological Impacts

Potential physiological impacts to aquatic fauna may be auditory or non-auditory. These impacts are discussed in more detail in the following sections.

Auditory Physiological Impacts

Exposure to loud or intense noise levels may cause permanent or temporary hearing loss, due to physiological damage to an aquatic animal's auditory system. Two types of potential auditory impact have been identified and are described in the following sections.

<u>Temporary Threshold Shift</u>

The onset of temporary threshold shift represents a temporary effect on hearing that is reversible. The effect on hearing will typically decrease over time after the underwater noise source is stopped and an aquatic animal's hearing will return to pre-disturbance noise levels in a few days, hours or minutes depending on the intensity and duration of the noise to which an aquatic animal was exposed. The effect on hearing is therefore reversible and does not represent physical injury or permanent hearing loss.

<u>Permanent Threshold Shift</u>

Exposure of an aquatic animal to intense underwater noise levels can produce a permanent threshold shift, which is a permanent shift in hearing sensitivity caused by irreversible damage to the sensory hair cells of the ear. Such a threshold shift represents a physical injury that causes hearing loss or degradation that is irreversible due to the permanent nature of auditory tissue damage.

Non-auditory Physiological Impacts

Intense underwater noise can induce physiological responses to noises that are non-auditory, such as minor internal bleeding or hematomas. There are no published guidelines or acoustic threshold criteria for potential non-auditory physiological impacts. The most sensitive aquatic fauna are species with swim bladders or other gas-filled organs, especially those fish species that have a swim bladder connected to the ear.

Trauma or Fatality

Exposure of an aquatic animal to extremely intense underwater noise levels can cause physical trauma or death. There are published acoustic threshold criteria above which the mortality of an aquatic animal is predicted to occur if it remains within the intense sound field.

The most sensitive aquatic fauna are species with swim bladders or other gas-filled organs, especially those that have a swim bladder connected to the ear.

12.4.3.2 Project Sources for Underwater Noise

Project activities that generate underwater noise and may potentially cause adverse impacts on aquatic fauna, and are considered in the residual impact assessment, are:

- Impact pile driving operations at the quay in the Purari River at the Logistics Base in PRL-15.
- Nearshore trenching and pile driving operations in Orokolo Bay and nearshore trenching in Caution Bay for the export pipeline.
- River dredging operations at the quay in the Purari River.
- Offshore construction (e.g., pipelaying and existing PNG LNG Gas Pipeline crossing works).
- River and marine vessel traffic.

The following embedded design controls address these potential impacts:

- All vehicles (including vehicles and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired. [ED019].
- Minimize noise from machinery, plant and equipment, as far as practicable [ED031].

As indicated earlier, LNG facilities inside the PNG LNG Plant lease boundary are excluded from the scope of this EIS, the related indicative information presented here will be refined as part of the downstream Papua LNG EIS.

12.4.4 Proposed Mitigation and Management Measures

Table 12.33 describes mitigation and management measures to further reduce impacts due to underwater noise. Project underwater noise reduction strategies focus mainly on the Project's construction phase. No additional mitigation or management measures are proposed for Project operations or decommissioning, as the impacts relate primarily to shipping and barging activities where there is limited scope for underwater noise reduction. Mitigation and management in Caution Bay in the PNG LNG project lease area will be further aligned with the PNG LNG project and downstream Papua LNG project.

The Project's principle impulsive noise sources relate to the use of diesel-driven or hydraulic impact hammers to drive steel pipe casings or sheet piles at the quay of the Logistics Base on the Purari River in PRL-15, and during trenching for the shoreline crossing at Orokolo Bay. The noise from impact hammers is impulsive in nature and results from the impact of the hard surface of the hammer with that of the steel pile, which creates sounds that are short, sharp and high in amplitude.

Table 12.33 – Underwater Noise Mitigation and Management Measures

Potential Impact	Mitigation Strategy	Relevant Management Plan
Physiological injury or behavioral disturbance to freshwater fauna due to underwater noise from impact driving of: ♦ Steel pipe casings or sheet piles at the Purari River quay. ♦ Sheet piles during trenching at Orokolo Bay.	♦ Provide for a ‘soft start’ for impact hammer piling activities to allow transitory and resident fauna in the vicinity the opportunity to move away before sound levels reach maximum levels [EM039]. ♦ If noise-sensitive aquatic species are sighted during the piling activities, initiate shut down procedures and stop the operations until the animal is observed to leave the noise exclusion zone or a set period has passed [EM040].	Biodiversity Action Plan
Physiological injury or behavioral disturbance to freshwater fauna due to underwater noise from river dredging at the quay	No additional mitigations measures proposed.	-
Physiological injury or behavioral disturbance to aquatic fauna due to underwater noise from vessel traffic in the Gulf of Papua and along the river transport corridor.	No additional mitigations measures proposed.	-
Physiological injury or behavioral disturbance to marine fauna due to underwater noise from offshore pipelaying and existing PNG LNG Gas Pipeline crossing works along the export pipeline route in the Gulf of Papua.	No additional mitigations measures proposed.	-

Note: A dash (-) denotes no management plan is required.

12.4.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to underwater noise subject to the embedded design controls in Section 12.4.3 and the successful implementation of the mitigation and management measures in Section 12.4.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

The impact assessment presented in this section is based on the underwater noise modeling and information presented in Part 1 of Volume 3. Where residual impacts have been assessed as being more than ***Negligible,*** further detail on the assessment is provided in the following sections. Detail on impacts assessed to be ***Negligible*** is not always provided; however, for all negligible impacts, this impact significance was based on a ***Minimal*** magnitude combined with sensitivities between ***Minimal*** and ***Medium***, depending on the faunal group and the underwater noise source. The results of these individual assessments are also presented in the summary table provided in Section 12.4.6.

12.4.5.1 Disturbance or Injury of Freshwater Fauna from Pile Driving at the Quay

During the construction phase, pile driving of steel pipes and sheet piles is required when installing the quay at the Logistics Base. The quay is located about 10 km downstream of the existing wharf at Herd Base. The residual impacts to freshwater fish, crocodiles and freshwater turtles are described in the following sections.

Freshwater Fish

The adopted acoustic damage threshold criterion of a peak sound pressure level of 206 dB re 1μPa$_{pk}$ rms for bony fish is predicted to be exceeded within 5 m of impact hammer pile driving. Peak noise levels are predicted to only affect those individual fish that are stationary and in this impact zone. The soft start of the impact hammer noise levels is expected to drive fish away from the immediate vicinity of pile driving; therefore, acoustic damage to fish is not predicted.

Exceedance of the acoustic behavioral disturbance threshold criterion of 150 dB re 1 μPa$_{rms}$ for all fish is predicted to occur up to 562 m from the source. The Purari River at this location is about 250 m wide; therefore, the threshold is exceeded across the total width of the river. This suggests that migration or other longitudinal fish movements could be temporarily disrupted during impact pile driving, although breaks between pile driving would allow for uninhibited movement during daylight hours and at nighttime.

Noise-sensitive fish (i.e., with a swim bladder connected to their ear, such as catfish and anchovies) have a ***High*** sensitivity to impact hammer pile driving, while the magnitude of impact is assessed as ***Minimal***. The residual impacts to noise-sensitive fish are therefore assessed to be ***Minor.*** This conclusion is based on the medium-term duration (i.e., two months) of impact pile driving, its intermittent nature, and the ability of fish to detect underwater noise gradients and avoid areas of higher noise levels closer to the pile driving sound source.

Residual impacts to noise-tolerant fish (i.e., without a swim bladder or other gas-filled organ, such as sawfish species) are assessed as ***Negligible***.

Crocodiles

Both saltwater crocodiles (*Crocodylus porosus*) and freshwater New Guinea crocodiles (*Crocodylus novaeguineae*) are known to respond to low frequency sounds in the 50 to 1,500 Hz range and, in addition to their hearing system, the scales of their face and bodies are sensitive to vibrations travelling through water (Kaplan, 2014). Crocodiles are likely to sense the vibrations from impact pile driving and may avoid the river segment affected by impact pile driving noise when active pile driving is taking place; however, given that both saltwater and freshwater crocodiles tend to be nocturnal, they may pass through this area during the night when pile driving is not occurring. Consequently, crocodile sensitivity to pile driving noise is ***Low***, while the magnitude is ***Medium***. The residual impact rating of pile driving on crocodiles is therefore assessed to be ***Minor***.

Freshwater Turtles

Exceedance of the behavioral disturbance threshold criterion of 175 db re 1 μPa$_{rms}$ for turtles is predicted to occur up to 32 m from the pile driving noise source, while injury thresholds are not exceeded. A 'soft start' will be implemented to allow noise-sensitive species to move away before maximum noise levels are reached, and shutdown procedures will be initiated if sensitive species are sighted. Residual impacts to turtles are therefore assessed to be ***Negligible.***

12.4.5.2 Disturbance or Injury of Freshwater Fauna from River Dredging

Dredging requirements will be determined during FEED; however, it is anticipated that dredging of approximately 6,000 m^3 of sand and sediment from the Purari River adjacent to the Logistics Base will be required to accommodate the drafts of various Project vessels and barges.

Freshwater Fish

Exceedance of the acoustic damage threshold criterion for all bony fish of a peak sound pressure level of 206 dB re 1μPa$_{pk}$ rms is not predicted to occur at the dredging site; therefore, acoustic damage to fish is not predicted from the non-impulsive, continuous or intermittent broadband noise generated by dredging. Exceedance of the behavioral disturbance threshold criterion of 150 dB re 1 μPa$_{rms}$ for all fish is predicted to occur up to 32 m from the dredging noise source. This distance represents a localized impact zone around the dredge, which would not inhibit fish migration or other longitudinal movements in adjacent parts of the river near the active dredging site. Fish are expected to avoid areas of higher noise levels closer to river dredging.

The sensitivity of noise-sensitive freshwater fish (e.g., those with a swim bladder connected to their inner ear, such as catfish and anchovies) to dredging noise is assessed as ***High*** while the magnitude is ***Minimal***. The residual impact rating of dredging noise for noise sensitive freshwater fish is therefore assessed to be ***Minor***.

The residual impact rating of noise-tolerant (or insensitive) fish (i.e., without a swim bladder or other gas-filled organ, such as sawfish species) is assessed to be ***Negligible***.

Freshwater Turtles and Crocodiles

Injury to freshwater turtles is not predicted to occur from the non-impulsive, continuous or intermittent noise generated by dredging given that exceedances of the acoustic threshold criterion for injury of a peak sound pressure level of 208 dB re 1μPa$_{pk}$ is not predicted to occur during dredging. Exceedance of the behavioral disturbance threshold criterion of 175 dB re 1 μPa$_{rms}$ for freshwater turtles and crocodiles is predicted to only occur within 2 m of the river dredging noise source. Residual impacts to freshwater turtles and crocodiles are therefore assessed to be ***Negligible***.

12.4.5.3 Disturbance or Injury of Marine Fauna from Nearshore Trenching and Piling Activities

Nearshore trenching is proposed at the shore crossing of the offshore export pipeline route in Orokolo Bay and Caution Bay for excavation, pipeline installation and post-installation burial. Sheet piles will also be driven near the water’s edge at Orokolo Bay to support trench walls. The assessment of nearshore trenching and piling activities has been completed for Orokolo Bay given the additional high impact sound generating activity at this location; however, the assessment is also applicable to trenching at Caution Bay.

Cetaceans

Low frequency hearing cetaceans, i.e., baleen whales, are unlikely to be found in the shallow nearshore waters of Orokolo Bay or Caution Bay, given their rare occurrence in the Gulf of Papua in general. Nonetheless, if present, acoustic damage impacts are not expected given the mitigation and management measures outlined in Section 12.4.4. Exceedance of the impulsive noise behavioral disturbance threshold of 160 dB re 1 μPa$_{rms}$ for low frequency cetaceans is predicted to occur up to 100 m from the nearshore pile driving operation. Given the habitat availability in the Gulf of Papua, this is a very small impact zone. The residual impact of nearshore trenching and pile driving is assessed as ***Negligible*** for all cetacean hearing groups (i.e., low, mid and high frequency).

Dugongs

Neither the physical injury threshold of 226 dB re 1 μPa$_{pk}$ or the behavioral disturbance threshold of 220 dB re 1 μPa$_{pk}$ for dugongs are exceeded at the in-water nearshore pile driving noise source. The residual impact of nearshore trenching and in-water pile on dugongs is assessed as ***Negligible.***

Sea Turtles and Crocodiles

The physical injury threshold of 208 dB re 1 μPa_{pk} for sea turtles or crocodiles is not exceeded at the nearshore trenching and in-water piling operation. The behavioral effects threshold of 175 dB re μPa_{rms} for turtles and crocodiles is predicted to be exceeded up to 2.2 m from nearshore trenching and in-water piling activities, which represents a small and highly localized impact zone. Residual impacts are therefore assessed to be ***Negligible***.

Fish

Exceedance of the acoustic behavioral disturbance threshold criterion of 150 dB re 1 μPa_{rms} for all fish is predicted to occur up to 100 m from the nearshore pile-driving activity, which represents a small and localized area. Thresholds for injury to bony fish are not predicted to occur from the non-impulsive, intermittent broadband noise generated during the backhoe trenching cycle. Residual impacts from in-water piling activities are therefore assessed to be ***Negligible***.

12.4.5.4 Disturbance or Injury of Freshwater Fauna from River Vessel Noise

The assessment of residual impacts of river vessel traffic has focused on Assessment Location 7, which is located downstream of the Logistic Base and is representative of other main channel river corridors (see Section 12.4.1 and Figure 8.29).

Fish

Exceedance of the acoustic behavioral disturbance threshold criterion of 150 dB re 1 μPa_{rms} for all fish is predicted to occur within 10 m from a typical barge, which represents a small area or volume of water mainly below and astern of the vessel. Noise above the threshold when the vessel is passing may cause behavioral responses in fish such as temporary vertical or horizontal displacement. The non-impulsive, broadband noise generated by vessel engines and propellers is unlikely to exceed thresholds for injury to bony fish. Residual impacts are therefore assessed to be ***Negligible***.

Freshwater Turtles and Crocodiles

River vessel noise does not exceed the thresholds for behavioral effects or injury to turtles and crocodiles. Residual impacts are therefore assessed to be ***Negligible***.

12.4.5.5 Disturbance or Injury of Marine Fauna from Offshore Construction Activities

The assessment of residual impacts of offshore construction has focused on underwater noise generated by pipelaying activities and concrete mattress installation to cross the existing PNG LNG Gas Pipeline (Section 4.10.6).

During their review of impacts on marine mammals due to underwater noise, Richardson et al. (1995) did not specifically note marine pipelaying as a distinct source of anthropogenic noise. It is reasonable to conclude that actual laying of the pipe on the seabed is unlikely to be a source of any noise of environmental significance. Most of the underwater noise generated by offshore construction relates to the non-impulsive, intermittent or continuous broadband noise generated by the construction support vessels (e.g., propulsion and thrusters) rather than the quieter noise levels generated by either the laying of the pipeline on the seabed or installing concrete mattresses to cross the existing PNG LNG Gas Pipeline.

Cetaceans

The non-impulsive broadband noise behavioral disturbance threshold of 120 dB re 1 μPa_{rms} for low-frequency hearing cetaceans (e.g., baleen whales) extends up to 15 km from pipelay activities and pipeline crossing construction activities. Given the habitat availability in the wider Gulf of Papua, this represents a relatively small area in the wider Gulf of Papua. Low-frequency hearing cetaceans, if present, are expected to detect the underwater noise gradient and not approach the sites of offshore construction activities. The residual impact of offshore construction is assessed as ***Negligible*** for all cetaceans, including mid- and high frequency hearing cetaceans that are less sensitive to non-impulsive broadband underwater noise.

Dugongs

Dugongs are generally absent in the offshore waters of the Gulf of Papua but do occur along the coast where they may be exposed to underwater noise propagating towards the coast from offshore construction activities. While there are no acoustic threshold criteria for behavioral disturbance in dugongs, McPherson et al. (2017), recommended that the non-impulsive broadband noise behavioral disturbance threshold of 120 dB re 1 μPa_{rms} for cetaceans also be adopted for dugongs; although, this is likely to be overprotective given the poorer hearing ability of dugongs compared to low-frequency cetaceans.

The adopted non-impulsive broadband noise behavioral disturbance threshold of 120 dB re 1 μPa_{rms} for dugongs extends up to 15 km from pipelay activities and pipeline crossing construction activities. Given that dugongs live or transit close to the coast where ambient noise levels are around an average of between 110 and 120 dB re 1 μPa_{rms}, the residual impacts of offshore construction are assessed to be ***Negligible***.

Sea Turtles and Crocodiles

The acoustic threshold criterion of 175 dB re 1 μPa_{rms} for behavioral disturbance in sea turtles and saltwater crocodiles is not exceeded further than 3.4 m from an offshore construction activity, which represents a very small acoustic disturbance impact zone. The residual impacts of offshore marine construction on sea turtles and crocodiles are assessed as ***Negligible***.

Fish

Acoustic thresholds for injury to marine fish are not predicted to be exceeded due to the non-impulsive, broadband noise generated during pipelay and pipeline crossing construction activities.

The acoustic disturbance threshold of 150 dB re 1 μPa_{rms} for marine fish is exceeded up to 158 m from pipelaying or concrete mattress installation. This represents a small behavioral disturbance impact zone of limited duration, as the pipelaying progresses along the export pipeline route. Overall, the residual impacts of offshore construction on bony and cartilaginous marine fish species are assessed to be ***Negligible***.

12.4.5.6 Disturbance or Injury of Marine Fauna from Marine Vessel Noise

The residual impacts of marine vessel traffic have focused on vessels transiting the Gulf of Papua. Background noise levels have been estimated at Assessment Location 2 (South of Kerema) and Assessment Location 3 (South of Ihu), and are representative of other locations along the offshore marine segment of the export pipeline route.

Cetaceans

Cetaceans are unlikely to be found in the shallow nearshore waters of Caution Bay, given their very rare occurrence in the Gulf of Papua in general. Nonetheless, if present, the underwater noise radiated by Project vessels crossing the Gulf of Papua does not exceed the acoustic damage threshold criterion of 180 dB re 1 μPa_{rms} for all cetaceans, as the vessel source sound pressure level does not exceed 175 dB re 1 μPa at 1 m. Exceedance of the acoustic behavioral disturbance threshold criterion of 120 dB re 1 μPa_{rms} for cetaceans is predicted to occur within 562 m from the vessels. This represents a small area in the Gulf of Papua. Low frequency hearing cetaceans (i.e., baleen whales) passing through the gulf sense underwater noise gradients and are anticipated to avoid or deviate around Project vessels, as they would do with other third-party ships and shipping lanes in general in the gulf. Mid-frequency and high frequency hearing cetaceans, such as toothed whales and dolphins, are less affected by vessel noise than low frequency cetaceans. Overall residual impacts are assessed to be ***Negligible*** for all cetacean hearing groups (i.e., low, mid and high frequency).

Dugongs

As for cetaceans, exceedance of the non-impulsive noise behavioral disturbance threshold criterion of 120 dB re 1 μPa_{rms} for dugongs is predicted to occur within 562 m of the vessels passing through the nearshore waters of the Gulf of Papua, while thresholds for injury are not exceeded. This represents a small acoustic impact zone in which transiting dugongs may be behaviorally disturbed by the transient non-impulsive, broadband noise generated by passing vessels. Seagrass meadows (i.e., source of dugong food) do not occur in the nearshore areas adjacent to the Purari Delta or Orokolo Bay; hence dugongs are unlikely to be present in these locations. The residual impact of marine vessel noise is therefore assessed to be ***Negligible.***

Sea Turtles

Acoustic thresholds for behavioral effects or injury for turtles are not exceeded further than 1 m from marine vessels. Residual impacts are therefore assessed to be ***Negligible***.

Fish

Exceedance of the acoustic behavioral disturbance threshold criterion of 150 dB re 1 μPa_{rms} for all fish is predicted to occur up to 18 m from a typical Project vessel, which represents a very small area or volume of water mainly below and astern of the vessel. Noise above the threshold when the vessel is passing may cause behavioral responses in fish such as temporary vertical or horizontal displacement. These effects are expected to be limited to near-surface pelagic fish, since fish in deeper water will not be exposed to sound levels exceeding the threshold. The non-impulsive, broadband noise generated by vessel engines and propellers will not exceed thresholds for injury to bony fish. Residual impacts for all fish are therefore assessed to be ***Negligible***.

12.4.6 Summary of Residual Impacts for Underwater Noise

Table 12.34 provides a summary of the assessment of residual impacts due to underwater noise including in which Project phase and location these impacts are expected to occur. The table should be read in conjunction with the mitigation measures provided in Table 12.33.

All residual impacts to aquatic fauna due to underwater noise from Project activities are assessed to be ***Negligible*** to ***Minor***.

Table 12.34 – Summary of Assessment of Residual Impact Significance for Underwater Noise

Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Key Sensitive Receptor	Residual Impact	
						Sensitivity/ Magnitude	Significance
Jetty construction (Logistics Base) – impact driving of steel pipe casings or sheet piles at the river quay.	Physiological injury or behavioral disturbance to freshwater fauna due to underwater noise	River transport corridor	C	♦ EM039 ♦ EM040	Freshwater fish with swim bladders connected to the inner ear	High/ Minimal	Minor
					Freshwater and estuarine crocodiles	Low/ Medium	Minor
					Freshwater turtles	Minimal/ Minimal	Negligible
					Freshwater fish without swim bladders	Minimal/ Minimal	Negligible
Dredging at the Logistics Base	Physiological injury or behavioral disturbance to freshwater fauna due to underwater noise	River transport corridor	C, O	None	Freshwater fish with swim bladders connected to the inner ear	High/ Minimal	Minor
					Freshwater without swim bladders	Minimal/ Minimal	Negligible
					Freshwater turtles	Minimal/ Minimal	Negligible
					Crocodiles	Minimal/ Minimal	Negligible
Construction of shore crossings – marine nearshore trenching and impact pile driving of sheet piles.	Physiological injury or behavioral disturbance to marine fauna due to underwater noise	Orokolo Bay and Caution Bay	C	♦ EM039 ♦ EM040	Low frequency cetaceans	Medium/ Minimal	Negligible
					Mid frequency cetaceans (e.g., small toothed whales and dolphins)	Minimal/ Minimal	Negligible
					High frequency cetaceans (e.g., turbid water dolphins)	Minimal/ Minimal	Negligible
					Dugongs	Low/ Minimal	Negligible

Table 12.34 – Summary of Assessment of Residual Impact Significance for Underwater Noise (cont'd)

Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Key Sensitive Receptor	Residual Impact	
						Sensitivity/ Magnitude	Significance
Construction of shore crossings – marine nearshore trenching and impact pile driving of sheet piles (cont'd)	Physiological injury or behavioral disturbance to marine fauna due to underwater noise	Orokolo Bay and Caution Bay	C	♦ EM039 ♦ EM040	Sea turtles and crocodiles	Minimal/ Minimal	Negligible
					Marine fish in general	Low/ Minimal	Negligible
Offshore construction – pipelaying activity	Physiological injury or behavioral disturbance to marine fauna due to underwater noise	Offshore Gulf of Papua and Caution Bay (export pipeline route)	C	None	Low frequency cetaceans	Medium/ Minimal	Negligible
					Mid- and high-frequency cetaceans	Minimal/ Minimal	Negligible
					Dugongs	Low/ Minimal	Negligible
					Sea turtles and crocodiles	Minimal/ Minimal	Negligible
					Marine fish in general	Low/ Minimal	Negligible
Offshore construction – PNG LNG Gas Pipeline crossing	Physiological injury or behavioral disturbance to marine fauna due to underwater noise	Offshore Gulf of Papua and Caution Bay (export pipeline route)	C	None	Low frequency cetaceans	Medium/ Minimal	Negligible
					Mid- and high-frequency cetaceans	Minimal/ Minimal	Negligible
					Dugongs	Low/ Minimal	Negligible
					Sea turtles and crocodiles	Minimal/ Minimal	Negligible
					Marine fish in general	Low/ Minimal	Negligible

Table 12.34 – Summary of Assessment of Residual Impact Significance for Underwater Noise (cont'd)

Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Key Sensitive Receptor	Residual Impact	
						Sensitivity/Magnitude	Significance
Vessel traffic between the Gulf of Papua and PRL-15	Physiological injury or behavioral disturbance to estuarine and freshwater fauna due to underwater noise	River transport corridor	C, O, D	None	Freshwater fish in general	Low/ Minimal	Negligible
					Freshwater turtles	Low/ Minimal	Negligible
					Freshwater and estuarine crocodiles	Low/ Minimal	Negligible
Vessel traffic in the Gulf of Papua	Physiological injury or behavioral disturbance to marine fauna due to underwater noise	Orokolo Bay, offshore export pipeline route, Caution Bay and logistics supply route	C, O, D	None	Low frequency cetaceans (e.g., baleen whales)	Medium/ Minimal	Negligible
					Mid-frequency cetaceans (e.g., small toothed whales and dolphins) and high frequency cetaceans (e.g., nearshore turbid water dolphins)	Minimal/ Minimal	Negligible
					Dugongs	Low/ Minimal	Negligible
					Sea turtles.	Low/ Minimal	Negligible
					Marine pelagic and mid-water fish	Low/ Minimal	Negligible

C = Construction, O = Operations, D = Decommissioning and closure.

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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 13: Impacts - Social

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

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13. Impacts: Social

13.1 Introduction

The principal objective of the social impact assessment is to provide an assessment of potential adverse and positive social impacts arising from Project activities, and to identify mitigations to manage these impacts.

A full description of social baseline characteristics for the Project area of influence (PAOI) communities is presented in Chapter 9 based on Parts 14 to 18 of Volume 2. This chapter focuses on distinguishing key baseline characteristics, identifying, mitigating and assessing potential impacts based on interactions between various Project activities (Chapter 4) and PAOI communities presented in Figure 13.1.

13.1.1 PAOI Communities

The PAOI includes 39 villages (including one settlement) and one government station with a combined population in 2016 of 12,763 people. The main populations lie along the coast, an area inland of Orokolo Bay, and an area spanning the Purari River delta that roughly conforms with the upper tidal reaches.

All villages in the Purari River delta are located on the banks of the Purari River's tributaries. Other than for the Orokolo area, population densities are low.

The PAOI is located across two local-level government areas (LLGs) – Baimuru Rural LLG and Ihu Rural LLG – in Kikori District, Gulf Province. The PAOI has seven distinct language groups – Pawaia, Koriki, Iare, Ahia, Kaimare, Maipua and Orokolo. Villages within each language group have similar history, cultural beliefs and traditional practices.

Language group is one of two features that contribute strongly to the homogeneity of each of the seven community groups in the PAOI, the second being ecological zone (defined in Section 7.7.3 and summarized as the environmental setting in which communities are located). The language that people speak defines where people came from, their ancestors and ancestral migration history (from the land on which they originated to the land they occupy in the present). As a result, it defines their cultural values, with whom they communicate, trade and marry, and in many cases, the behavioral and social norms they are expected to observe. People in the PAOI depend significantly on their natural resources for survival and wellbeing; hence, their environmental setting significantly influences their day-to-day activities.

The most common sources of income in the PAOI are the sales of betel nut, fish, crabs, garden produce and sago. Small business activities, such as selling fuel and trade stores, also contribute to household income for some people; however, the majority of people in the PAOI are involved in subsistence activities and are not formally employed.

Consistent with onshore Project activities, the PAOI is divided between three areas as defined in Chapter 1, being PRL-15, the export pipeline route, and the river transport corridor.

13.1.2 PRL-15

PRL-15, in the upper Purari River catchment, is in the Gulf Province, in the Kikori District and Baimuru Rural LLG area.

The Pawaian people (i.e., people who speak the Pawaia language) are the principal users of the PRL-15 area and the Pawaian people occupy parts of the Simbu, Gulf and Eastern Highlands

POTENTIALLY-AFFECTED COMMUNITIES IN THE PAOI

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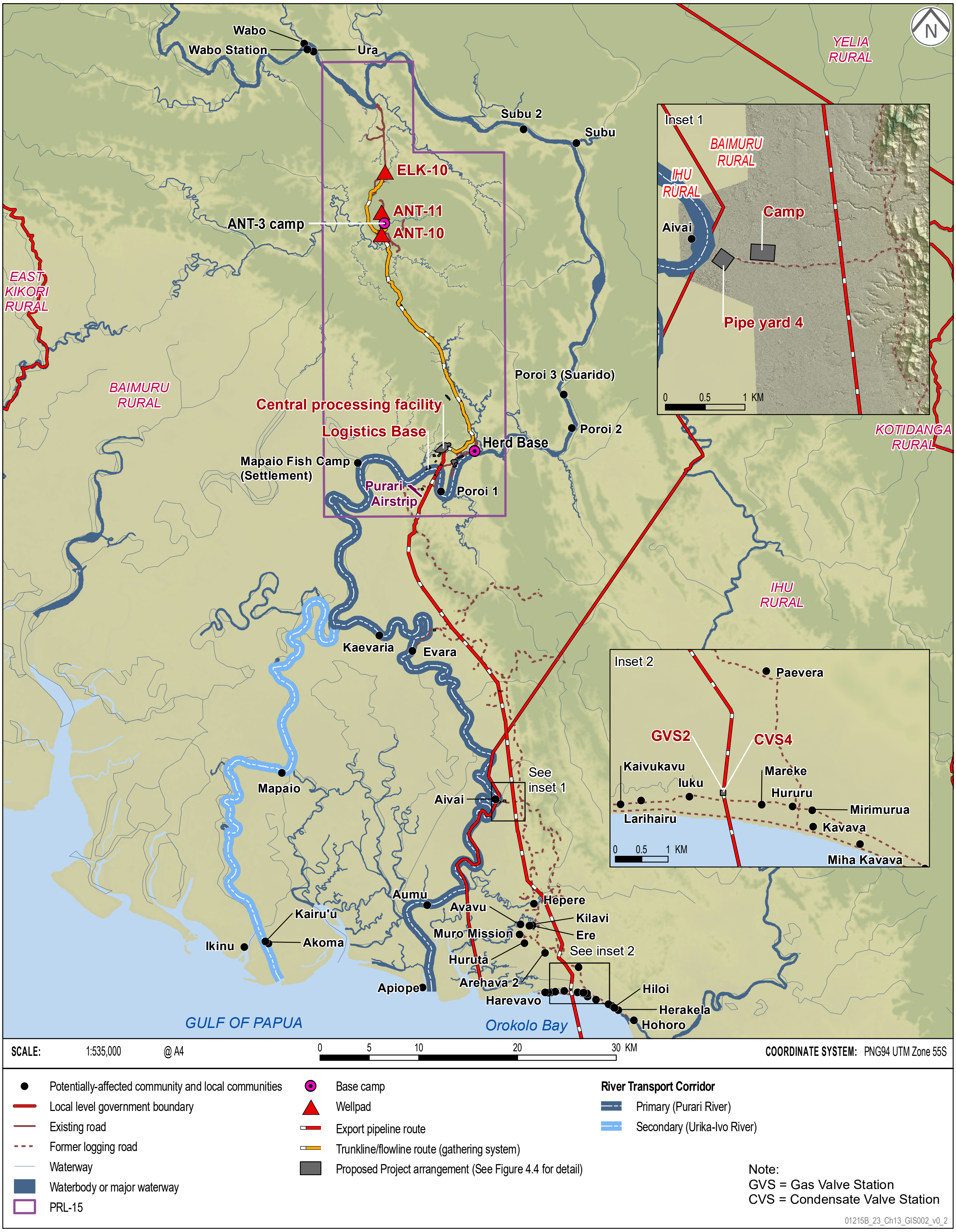
FIGURE 13.1



provinces. The Pawaians who reside along the Purari River bank, near the Elk-Antelope gas field, are generally referred to as the lowland Pawaians.

Nine villages (including one settlement) have been identified in or near the PRL-15 area. Those inside the PRL-15 boundary include Poroi 1 and the settlement of Mapaio Fish Camp and a single residence (Purari Airstrip House). Those outside but near the PRL-15 boundary include Poroi 2 and Poroi 3, Subu, Subu 2, Ura, Wabo and Wabo Station. All communities are small, isolated and have limited access to basic services like schools and health clinics (see Figure 13.2). Low population density in the PRL-15 area has meant that there has been little agricultural pressure on the land, and primary forest or logged hill forest and alluvial forest covers the vast majority of Pawaian territory.

Access to and within the PRL-15 area is limited, with no roads linking PRL-15 with other parts of Gulf Province or other provinces. Access is via boat on the Purari River, via air using the Purari Airstrip, or on foot using existing tracks.

There are three major means of access to the PRL-15 area:

- People may walk down to Wabo, Ura and Wabo Station from the highlands, potentially drawing upon their pre-existing social relationships and connections with Pawaia people.
- People may also access this area by boat or canoe along the Purari River, meaning that in-migrants will be able to reach this area from the coast (or other villages in the Purari delta) or from further upstream past Wabo.
- Access by air is unlikely for most in-migrants not already associated with local residents (i.e., through marriage, adoption, partnerships and business ventures) or with the Project (i.e., through employment or contracts).

In 2016, in-migration to the PRL-15 area was already evident. At Ura village, 15 families had migrated from Karimui and other locations in the highlands in search of work. In 2012, one study noted that migrants from the Highlands region, including Karamui in Simbu province and Eastern Highlands and Enga provinces, were residing at Wabo (Sullivan, 2012).

The baseline studies (see Chapter 9) indicate that relatively limited out-migration has occurred from the PRL-15 area, compared with the river transport corridor or export pipeline route areas, which may reflect the limited period of interaction that the PRL-15 area villages have had with other parts of Papua New Guinea.

13.1.3 Export Pipeline Route

The onshore export pipeline route is located in the Ihu and Baimuru LLG areas in the Kikori District in the Gulf Province. Pawaian speaking people occupy the northern end of the onshore export pipeline route nearest PRL-15. In the south, communities in Orokolo Bay speak Orokolo language[1].

From south of the PRL-15 boundary, there are no villages located along the export pipeline route until it nears Hepere in the Orokolo Bay hinterland. From there it tracks in the vicinity of the coastal villages of Arehava 2, Paevera, Iuku and Mareke on its approach to the shore crossing. These villages generally range in size from less than 200 people to more than 800 people.

1 From a social perspective, Orokolo Bay communities maintain their own cultural heritage identify (Part 17 of Volume 2).

COMMUNITY FACILITIES IN AND AROUND PRL-15

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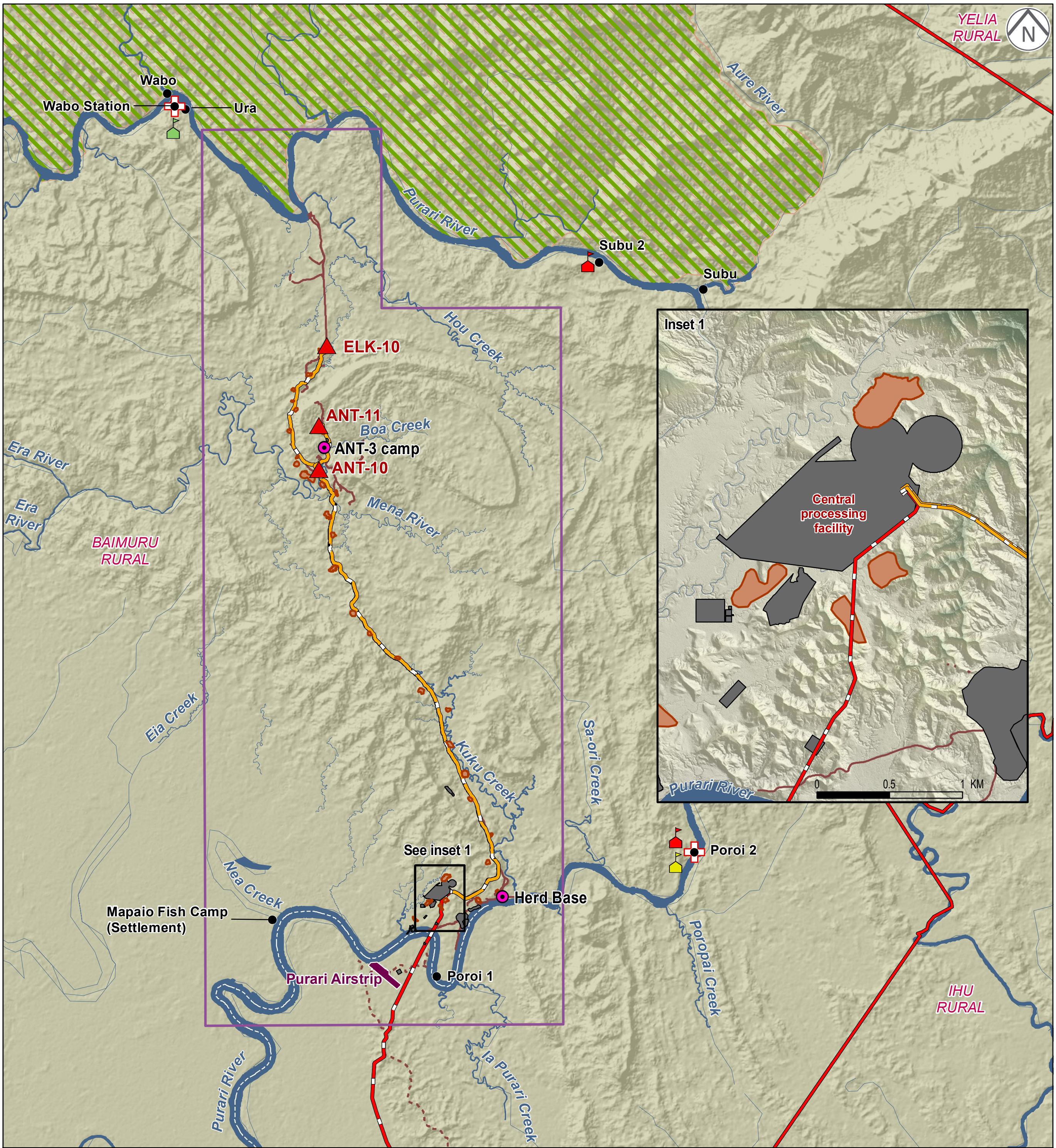
FIGURE 13.2



SCALE: 1:300,000 @ A4 | 0 2.5 5 10 15 KM | COORDINATE SYSTEM: PNG94 UTM Zone 55S

- Potentially-affected community and local communities
- Local level government boundary
- Existing road
- Former logging road
- Waterway
- Waterbody or major river
- Base camp
- Wellpad
- Export pipeline route
- Trunkline/flowline route (gathering system)
- Proposed Project arrangement (See Figure 4.4 for detail)
- Spoil disposal site
- Crater Mountain Wildlife Management Area
- PRL-15

River Transport Corridor
- Primary (Purari River)

Schools
- Elementary
- Elementary and Primary
- Primary

Health Facilities
- Aid post, partially operating

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Communities in PRL-15 and also communities along the Purari River (e.g., Aivai, on the river transport corridor, see Section 13.1.4) use the remote northern part of the export pipeline route for hunting and collecting of native flora and fauna. In the south, along coastal villages, people are engaged in subsistence and income earning activities through harvesting sago palms, coconuts, bananas, garden produce, and fishing activities.

There are no public roads along the Orokolo Bay coastline where most of the Project-affected communities and local communities are located around the export pipeline route. Access is primarily by boat or on foot, as the beach provides a pathway connecting villages along the coast (Section 13.9).

Approximately 10,000 people live in Orokolo Bay villages with some living outside the PAOI (see Chapter 9). The Orokolo people have experienced a much longer history of engagement with outside groups due to the coastal location of many of these villages. These villages were historically involved in trade and exchange activities that extended along the southern coastline of mainland Papua New Guinea – most notably the *hiri t*rade (see Section 9.2.2). There is a much higher level of population movement between these villages, Kerema and Port Moresby. Orokolo villages record the highest level of out-migration in the PAOI, which is likely to be due to their access to coast transport and historical engagement with outsiders. Communities in Orokolo Bay have greater access to community facilities such as schools and health facilities than communities in and around PRL-15 (Figure 13.3).

13.1.4 River Transport Corridor

Two Purari River delta distributaries will be used for Project transport and logistics activities, these are located in Baimuru Rural and Ihu Rural LLGs. The main river transport route is expected to be the Purari River; and the route will pass by Apoiope, Aumu, Aivai, Evara, Kaevaria and Mapaio Fish Camp settlement before reaching the proposed new Logistics Base and Herd Base. The Urika-Ivo River will be used as a secondary transport corridor when the Purari River is impassable, and river traffic would pass by Akoma, Kairu'u, Ikinu, Mapaio, and Mapaio Fish Camp settlement before reaching the proposed new Logistics Base and Herd Base.

Eight villages have been identified as directly adjacent to, and are dependent on, the two main Purari River delta distributaries to access food, materials and services to support their livelihood, and hence may be affected by Project activities. Five languages belonging to the Trans-New Guinea family (Koriki, Iare, Ahia, Kaimare and Maipua) are spoken by communities along the riverway access.

Wild sago and planted banana are the primary staple foods for riverway communities. Protein is obtained from fishing and hunting of wild pigs, cassowary, bandicoots, crocodiles and turtles.

Locations of PAOI villages and related language groups can be seen in Figure 9.2. As described in baseline studies in 2016 (see Chapter 9), all villages in the river transport corridor area are located close to these rivers and are therefore easily accessed by canoe or boat from the coastal areas (or conversely, from inland via the Purari River). Temporary roads have been constructed around the river transport corridor for logging activities.

The baseline studies indicate only modest population increase among the Koriki, Iare and Kaimare language groups over the last 100 years, estimated at approximately 34%, 27% and 10%, respectively. These communities record a higher level of out-migration than the onshore export pipeline route and PRL-15 communities, considered to be due to their access to coastal transport and historical engagement with outsiders. People have migrated in search of employment and economic opportunities and access to better services, reflecting the isolation, limited opportunities and service provision in the river transport corridor.

COMMUNITY FACILITIES ALONG THE EXPORT PIPELINE ROUTE

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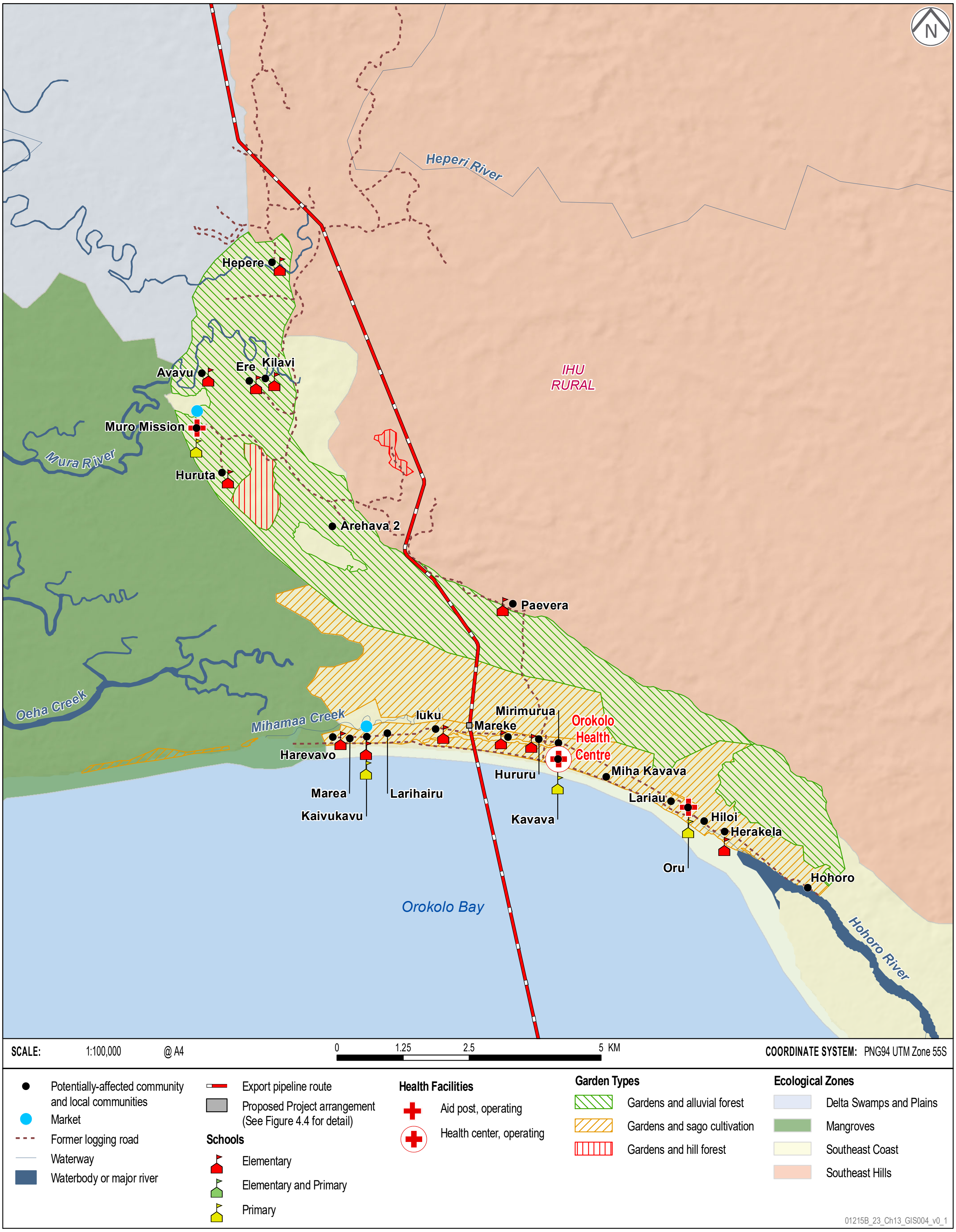
FIGURE 13.3



13.1.5 National Context

As discussed in the socio-economic baseline reports and summarized in Chapter 9, the formal economy in Papua New Guinea is dominated by resource exploration and production, commercial agriculture, tuna processing and logging, with a small manufacturing sector. The informal economy, which supports approximately 85% of the population, primarily depends on subsistence agriculture (ADB, 2015). Papua New Guinea has experienced strong growth in its gross domestic product over the past decade, with much of the growth in 2014 and 2015 attributed to the PNG LNG Project.

Oil has been extracted from the Gobe Main and South East Gobe oil fields located in the Kikori River catchment since 1998. Although not in operation, the exploration and development stages of the Papua LNG Project have provided an important source of local employment (and various other services), particularly among Pawaia villages.

The majority of Papua New Guinea’s prawns are captured in the Gulf of Papua and subsequently processed in Port Moresby. The main industries in Gulf Province are oil production and petroleum exploration, prawn fishing and logging.

Gulf Province contains five large-scale logging operations. Large-scale economic activity in the PAOI includes the Vailala Block 3 logging project operated by Frontier Holdings (where activity is winding down). PRL-15 is in commercial logging concession Baimuru Block 3.

13.1.6 Project Social and Economic Development Context

The economic development potential to be considered in this social impact assessment is that the Project is expected to generate financial benefits to Papua New Guinea that will increase the gross domestic product and national government revenue. The preliminary median capital cost estimate for the upstream portion of the Papua LNG project is estimated at US$4.0 billion in 2018 Real Terms for the initial development, plus about US$0.9 billion for the subsequent compression phases. This estimate only considers costs incurred after final investment decision and excludes costs incurred prior to final investment decision such as significant exploration and appraisal costs to discover the Elk and Antelope fields costs, reservoir studies costs, studies to define the development scheme, and so on.

The initial estimate of direct and indirect statutory benefits to the government during the upstream construction phase is anticipated to be approximately US$2 billion or an additional annual revenue of approximately US$0.3 billion. During the upstream operations phase, the incremental revenue for the government is estimated at approximately US$3 billion or an additional annual revenue of around US$140 million. These estimates reflect only the upstream portion of the Project and the benefits described accrue due to the integrated nature of the upstream and downstream segments of the Project and synergies achieved by sharing downstream costs with other upstream projects in PNG so that the incremental benefit to Papua New Guinea of the combined upstream and downstream project is likely to be higher.

The forward-looking estimates described are preliminary and will be further refined as the Project matures. These forward-looking estimates consider many factors including, without limitation, those concerning the cost of material required to construct the upstream project, LNG prices and the completion and commencement of commercial operations of the Project. Although TEP PNG is of the opinion that the analysis reflected in such forward-looking estimates is reasonable, actual results could differ materially from those set out in the forward-looking estimates.

The aim of TEP PNG’s strategy is to develop a PNG workforce, involve local businesses and assist with the socio-economic development of communities in the PAOI and Papua New Guinea as a whole. The Project aims to achieve a maximum percentage of nationals working on the Project (upstream), including both directly hired and contracted workers, approximately one to two years after operations commence (see Chapter 4).

13.1.7 In-migration

Project-induced in-migration, or influx involves the movement of people into an area in anticipation of, or in response to, economic opportunities associated with the development and/or operation of a new project (IFC, 2009). This is a common phenomenon at all resource development projects in Papua New Guinea and a major source of social impact (Bainton & Banks, 2018; Bainton, 2017). The Papua New Guinea Constitution (PNG Constitution, 1975) grants citizens freedom of movement throughout the country, and resource companies cannot legally prevent people from migrating to the PAOI; however, companies can implement measures to manage and mitigate the impacts associated with in-migration (Bainton et al., 2017).

Project-induced in-migration can comprise:

- Workers from outside of area but that are brought in directly by the project and its contractors and are living in camps and accommodations provided by the Project.
- Families/relatives of these workers that may decide to move into the area.
- Opportunistic migrants that are not hired or contracted by the Project, but which nevertheless move in the area with the hope to benefit indirectly from the Project value-chain.

In-migration can benefit trade and business, employment, infrastructure, and services. This same phenomenon can also negatively affect the PAOI and host communities, especially with regards to environmental, social and health issues. It can be either a short-term phenomenon or longer lasting. In the short term, migrants may move temporarily to a Project-affected area to claim or support local claims to State financial payments related to land ownership as evidenced by the PNG LNG project (D'Appolonia et al, 2014). In the long term, migrants may create new settlements around areas of high Project activity or stay in existing settlements for the same reasons. D'Appolonia et al (2014) also reports there was no significant in-migration directly related to the PNG LNG project. As in-migration already exists in the PAOI, and an influx of people is likely to contribute to the social impacts derived from the Project, it is therefore considered in this impact assessment as a source of further induced impacts in all social aspects assessed (i.e., health, education, etc.). This section provides background to potential major drivers for and locations where influx may occur.

13.1.7.1 Major Drivers for In-migration

Major drivers for in-migration are likely to be Project employment, the expectation of access to State financial payments or indirect economic opportunities created by the Project workforce, and anticipation of overall development of the area, e.g., expectations of improved social and health infrastructure and services through increased government spending and Project community investment programs. In-migration can mainly be expected to occur close to the construction and operation areas, and areas where workers and contractors are accommodated.

Indicators favoring in-migration include:

- Accessibility from other population centers (i.e., Kerema, Baimuru, Port Moresby) or villages.
- Evidence of pre-existing migration pathways and clan/social relationships.
- Close proximity to areas where construction and operation activities will, or are expected to take place, and where there are likely to be expectations of employment opportunities.

- Presence of business opportunities associated with the Project (i.e., service-based businesses), or where community development initiatives, such as improvements to education or health facilities, are planned.
- Villages where clan groups reside that claim customary ownership over land that will be directly impacted by the Project, and where State financial payments are likely to be distributed or Project opportunities may occur.

13.1.7.2 Potential Locations where Influx may Occur in the PAOI

In-migration may be greatest during the construction phase when more local jobs will be available but may continue through operations when local income levels rise (i.e., from State financial payments) and people identify business opportunities due to these higher incomes. During the construction phase when the workforce will be largest, people may also migrate into villages or settlements (or attempt to create new settlements) in PRL-15 or neighboring villages (e.g., Mapaio Fish Camp and Poroi 1) in the hope of providing goods or services to Project workers. Access to these areas is only by river, which may, limit population increase.

Table 13.1 presents areas where Project-induced in-migration has the potential to occur, based on the indicators favoring in-migration.

Table 13.1 – Areas in the PAOI Where Project-induced In-migration Could Occur

PAOI Communities Potentially Affected by In-migration	Accessibility	Pre-Existing In-migration	Proximity to Project Camps and Facilities	Proximity to Project Business Opportunities or Benefits	Proximity to Beneficiaries of State Financial Payments
Wabo Station	Low - existing pathways from the highlands, Wabo airstrip, Purari River.	Yes	No	Yes	Yes
Wabo	Low - existing pathways from the highlands, Wabo airstrip, Purari River.	Yes	No	Yes	Yes
Ura	Low - existing pathways from the highlands, Wabo airstrip, Purari River.	Yes	No	Yes	Yes
Subu	Very isolated - only the Purari River.	No	No	Yes	Yes
Poroi 3	Very isolated - only the Purari River.	No	No	Yes	Yes
Poroi 2	Very isolated - only the Purari River.	Yes	No	Yes	Yes
Poroi 1	Low - Purari River and Purari Airstrip.	Yes	Yes	Yes	To be confirmed
Mapaio Fish Camp Settlement	Low - Purari River and Purari Airstrip.	Yes	Yes	Yes	To be confirmed
Aivai	Very isolated - only the Purari River.	Yes	Yes	Yes	Yes
Apiope	Very isolated - only the Purari River.	Yes	No	Yes	No

Table 13.1 – Areas in the PAOI Where Project-induced In-migration Could Occur (cont'd)

PAOI Communities Potentially Affected by In-migration	Accessibility	Pre-Existing In-migration	Proximity to Project Camps and Facilities	Proximity to Project Business Opportunities or Benefits	Proximity to Beneficiaries of State Financial Payments
Iuku	Isolated - only by sea.	Yes	Yes	Yes	Yes
Mareke	Isolated - only by sea.	Yes	Yes	Yes	Yes
Other PAOI villages in Orokolo Bay	Isolated - only by sea.	Yes	No	Yes	To be confirmed

The level of Project-induced in-migration is considered negligible due to an absence of the drivers described in Table 13.1 for all other villages in the PAOI.

13.2 Social Impact Assessment Method

The significance assessment approach described in Chapter 3 was used to characterize social impacts, which have been grouped into the following seven categories:

1. Economic displacement and livelihoods.
2. Economic development and employment.
3. Education and workforce training.
4. Community health and safety.
5. Governance, leadership and social structure.
6. Social cohesion, conflict, law and order.
7. Transport and access.

These categories were developed and refined iteratively during the process of impact identification, their purpose being to provide a structure to the impact assessment. The categories are not intended to be rigid or mutually exclusive: some impacts fall into multiple categories, in which case they are placed in the most relevant category and assessed and assigned mitigation, management and optimization measures accordingly.

Explanation on how both pre-existing and Project-induced vulnerability have been considered in the social impact assessment is provided in Box 13.1.

Box 13.1 – Consideration of Vulnerability in Social Impact Assessment

Vulnerability is generally defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made change. The concept is relative to the local context and dynamic in that it can change over time as either circumstances change or people's capacity changes. Vulnerability is most often associated with poverty, but it can also arise when people are isolated/remote, insecure and defenceless in the face of risk, shock or stress and other factors.

Best practice social impact assessment requires project proponents to identify vulnerable groups and individuals, and to tailor mitigation and management measures to address the issues unique to these groups (IFC, 2012).

Most people living in the PAOI present some pre-existing vulnerability characteristics. Women's groups (and village leaders' groups) identified households headed by women, single mothers and widows to be the main disadvantaged people in communities. Village leaders identified disability as a main type of disadvantage, second to households headed by women.

Box 13.1 – Consideration of Vulnerability in Social Impact Assessment (cont'd)

Baseline studies clearly define the use of terms 'vulnerability' and or 'disadvantage/d' for the purposes of and use in this document. Vulnerability is defined in terms of both pre-existing and Project-induced vulnerability as follows:

- Pre-existing vulnerability, where groups or individuals find it difficult to sustain themselves or their families under everyday conditions, irrespective of project development.
- Project-induced vulnerability, where groups or individuals have a diminished capacity or lack of capacity to understand, anticipate, cope with, resist or recover from the consequences of a potential impact or other threat (TOTAL general specifications).

This social impact assessment focuses on identifying both pre-existing and Project-induced vulnerable groups and individuals across the PAOI against the 9 vulnerability criteria and related findings summarized in Table 9.21 in Chapter 9. Potential impacts related to these groups have been identified throughout this and other chapters in the EIS and summarized in the table below.

Summary of Potential Pre-existing Vulnerability and Gender Inequality Impacts

Vulnerability Criteria	Potential Impact	Reference Section/ Chapter
Local identification	Increased pressure on pre-existing vulnerability and gender inequality.	Various – see below
Poverty	♦ An increase in direct and indirect employment opportunities. ♦ A decrease in direct and indirect employment opportunities.	Section 13.4
Food security	Ecosystems services impacts identified in Chapter 16.	Chapter 16
Housing	Improved housing and living conditions as a result of increased economic activity and employment.	Section 13.4
Livelihood security	♦ Reduction of livelihood of PAOI communities. ♦ Further impacts identified in Chapter 16.	Section 13.3 and Chapter 16
Household composition	♦ Changes to traditional way of life. ♦ Improvements to housing and living conditions.	Section 13.4
Access to infrastructure	♦ Improved economic infrastructure. ♦ Improved access to economic infrastructure ♦ Temporary loss of access to education, health and economic services.	Section 13.4 Section 13.9 Section 13.9
Education	♦ Increased pressure on local education services and facilities. ♦ Improved workforce skills, training and experience.	Section 13.5
Women	♦ Increased opportunity for women's involvement in decision-making processes. ♦ Changes to traditional way of life. ♦ Increased tension related to antisocial behavior and crime. ♦ Impacts associated with social determinants of health (specific to gender, substance abuse and violence). ♦ A reduction in the use of cultural health practices, such as traditional medicines and attribution to sorcery. ♦ Increased acceptance of modern health practices and a reduction in the practice of sorcery or traditional medicines.	Section 13.7 Section 13.4 Section 13.8 Section 13.6 Section 13.6 Section 13.6

13.2.1 Identification of Potential Impacts

This chapter identifies and assesses impacts based on:

- The regulatory framework presented in Chapter 2.
- Definitions of direct, indirect and induced impacts provided in Chapter 3 and 21.
- The Project description and associated activities presented in Chapter 4.
- Stakeholder engagement activities presented in Chapter 6.
- Interaction between the Project and the cultural heritage and archaeological environment described in Chapter 14.
- Assessment of impacts to terrestrial, marine, cultural heritage, amenity and climate change contexts along with ecosystems services described in Chapters 11, 12, 14, 15 and 16 respectively, and how these may influence social impacts.

13.2.2 Assessment of Potential Impacts

The assessment of initial and residual impacts is conducted by examining both the magnitude of the potential impact (Table 13.2) and the sensitivity (Table 13.3) of the individuals, organizations, groups or resources (receptors) (Table 13.4) being impacted. The Project phase in which the activity and the impact occurs has also been considered.

Analysis of the likelihood of the impact has not been included, since the impacts described are all assessed as being credible outcomes of Project development (see Chapter 3).

13.2.2.1 Magnitude

As described in Section 3.5.2.2, the criteria used to define the magnitude of an impact reflect the size and nature of the change based on several elements, namely, the geographical extent, duration, scale and frequency of the change generated:

- Geographical extent: The spatial extent of the impact where this is defined as site (which may be localized to all, parts or a part of the site), local, regional or widespread (e.g., provincial, national or transboundary).
- Duration: The timeframe over which an impact will occur; this may include temporary (less than six months), short term (six months to one year), medium term (one to five years), long term (more than five years) and permanent (beyond the life of the Project).
- Reversibility: The degree or scale of disruption or improvement at a household or community level, to livelihoods, quality of life and social structure. For example, an impact that leads to a fundamental change in the way of life of people, in the nature of relationships in a community, or in livelihood patterns that could be highly disruptive or beneficial, while one that results in only subtle changes in conditions could be low in disruption or benefit. Reversibility could occur in the temporary, short or longer term and irreversible would be permanent.
- Frequency: The consistency or periodicity of an impact. A ‘constant’ impact is defined as 'permanent', 'often' occurs at least once a month, 'occasional' occurs at least once every six months, 'rare' occurs about once a year, and 'remote' occurs less often than once a year or is an impact that will only occur once.

Magnitude criteria used for the socio-economic impact assessment are presented in Table 13.2.

13.2.2.2 Sensitivity of Receptor

Sensitivity is defined as the susceptibility of the social receptor to change, including its capacity to adapt to or accommodate the kinds of changes that the Project may bring about. There is possibility for sensitivity to change over time, particularly in the case of human capital and where capacity building occurs (e.g., increased skills and health outcomes). Sensitivity considers:

- Social capital (social networks and organizations, culture, religion and decision-making structures).
- Human capital (skills, education, health and leadership capacity).
- Natural capital (land, forests, water and biodiversity).
- Economic capital (diversity, legitimacy and productivity of livelihoods, cash and income).
- Infrastructure, equipment and facilities.
- Formal status (where this may be assigned by statutory or regulatory authorities or by appropriately recognized national or international organizations.

This can involve legislation, regulations, international conventions or other mechanisms, rarity or uniqueness in and beyond the immediate area of interest (i.e., its vulnerability, and level of replaceability), and importance to local communities and society or its iconic or symbolic importance to cultural value systems.

Sensitivity criteria used for the socio-economic impact assessment are presented in Table 13.3.

13.2.2.3 Social Receptors

Social receptors are the individuals, organizations, groups or resources that can be affected by Project activities. For this social impact assessment, receptors can be broadly defined according to the groups presented in Table 13.4.

These groups comprise individuals and groups that may have different levels of vulnerability and that vulnerability is multidimensional (e.g., one individual may be vulnerable to one type of impact, but resilient to another). The social impact assessment has assessed impact significance based on the overall sensitivity of the broader group given in Table 13.3 but, where relevant, the description of the impact also identifies individuals or groups in the wider receptor group who may be particularly vulnerable to the specific impact.

Vulnerable groups identified in the overall population are described in Chapter 9 and outlined in Section 13.8.

13.2.2.4 Initial and Residual Assessment

Initial impacts are identified and assessed according to the interaction between magnitude, sensitivity and receptors in the absence of mitigation and management. Residual impacts are assessed assuming the effective implementation of (i) avoidance, mitigation and management measures for adverse impacts and (ii) measures to optimize opportunities. This interaction between magnitude and sensitivity is expressed in an impact assessment matrix, presented in Table 13.5.

Table 13.2 – Social Impact Assessment Magnitude Criteria

	Very High	High	Medium	Low	Negligible	Positive
E	♦ Impacts may be widespread, i.e., large number of people affected/experienced on a provincial, national or transboundary level. ♦ Single/multiple loss of life or permanent damage to persons due to Project-related activities.	♦ Impacts may be regional, i.e., experienced by all or almost all of the PAOI communities. ♦ Reversible injury or moderate irreversible damage or impairment to one or more persons, due to Project-related activities. Typically, a lost time injury.	♦ Impacts may be moderate and experienced by specific community/ies or small part of the PAOI. ♦ Reversible/minor injuries due to Project-related activities, not leading to restricted duties. Typically, a medical treatment.	♦ Impacts localized and may be experienced by individual community/ some households only. ♦ Low level or short-term inconvenience or symptoms, due to Project-related activities, typically treated by first aid.	♦ No appreciable adverse impact/change compared to baseline conditions to safety, security, community activities, health, education, human rights and/or social functioning. ♦ No lost time injuries and low first aid treatments required due to Project-related activities.	♦ Impacts may be experienced on a transboundary, national, provincial, local or PAOI level. ♦ Permanent, temporary, long or short term/often or occasional improvement compared to baseline conditions to: – Safety, security, community activities, health, education, human rights and/or social functioning. – Social diversity and equality. – Local/regional and/or national investment. – Development of new social structure which adequately satisfies the needs of the local communities.
D	♦ Permanent, adverse impact/change compared with baseline conditions to health, safety, security, community activities, community services, human rights and/or social functioning.	♦ Long-term (more than five years), adverse impact/change compared to baseline conditions to safety, security, community activities, health and education, human rights and/or social functioning.	♦ Medium-term (one to five years), adverse impact/change compared to baseline conditions to safety, security, community activities, health, education, human rights and/or social functioning.	♦ Short-term (six months to one year), adverse impact/change compared to baseline conditions to safety, security, community activities, health, education, human rights and/or social functioning.	♦ Temporary impact/change compared to baseline conditions to safety, security, community activities, health, education, human rights and/or social functioning.	
R	♦ Irreversible adverse impact/change to demographic and social structure, key economic activities, access and/or livelihoods.	♦ Adverse impact/change to demographic and social structure, key economic activities, access and/or livelihoods, reversible in the long term (after five years).	♦ Adverse impact/change to demographic and social structure, key economic activities, access and/or livelihoods, reversible in the medium term (one to five years).	♦ Adverse impact/change to demographic and social structure, key economic activities, access and/or livelihoods, reversible in the short term (less than one year).	♦ No appreciable impact/change to demographic and social structure, key economic activities, access and/or livelihoods.	
F	♦ Adverse impacts are constant due to Project-related activities, i.e., permanent.	♦ Adverse impacts are often due to Project-related activities (at least once a month).	♦ Adverse impacts are occasional due to Project-related activities (at least once every six months).	♦ Adverse impacts are rare due to Project-related activities (once a year).	♦ Adverse impacts are remote or never occur due to Project-related activities.	

E = Extent, D = Duration, R = Reversibility, F = Frequency.

Table 13.3 – Social Impact Assessment Sensitivity Criteria

Low	Medium	High
♦ The social receptor is easily adaptable/more resilient to change (or no change required). High capacity to realize opportunities evidenced by communities, items or areas already demonstrating resilience to this impact, prior to Project interaction. ♦ Highly skilled and experienced labor ‘pool’. ♦ The resource or area has minimal importance to cultural or traditional value systems. ♦ The resource upon which local people are rarely dependent for providing food, income, health or infrastructure. ♦ The community has the capacity to access nearby alternatives to the affected resource or service. ♦ The resource can be relocated or replaced or is a type that is common in the surrounding region. ♦ The attribute or quality is considered unimportant to the relevant community. ♦ Changes due to Project activities will not noticeably degrade attributes or quality of the resource or social receptor. ♦ The health attribute or quality has plentiful capacity and means to absorb change.	♦ The social receptor has some resilience to change, or capacity to realize opportunities. ♦ Some sign of exposure to this impact is already evident in the community, item or area prior to Project interaction. ♦ Some skills in the labor ‘pool’ with only limited experience. ♦ The resource or area has moderate importance to cultural or traditional value systems. ♦ The resource on which local people are occasionally dependent for providing food, income, health, infrastructure, etc. ♦ The community has limited capacity to access nearby alternatives to the affected resource or service, on which parts of the community depend. ♦ The resource can be relocated or replaced, or data/artefacts recovered in consultation with stakeholders. ♦ Changes due to Project activities may lead to some degradation of the attributes or quality of the resource or social receptor. ♦ The health attribute or quality is considered to be of some importance to the relevant community and has limited capacity to absorb change.	♦ The social receptor limited or no capacity to adapt to change, limited or no capacity to realize opportunities. ♦ The community, item or area is unaffected by this impact prior to Project interaction or has been affected and has demonstrated no capacity to adapt to change. ♦ The resource or area has high symbolic importance to cultural or traditional value systems. ♦ Lack of a skilled and experienced labor ‘pool’. ♦ The resource that provides the sole source of food, income, health or infrastructure for local people, or on which they are frequently dependent. ♦ Many communities depend on the resource, benefit or service, and have no capacity to access nearby alternatives. ♦ The resource cannot be relocated or replaced without major loss of cultural values. ♦ Changes due to Project activities would lead to substantial changes to attributes or quality of the resource or social receptor. ♦ The health attribute or quality is considered of critical importance to the relevant community and has very little capacity or means to absorb any change.

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Table 13.4 – Social Receptors

Receptor	Description
Project Area of Influence Communities	
In and around PRL-15	
Project-affected persons	Individuals or groups who live in PRL-15, or have legal or customary rights to land or assets in PRL-15, that could be affected by land access, relocation, or loss of income associated with Project-changes in use of land, water and/or other natural resources.
Project-affected communities	Communities and settlements in PRL-15 that could be directly affected by Project activities Poroi 1and Purari Airstrip House.
Local communities in and around PRL-15	Communities and settlements located in or near PRL-15, that could be indirectly affected by Project activities: Mapaio Fish Camp settlement, Poroi 2, Poroi 3 (Suarido), Subu, Subu 2, Ura, Wabo, Wabo Station.
Traditional leadership	Traditional leaders and structures in communities in or nearPRL-15 that could be indirectly affected by Project activities.
Religious leadership	Religious leaders and structure in communities in or nearPRL-15 that could be indirectly affected by Project activities.
Landowner organizations and Community Owned Companies.	Organizations representing the interests of landowning clans and persons in or near PRL-15.
Export Pipeline Corridor	
Project-affected persons	Individuals or groups who live adjacent to the proposed export pipeline right of way, or have legal or customary rights to land or assets along the right of way, that could be directly affected by land access, or loss of income associated with Project-changes in use of land, water and/or other natural resources.
Project-affected communities	Communities who live adjacent to the export pipeline route that could be directly affected by Project activities, including: Hepere, Arehava 2, Paevera, Iuku and Mareke.
Local communities along the export pipeline route	Communities along the export pipeline route that could be indirectly affected by Project activities.
Traditional leadership	Traditional leaders and structures in communities along the export pipeline route, which could be indirectly affected by Project activities.
Religious leadership	Religious leaders and structure in communities adjacent to the export pipeline route that could be indirectly affected by Project activities.
Landowner organizations and Community-owned companies.	Organizations representing the interests of landowning clans and persons along the export pipeline route.
River Transport Corridor	
Project-affected communities	Communities along the Purari and Urika-Ivo rivers (the primary and secondary transport corridors) that could be directly affected by Project river transport activities, including: Apiope, Aumu, Aivai, Evara, Kaevaria along the Purari River; and Mapaio, Kairu'u, Akoma, Ikinu, along the Urika-Ivo River. Mapaio Fish Camp settlement and Poroi 1 are common to both distributaries on the river transport corridor.
Traditional leadership	Traditional leaders and structures in communities along/near the river transport corridor that could be indirectly affected by Project activities.
Religious leadership	Religious leaders and structure in communities along/near the river transport corridor that could be indirectly affected by Project activities.
Project Area of Influence Services and Infrastructure	
Schools	Local schools located in the PAOI.
Health facilities	Local health facilities and aid posts in the PAOI.
Police force	Local police responsible for law enforcement in the PAOI.

Table 13.4 – Social Receptors (cont'd)

Receptor	Description
Project Area of Influence Services and Infrastructure (cont'd)	
Logging and mining businesses	Resource companies and businesses operating in the PAOI.
Project workforce – skilled workers	Workers employed on the Project (direct and contracted). Skilled workers are more likely to be able to access jobs and are likely to have greater awareness of their employment rights than unskilled workers.
Project workforce – unskilled workers	Workers employed on the Project (direct and contracted). Unskilled workers are likely to face more challenges accessing jobs and have lower awareness of their employment rights than skilled workers.
Local, Provincial and National	
District, local level government and wards	Baimuru Rural LLG, Ihu Rural LLG, and Kikori District representatives (technical and political staff). Wards: Aikavaravi, Akoma, Apiope, Ara'ava, Aumu, Ikinu, Kairimai, Kapai, Kapuna, Kinipo, Maipenairu, Mapaio, Mariki, Poroi and Wabo Wards (within Baimuru LLG) and Arehava, Avavu, Harevavo, Harilarewa, Kaivukovu, Kavava and Lariau (within Ihu LLG).
Provincial government	Gulf Province representatives (technical and political staff).
National government	Technical staff in relevant government agencies and members of parliament.
National, provincial and local level business community	National economic actors including Small and Medium Sized Enterprises (SMEs), larger companies, contractors, sub-contractors and professional services companies.
Supply chain workers	Workers indirectly employed in the Project supply chain (e.g., agri-labor workers that supply food products to the Project).

Table 13.5 – Social Significance Assessment Matrix

Magnitude of Impact	Sensitivity of Receptor		
	High	**Medium**	**Low**
Very High	Severe	Major	Moderate
High	Major	Moderate	Moderate
Medium	Moderate	Moderate	Minor
Low	Minor	Minor	Minor
Negligible	Negligible	Negligible	Negligible
Positive	Positive	Positive	Positive

13.3 Economic Displacement and Livelihoods

13.3.1 Context

Project-related land access and restrictions on land use or on the use of communal property or on the access to natural resources can adversely impact communities and persons that use this land or communal property. Involuntary resettlement refers both to physical displacement (e.g., relocation or loss of shelter) and to economic displacement, i.e., loss of assets or access to assets that leads to loss of income sources or other means of livelihood due to project-related land access and/or restrictions on land use (IFC, 2012).

The majority (97%) of land in Papua New Guinea is under customary ownership, and most of the population resides on customary-owned (clan) land where people have rights of ownership, access or control. In the PAOI, all land is customary owned except Wabo Station, Muro Mission and Kapuna Health Center, which have been alienated. Alienated land is no longer held under customary ownership because it has been excised by the Government as either state land (2%) or private freehold land, including conditional freehold land (1%) (see Section 9.2.3).

Access to land required for petroleum extraction and infrastructure development is granted under the terms and conditions of the *Oil and Gas Act 1998* via the award of a petroleum licence. The *Oil and Gas Act 1998* declares a broad list of petroleum-related activities to be a 'public purpose'. The list appears sufficiently broad that it will encompass the scope of the Project to the extent it is presently defined. Once granted, licencees have the right to enter the land and use that land to the extent reasonably necessary to conduct the operations for which the licencee has been granted. Such access rights are conditional upon providing appropriate compensation to the lawful owners and rightful occupiers of the land (see Section 2.2.2.2). Compensation can be payable under either or both the *Oil & Gas Act 1998* and the *Environment Act 2000* for loss of or damage to an interest in land. This could include damage to improvements on the land, such as crops, trees, structures and cultural heritage sites, and social inconvenience from lack of ongoing access to portions of the claimants' land.

The *Oil & Gas Act 1998* (Section 118) and the *Environment Act 2000* (Part VII, Division 3) provide for compensation to be paid to landowners, and to lawful occupants on land owned by the State of Papua New Guinea, and also provides for compensation to a broader set of claimants, i.e., 'owners and occupiers of, and any person with customary rights in, any private land in relation to their several interests'.

TEP PNG's approach to acquiring the rights of access to land needed for the exploration phase and development studies for the Project has been through good faith negotiation of clan land-use agreements and short- term leases conditional upon providing compensation to the lawful owners and rightful occupiers of the land.

Short-term leases are used by TEP PNG to effectively reserve uninhabited land for relatively short durations (e.g., 12 months, extendable by up to two six-month terms) in return for payment of a 'Restricted Use Fee'. Short-term lease conditions enable owners and occupants to continue their existing land uses particularly for access to natural resources but restrict them from settling or constructing new homes or buildings on a defined parcel while TEP PNG determines where its permanent facilities will be located.

For the next phase of the Project, in compliance with the *Oil and Gas Act 1998*, the Regulator Department of Petroleum and Energy (DPE) will review and validate the customary landowners identified through the social mapping and land investigation (SMLI) studies and make recommendations for the Minister of Petroleum and Energy to issue a Ministerial determination.

TEP PNG will engage in negotiations with the landowners for the long-term lease (50 to 99 years) covering the permanent facilities and the export pipeline route.

The PNG Government plays a central role in land access processes. Identifying the lawful landowner and the rightful land occupiers is the subject of legal landowner identification and mapping processes under the *Oil and Gas Act 1998* (see Section 2.2.2.3) that are outside the scope of this EIS. Those processes determine rights to customary lands and thus entitlements and compensation for permanent and or temporary loss of the land. Although compensation is negotiated and agreed by the licencee/ permit holder under both the Oil and Gas and Environment Acts, where necessary the valuation of property can be sought and administered under the *Valuation Act 1967* (Chapter 327) and the *Valuation (Amendment) Act 2016* (see Section 2.3) however the *Oil and Gas Act 1998* also makes reference to the Valuer General's Compensation Schedule for trees and plants (Filer et al. 2000).

In Papua New Guinea the *Land Act 1996,* prevents customary landowners from directly leasing land to developers. Thus, landowners wishing to engage in direct land dealings are able to enter into a freehold sale or lease back arrangement with the government. The land will then be leased from the government by the Project to conduct operations on the land. The customary landowners will receive rental payments for the land used by the Project and royalty payments from the Government via the establishment of Incorporated Land Groups (ILG). Land accessed by the Project will revert to its customary owners once Project activities have been completed and/or at the expiration of the lease.

International Finance Corporation performance standard 5 (IFC PS5) applies to physical and/or economic displacement resulting from land access processes including: expropriation or other compulsory procedures; negotiated settlements with property owners or those with legal rights to the land if failure to reach settlement would have resulted in expropriation or other compulsory procedures; involuntary restrictions on land use and access to natural resources cause a community or groups; project situations requiring evictions of people occupying land without formal, traditional, or recognizable usage rights; and restriction on access to land or use of other resources including communal property and natural resources such as marine and aquatic resources, timber and non-timber forest products, freshwater, medicinal plants, hunting and gathering grounds and grazing and cropping areas. IFC PS5 (2012) was developed on the premise that cash compensation alone is frequently insufficient for restoring displaced people's living standards and livelihoods. Accordingly, IFC PS5 promotes provision of resettlement assistance, replacement housing and measures to restore livelihoods in addition to cash compensation.

13.3.2 Identification and Initial Assessment of Potential Impacts

Approximately 1,800 ha of land will be required for the Project. Land requirement estimates at pre-FEED stage are set out in Table 13.6 and include:

- 140 ha of customary-owned (clan) land already used by TEP PNG during the exploration and early Project phases.
- 912 ha of additional land required for Project facilities.
- 230 ha (or 15%) contingency for potential unexpected land intake during construction.
- 518 ha of land acquired around the CPF area to establish a safety and security exclusion zone.

The final land requirements will be refined during FEED and the physical construction of the facilities and will account for future pre-construction survey findings.

Table 13.6 – Estimated Customary Land Requirements at Pre-FEED Stage

Project Facilities	Total Land Requirements (ha)
(A) PRL-15 Production Facilities	
Well Pads (ANT-10, ANT-11, ELK 10)	21
Drilling camp and log base (old ANT-3 camp)	21
Water dams (Ant 10, ELK 10)	2
Trunklines and flowlines (40 m wide average ROW)	170
Sub-total for A	***214***
(B) Industrial Area (CPF) in PRL-15	
New Logistics Base	7
CPF (Production facility, camps, construction area, flare and vent, waste and landfill storage)	100
Sub-total for B	***107***
(C) Other Infrastructure in PRL-15	
Herd Base Operations Camp (with an additional lay-down area for the export pipelines)	58
Purari Airstrip and access road	103
Project roads R1, R2, R4, R5, R6, R7	132
Spoil dumps and their access	120
Quarries	52
Telecommunications	3
Sub-total for C	***468***
(D) Onshore Pipeline Export Route (PER)	
PER 61 km x 40 m ROW (incl. four valve stations and spoil dumps)	244
Export pipelines – laydown areas and a construction camp	19
Sub-total for D	***263***
Summary	
Total land required for Project facilities (A+B+C+D)	1,052
(i) Land currently in use	140
(ii) Additional Project impacted area	912
15% Design and Construction Contingency	230
CPF exclusion zone	518
Estimated Total Land Requirement	***1,800***

Note: area estimates are approximate.

Customary clan land will be acquired, leased or secured by short-term and long-term land agreements. Clan land generally includes common areas of land in which all clan members can fish, hunt and collect resources, and specific land areas allocated to families where people will live and make gardens. Land areas allocated to families are most often the more fertile where gardens can be grown and, because of this fact, are generally close to where villages have been established.

The proposed Project design and its onshore infrastructure incorporated the findings of the socio-economic baseline studies in order to avoid the permanent loss of primary residential structures or shelter (physical displacement or resettlement) of PAOI individuals or communities. Acquiring land will cause the temporary and permanent loss of land and resources used for livelihoods (economic displacement) in the Project footprint and, in some cases, will also cause involuntary restrictions on land use and access to natural resources and communal property for PAOI communities.

Most land (approximately 73% or 1,300 ha) to be acquired for Project components is in the largely unpopulated PRL-15. This land includes a safety and security exclusion zone of approximately 518 ha that will be established around the CPF. The Project will not adversely affect this exclusion zone. Engagements will take place with customary landowners and land users to enable access to natural resources, while the land use restrictions to avoid any development or settlements near the CPF are respected. The remainder of the Project's land required (approximately 27%) will be needed for the export pipeline route (which is largely unpopulated except for the shore crossing at Orokolo Bay), and associated infrastructure (construction camp, pipe yards, condensate and gas valve stations).

Thus, Project land access will primarily impact Project-affected persons, Project-affected communities and local communities in and around PRL-15 and, to a lesser extent, Project-affected persons who live around the export pipeline route.

13.3.2.1 Reduced Livelihood of Project-affected Persons Living in and Around PRL-15 due to Land Access

Land access for the construction and operation of all permanent and temporary Project components in PRL-15 will remove approximately 0.95% of the area of PRL-15, that may be used for subsistence resources for Project-affected persons living in and around the PRL-15 area. These groups are wholly dependent on land natural resources, some of which are located outside of PRL-15, for their subsistence-based livelihoods, including for food (e.g., forest animals, fish, and plants), medicine, housing and canoe building materials and firewood for fuel (see Section 9.8.6).

All clan land to be acquired by the Project in PRL-15, is on land that comprises either primary or logged hill forest and alluvial forest (Table 16.5). The availability of forest habitat for wild food provisioning is considered a medium value priority ecosystem service for inland communities, as these communities have greater access to forest resources in surrounding areas (Table 16.8), i.e., these resources are largely replaceable. The loss of natural resources due to land access is largely replaceable for Project-affected persons living in and around PRL-15, therefore, a ***Medium*** sensitivity rating is applied.

Project-affected persons living in and around PRL-15 have had previous experience of land access processes since exploration activities commenced in PRL-15 in 2006 (see Section 1.4). These groups have had and continue to have exposure to land leasing arrangements with the commercial logging industry under the Baimuru Block 3 logging lease which covers PRL-15 (see Section 9.8.3). Project-affected persons living in and around PRL-15 are; therefore, considered to have some resilience to change having already had exposure to land access impacts, thus a ***Medium*** impact magnitude rating is applied to land access for these communities. The initial social impact significance is therefore assessed as ***Moderate.*** This rating is applied to the Project operations phase which will have the longer duration of impact compared to the temporary and smaller construction areas that will only be utilized for a short (1 to 4 years) period of time.

13.3.2.2 Reduced Livelihood of Project Affected Persons Living around the Onshore Export Pipeline Route due to Land Access

TEP PNG will acquire approximately 263 ha of land for the onshore export pipeline ROW, including land for associated temporary and permanent infrastructure and facilities. Temporary land access may also include land along the Purari River, as the construction camp and pipe yard 4 near the Purari River opposite Aivai will require an estimated 19 ha. Permanent land-use restrictions to preserve the integrity of the pipeline will apply over the export pipeline right of way once restoration and rehabilitation works are complete. The gas and condensate valve stations (a total area of 6 ha) will be permanently fenced.

In the export pipeline route approximately 0.6% (6 ha) of the land to be accessed by the Project is in customary gardens and sago cultivation while approximately 8.2% (81 ha) comprises customary-owned stands of wild sago and forest complexes (Section 16.12). These forest and garden complexes are assessed as providing high value provisioning ecosystem services for communities, and particularly for Project-affected persons living in the Orokolo Bay coastal area (Section 16.4.3). These services include wild foods (e.g., plants, nuts and fruits), food crops (sago), firewood (including marine driftwood), timber and wood products, fresh water for domestic use, transportation, access and fisheries. While communities around Orokolo Bay rely on these food sources with some limitations to source alternatives, the overall area of land to be acquired for construction and operation of the onshore export pipeline is comparatively small, thus an overall ***Medium*** impact magnitude and sensitivity rating is applied. Thus, the initial social impact significance is assessed as ***Moderate***.

Section 13.9 discusses the potential impacts associated with community access to the Purari River, nearshore marine environment and beaches along Orokolo Bay during pipeline construction; therefore, these impacts are not assessed further in this section.

13.3.2.3 Reduced Livelihood of Project-affected Persons due to Loss of Income from Forest Logging Resources

Most of the land in commercial logging concession Vailala Block 3 to the south of the Purari River has already been logged. PRL-15 is in commercial logging concession Baimuru Block 3. Construction-related clearing will remove an estimated 745 ha of potentially commercial production forest in PRL-15, of which 150 ha has already been logged and 595 ha is unlogged (Section 16.5.1.8). The estimated construction-related clearing area represents less than 0.2% of Baimuru Block 3. Chapter 16 assesses the potential loss of commercial forestry resources in terms of ecosystem services for commercial asset owners and royalty payments to landowners; therefore, these impacts are not assessed further in this section.

13.3.2.4 Reduced Access for Project-affected Communities along the River Transport Corridor

Rivers are the main transport routes for communities to access schools, hospitals, markets, food gardens, sago processing sites and fishing areas (see Figure 13.1). The predicted increase in barge traffic associated with Project construction activities is unlikely to restrict access and community use of the primary and secondary river transport corridors, respectively Purari River and Uriko-Ivo River.

Section 13.9 discusses the potential impacts associated with community access to the Purari River, nearshore marine environment and beaches along Orokolo Bay during pipeline construction; therefore, these impacts are not assessed further in this section.

13.3.2.5 Increase in Community Tension due to Land Access, Compensation and State Financial Payments

In Papua New Guinea clan disputes over land ownership and associated compensation and State financial payments have driven community tension on most of the large resource extraction projects to date (Section 9.14.2). While no significant land disputes have occurred between customary landowners related to the Project temporary land access in the PAOI, land disputes were a major cause of tension among Pawaia groups for a proposed hydropower dam in the

Purari River catchment in the past (see Part 15 of Volume 2). In Gulf Province too, logging activities have the potential to be a source of adverse social and environmental impact causing clan disputes, as landowners are generally not benefited as expected (see Part 15 of Volume 2).

Section 13.8 discusses the potential impacts associated with increases in community tension including impacts related to land access activities; therefore, these impacts are not assessed further in this section.

13.3.2.6 Summary of Identified Potential Impacts of Economic Displacement to Livelihoods

The Project has the potential to cause economic displacement and reduce livelihoods in PRL-15 and along the onshore export pipeline route to due land access activities.

The following embedded design controls address potential impacts of economic displacement and livelihoods:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g.: avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

13.3.3 Proposed Mitigation, Management and Optimization Measures

The PNG legal land access and leasing processes that will apply to the Project are outlined in Section 13.3.1. In securing the rights to land necessary for planning, constructing and operating the Project, TEP PNG is committed to meeting the requirements of PNG legislation, the IFC PS 5 and TOTAL's own corporate policies, standards and guidelines (see Chapter 2). TEP PNG will make compensation and lease payments directly to the affected clans or individual landowners in separate agreements for each area of damage or loss, and for each lease.

TEP PNG will develop a Land Access and Resettlement Framework (LARF) for the Project, as a precursor to preparing a Land Access and Livelihood Development Plan (LALDP) and where required a Resettlement Action Plan (RAP). Based on the Project design described in Chapter 4, physical displacement is avoided, and a RAP is therefore, not expected to be required. Nonetheless, it is not possible to disregard the need to prepare a RAP until completion of detailed engineering design, which will define final Project land requirements, and the Project-affected communities and businesses that will be physically and/or economically displaced by the Project.

The LARF will comprise measures to mitigate the potential impacts arising from land access, economic displacement, and possible physical resettlement of Project-affected persons that are described in Table 13.7. Land access is required to commence early works and construction.

Mitigation measures to be implemented during various Project phases to further manage these impacts are described in Table 13.7.

Table 13.7 – Land Access and Economic Displacement Mitigation Strategies and Management Plans

Potential Impact	Mitigation Measures	Relevant Management Plan
Land Access		
Reduction of livelihood of Project-affected persons living in and around PRL-15, around export pipeline route due to land access.	♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g., roosting, breeding, nesting and threatened species sites, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001]. ♦ Development of Project Land Access and Livelihood Development Plans (LALDP) consistent with the goals, objectives, principles and processes described in the Land Access and Resettlement Framework (LARF) and continuously drawing on lessons learned from the land access and resettlement activities. The LALDP will adequately cater for the respective interests of the Project-affected persons (PAPs) in accordance with criteria for eligibility and the PAPs' choice of type of compensation (e.g., cash or in-kind). The LALDP will: – Describe processes for appropriate disclosure of information, consultation and the informed participation of Project-affected persons with the aim of obtaining their free, prior and informed consent. – Provide a compensation framework with compensation for loss of assets at replacement cost; – Design livelihood programs which aim to improve or at least restores the livelihoods and standards of living of displaced persons which choose to remain in the project area of influence; and – Include special provisions for identified vulnerable individuals or groups. – If physical displacement of primary residents is required; include provisions to improve living conditions among displaced persons which have chosen in-kind compensation through provision of replacement housing. – Provide a monitoring framework for the implementation of LALDP [SM001]. ♦ The Project will, in consultation with local communities, government and civil society, design and deliver a diversified livelihood program that provides eligible Project affected people which choose to remain in the project area of influence with opportunities for improving their existing livelihoods and that contributes to the diversification of skills with the aim of triggering income generating activities. Livelihood programs will consider how project affected persons can be involved in Project employment opportunities (direct and indirect) and how skills learned on the Project can be applied to other sectors in the local area [SM002]. ♦ As part of the Land Access and Resettlement Framework (LARF): – Provide a framework for stakeholder engagement on land access and livelihoods including public consultation, disclosure and grievance resolution. – Provide preliminary information to stakeholders (e.g., government, civil society) about the standards and procedures for the LARF [SEM003].	Land Access and Livelihood Development Plan; Resettlement Action Plan (if required); Community Development Plan; Stakeholder Engagement Plan.

13.3.4 Residual Impact Assessment

The following section provides the assessment of residual impacts of Project land access to livelihoods of Project-affected persons, including to local business asset operators in the Project area, assuming successful implementation of the proposed mitigation measures.

13.3.4.1 Reduction in Livelihood of Project Affected Persons Living in and Around PRL-15 due to Land Access

The Project will acquire a very small part (estimated 0.95%) of PRL-15 to construct and operate the Project. As PRL-15 is largely uninhabited, the natural resources are assessed as being non-priority and replaceable resources for the PRL-15 Project-affected persons and communities. Under the LARF, eligibility for compensation and livelihood assistance will be determined with reference to the provisions of *the Oil and Gas Act 1998* and IFC PS 5. The definition of eligible groups, their compensation entitlements and compensation rates will be progressively refined based on the findings of the household and socio-economic surveys, land and asset inventories, market price studies and through consultation with the Project-affected persons.

Eligible groups will be compensated in cash (at full replacement cost) and/or in-kind compensation and will participate in livelihood development programs. In addition, there will be other measures that will favor Project-affected persons in Project local procurement and employment opportunities and will provide special assistance to vulnerable or disadvantaged individuals or groups. These specific mitigation measures for displacement impacts, alongside potential benefits arising from the Project Community Development Plan (described throughout this chapter) are expected to largely reduce potential livelihood losses due to Project land access.

Thus, a ***Low*** residual impact magnitude is attributed to a reduction in livelihood as a result of land access. As outlined in Section 13.3.2.1, potential loss of livelihood from land access is attributed ***Medium*** sensitivity for PRL-15 Project-affected persons. Based on these ratings, the impact significance to livelihoods of PRL-15 Project-affected persons from Project land access is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment.

13.3.4.2 Reduction in Livelihood of Project-affected Persons Living around the Export Pipeline Route due to Land Access

The Project will acquire an estimated 263 ha of land over the approximate 61 km of the export pipeline route and associated infrastructure near Aivai. Permanent land-use restriction will apply on the final right of way upon its restoration and rehabilitation, and the condensate and gas valve station of approximately 6 ha will be permanently fenced.

As for PRL-15, under the LARF, eligible groups along the export pipeline route will be compensated in cash (at full replacement cost) and/or in-kind compensation and will participate in livelihood development programs. In addition, there will be other measures that will favor Project-affected persons in local procurement and employment opportunities (see Section 13.4.3) and will provide special assistance to vulnerable or disadvantaged individuals or groups.

Thus, a ***Low*** residual impact magnitude rating is attributed to land access processes along the export pipeline route and for associated infrastructure near Aivai.

Potential loss of livelihood from land access is attributed ***Medium*** sensitivity. Based on these ratings, the residual impact significance due to Project land access along the export pipeline route is reduced from ***Moderate*** for the initial assessment, to ***Minor*** for the residual assessment.

13.3.5 Summary of Residual Economic Displacement and Livelihoods Impacts

A summary of the assessment of residual impacts to economic displacement and livelihoods is provided in Table 13.8, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.7.

Both residual impacts are assessed to be ***Minor***.

Table 13.8 – Summary of Assessment for Residual Impact Significance for Economic Displacement and Livelihoods

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Land access.	Reduction of livelihood of Project-affected persons living in and around PRL-15 due to land access.	Direct	Project-affected persons, living in and around PRL-15.	C, O	♦ EM001 ♦ SM001 ♦ SM002 ♦ SEM003	Medium/Low	Minor
	Reduction of livelihood of Project-affected persons living around the export pipeline route due to land access.	Direct	Project-affected persons, along the export pipeline route.	C, O		Medium/Low	Minor

C = Construction, O = Operations.

13.4 Economic Development and Employment

13.4.1 Context

The formal economy in Papua New Guinea is dominated by resource exploration and production, commercial agriculture, tuna processing, logging and a small manufacturing sector. The informal economy, which supports approximately 85% of the population, primarily depends on subsistence agriculture (ADB, 2015).[2] Most people in the PAOI live predominantly subsistence-based lifestyles, with some employment by government, church agencies, logging and petroleum exploration. Most households earn cash income from the sale of betel nut, sago, fish and garden produce, and village leaders from Mapaio, Aivai, Upaia and Wabo identified logging royalties as a main source of cash income for their villages.

Cumulative impacts associated with economic development and employment are discussed in Chapter 17.

13.4.1.1 Income and Livelihoods

The main occupation in the PAOI is subsistence activities, where 63% of males and 76% of females aged 16 years and above were engaged primarily in providing food, water and shelter in 2016 (see Part 15 of Volume 2).

Men and women in the PAOI perform distinct roles. Men are primarily, but not totally, responsible for heavy manual labor tasks, such as hunting, making canoes and building houses, while women will more likely spend time making sago and performing other duties, such as caring for children, collecting water, cleaning and cooking.

Most of the workforce is engaged primarily in subsistence activities; although, 46% of males and 14% of females aged 16 years and above have had some previous formal work experience. The most common types of employment were laboring positions, logging/milling (7%), administration/clerical positions, carpenters, cooks/catering, pastors and security; however, various additional technical positions were also identified, including plumbers, plasterers, painters and surveyors. The main employers identified during the baseline surveys were the government, churches and TEP PNG contracting agents, the latter being particularly prevalent among Pawaia villages.

The average fortnightly income was PGK299 per household; however, this was heavily skewed due to a few relatively high incomes. The median fortnightly income level, which often better reflects the population, was PGK80 per household, which could be extrapolated to PGK2,080 per household per annum. This is PGK312 per capita per annum. Income levels are; therefore, low when compared to PNG standards; and furthermore, income is also irregular, as 21% of households recorded no cash income in the fortnight prior to the survey.

Most households earn some form of income from the sale of products derived directly from the local environment. Wages provided the main source of income for 9% of households, and business activities were the main source of income for an additional 7% of households. The most common business activities are trade stores, fuel sales and canoe or dinghy hire.

2 The informal economy is not monitored by any form of government nor is it taxed. Unlike the formal economy, activities of the informal economy are not included in the gross national product or gross domestic product.

The main constraints to household income identified during baseline surveys were poor transport access and high transport costs. Added to this, relatively few buyers visit the PAOI to purchase local products.

Most household expenditure across the PAOI was allocated to food (29% of all expenditure), fuel and transport costs (16% of all expenditure), alcohol and tobacco (9% of all expenditure), and customary payments and business costs (combined 7% of all expenditure).

Table 9.21 identifies that households living below the national poverty line are present in all baseline survey-participating communities in the PAOI (21 to 63% of households) and that most communities have households that did not receive any income in the previous two weeks. Almost two thirds of communities from most language groups, except the Maipua people from Apiope in the Purari river transport corridor, also had households that regularly went a day without eating and 30% of communities amongst the Iare, Koriki, Orokolo and Pawaia language groups surveyed had households that spent more than 40% of their income on food.

The same table identifies only one or two households from the Orokolo communities of Harevavo and Herekela, and the Kaimare community of Mariki did not participate in subsistence activity in the previous two weeks (11% of communities and 3% of each of those two language groups). Given the extent and importance of subsistence activity in the PAOI, failure to participate in subsistence activity over an extended period of time is likely to contribute to hardship and vulnerability, but they are not significantly present at this time.

In addition, households headed by women were present in all but one language group, particularly the Iare communities where they made up almost 10% of households, and households with all female members were present in five of the seven language groups, except the Koriki and Maipua communities.

These are all indicators of pre-existing vulnerability (see Section 9.15.1).

13.4.1.2 Housing and Household Assets

Most houses in the PAOI are made from traditional materials gathered locally; although, house designs vary substantially, particularly between the Pawaian and coastal communities.

The most common main sources of power for lighting are solar (53% of households), torches (26% of households) and battery-powered lamps (17% of households). The main sources of drinking water are rainwater catchments (37% of households), tanks (32% of households), rivers and creeks (16% of households) and shallow wells (8% of households). Rainwater catchments include any drums, pots or other containers that can be used to collect and store rainwater from a roof.

Most households own various basic assets, many of which are required for gardening, fishing, hunting or house construction. Very few households own such items as refrigerators, freezers, chainsaws, a gun or a rifle. Approximately 66% of households have canoes, while only 15% of households have a dinghy and 21% of households own an outboard motor (which could be attached to either a canoe or dinghy). No motor vehicles or motorbikes were recorded in the PAOI.

Data collected during baseline surveys indicated the Pawaia (PRL-15) and Orokolo (export pipeline route) language groups had the greatest percentage of households (46%) above the average village household size (6.1 people per household in Gulf Province), which is a proxy for overcrowding, followed by the Iare (PRL-15 and river transport corridor) communities at 41%. Overcrowding is likely to exist to some extent in all language groups and is a potential source of pre-existing vulnerability (see Section 9.15.3).

13.4.1.3 Economic Infrastructure

Economic infrastructure is defined in the EIS, as the physical structures and services in the PAOI, excluding transport infrastructure (which is described separately in Section 13.9). Economic infrastructure in the PAOI is limited when considering access to communications, electricity, banks and other commercial services.

Approximately 66% of villages surveyed have mobile phone reception, and the only source of electricity is from generators or solar power. Twenty-eight percent of households have access to generators, and 53% have access to solar panels (providing electricity).

Most communities had households that did not have access to electricity across all language groups. The Koriki (river transport corridor) communities were the highest with 55% of households without electricity. No or limited access to electricity is a source of potential pre-existing vulnerability, e.g., it prevents people from fulfilling basic needs, generating income and communicating.

No banks or banking agencies exist in the PAOI. The nearest bank is in Kerema. Thirty-one percent of households surveyed indicated that they (or at least one family member) had a bank account (see Part 15 of Volume 2).

13.4.2 Identification and Initial Assessment of Potential Impacts

13.4.2.1 Increase in Business Activity and Employment Opportunities

PAOI community income levels are anticipated to increase due to the Project through:

- State financial payments (i.e., statutory benefits, development grants).
- Project benefits, compensation and lease payments.
- Direct and indirect employment opportunities (i.e., the Project workforce and supply chain)
- Expanded local business activity due to:
  - An increase in local sales of fish, betel nut and garden produce and/or an increase in the extraction and sale of timber products or cash crops.
  - An increase or expansion in local trade stores, cooked food, transport hire and guesthouses due to higher income levels in the PAOI.

The construction period is projected to provide the highest number of local jobs and employment opportunities, with the operations phase providing fewer opportunities. Income and employment levels are expected to return close to pre-Project levels after Project construction, and then after operations, due to a reduction in workforce requirements.

The opportunity to earn income from employment or other Project-related activities will attract people from neighboring areas and elsewhere in Papua New Guinea. Project-induced in-migration is discussed in Section 13.1.7.

Financial Payments and In-kind Benefits

The Project will make direct or indirect payments to the State of Papua New Guinea, the provincial and local-level governments and relevant landowners, which will extend to the end of the Project operations phase (i.e., it will be different than income from employment and procurement). Four types of benefits include: (i) statutory benefits (i.e., royalties, development levy, production levy and equity benefits) (ii) statutory development grants, (iii) Project benefits, and (iv) compensation and lease payments.

Of the four types of benefits, the State of PNG administers the following 'State financial payments':

- Statutory benefits: The *Oil and Gas Act 1998* states that a royalty (equal to 2% of the value of wellhead production paid to the national government), a development levy (equal to 2% of the value of wellhead production), a production levy[3] (equal to 2% of the value of wellhead production) and equity benefits (equivalent to 2% of the dividends, provided the national government takes an equity share in the Project, limited to 22.5%) will be shared among the relevant provincial and local-level governments and the licence area landowners in proportions determined by the Minister for Petroleum and Energy during the Development Forum.

  Project area landowners (as defined in the *Oil and Gas Act 1998*) will receive benefits that depend on the activities carried out on their land and are split three ways:

  - 30% to a Future Generations Trust.
  - 30% to a Community Infrastructure Trust.
  - 40% cash payment to defined landowners or landowner entities.

- Statutory Development Grants: Infrastructure Development Grants (IDG) are allocated by the State of PNG for infrastructure development and maintenance in the affected Project communities, local level government, district and province. Business Development Grants (BDG) are also provided by the State of PNG to assist landowner companies in business development activities. Both the IDG and BDG are negotiated and agreed during the Development Forum between the State of PNG, landowners and government representatives, independent of the Project.

The Project administers the following 'Project benefits and compensation payments':

- Compensation and lease payments, made under the *Oil & Gas Act (1998)* and the *Environment Act (2000)* for loss of or damage to an interest in land for Project land access, are discussed and assessed in Section 13.3.
- Project benefits. This is a non-technical term used in this chapter to refer to contributions by TEP PNG for relevant provincial and local community development projects in health, education, livelihoods, environment and/or other areas. The objectives of Project benefits are to maintain and enhance TEP PNG's social license to operate and to mitigate potential socio-economic impacts associated with the Project. Funds provided through the Project benefits stream may be used on programs implemented by nongovernmental organizations, TEP PNG and/or for-profit organizations.

State financial payments along with Project benefits, compensation and lease payments are likely to contribute to economic impacts either because they cause increased income or because they increase the liquidity of the recipient (compensation, see Section 13.3); in both instances they contribute toward an increased cash economy.

As described in State financial payments earlier, the Project will provide revenue to the State of PNG which will allocate funds to the relevant provincial and local level governments; the magnitude and allocation is decided at the Development Forum. The Project will contribute to Papua New Guinean gross domestic product growth, export growth and government revenue at a

3 The Project has agreed to pay this production levy to the State; and it is not yet, but is expected to be, a statutory requirement.

national, provincial and local level. Formal employment will also increase at a national and provincial level.

As described in Section 13.7, opportunities arising from State financial payments may not be realized in an equitable nor timely manner by Project-affected persons, communities and local communities, due to potential increased challenges to government administration.

Direct and Indirect Employment

Fifty to 6,000 workers are anticipated to be required during the initial stages of early works to the period of peak construction activities. The construction workers will be demobilized once construction is completed. The operation of the upstream facilities (e.g., wellpads, trunklines, flowlines, CPF and export pipelines) will require approximately 180 Project workers and 70 security workers. Further information on workers can be found in Chapter 4.

The number of workers from the PAOI has not been estimated; however, TEP PNG is committed to conducting skills assessment surveys, and providing training and employment opportunities according to a geographic hiring prioritization scheme, which gives the highest priority to people most affected by the Project TEP PNG has set the following objectives and activities to develop the local (i.e., PAOI) and national workforce in its National Content Plan:

- Use early works to provide on-the-job training to local workers in the lead-up to the construction phase.
- Developing technical and vocational education and training initiatives to facilitate local workforce participation in the Project construction phase.
- Developing the skills of PNG nationals employed during the construction phase, and working with contractors and their subcontractors to implement short training courses to assist in meeting this objective so that Papua New Guineans develop new skills intended to outlast the Project lifetime.

The number of expatriates employed by the Project is expected to decline steadily over time as PNG nationals acquire relevant competency and experience, and according to training and localization plans approved by the PNG Government.

The employment focus will remain on meeting and delivering the National Content Plan objectives and activities, given the low literacy and low education levels in the PAOI (see Section 13.5), and the limited number of people with relevant technical skills or experience.

Opportunities for moderately skilled and unskilled workers exist in security, camp cooking and maintenance. While some local people may gain employment and have relatively high wage levels, the overall impact on income levels in the PAOI, particularly for Project-affected persons and communities in and around PRL-15 and along the export pipeline route, due to direct Project employment may be relatively small. The PNG LNG project found that most low-skilled workers during the construction phase were local workers with limited training who were engaged for short periods and; therefore, left with limited capacity to gain further employment (Voigt-Graf & Odhuno, 2019).

Given the lack of previous business experience in the petroleum (or other) industries, there is risk that a relatively small proportion of contracts (by value) is awarded to community-owned businesses in the PAOI, except for joint ventures between local (PAOI-based) companies and larger, experienced companies from elsewhere in Papua New Guinea or abroad. Some local business people may be awarded contracts with TEP PNG or their major contractors, but the main direct benefit to local people will be in the employment created by these contracts; however, many of the employees will need to be sourced from outside the PAOI if the contracts require technical skills. The degree to which local business contracts increase income levels in the PAOI may potentially be relatively small.

Consistent with Section 129 of the *Oil & Gas Act 1998*, the Project will procure goods and services from local businesses, whenever those goods and services are available under comparable terms and conditions with foreign suppliers. In addition, and under its National Content Plan, TEP PNG has committed to develop objectives and initiatives to encourage in-country procurement, development and support of PNG businesses. Objectives and initiatives are focused on work packages specifically designed for local sourcing, supporting training and capacity building, and appointing Business Development Officers to assist small and very small-scale business in the Project area.

Expanded Local Business Activity

A range of direct and indirect business opportunities in the PAOI may be created due to an increased cash economy and a modest increase in wealth due to Project employment and procurement. Opportunities may include produce sales in trade stores, cooked or processed food sales in local stalls, transport services (particularly dinghies), fuel sales, and potentially guesthouses, as people migrate towards the PAOI in search of employment or business opportunities. These opportunities are expected to occur predominantly where population growth is expected from natural increases and or in-migration (see Table 13.1) and where community development initiatives such as improvements to education or health services are planned.

The expected increase in wages due to direct and indirect Project employment may also increase local expenditure, which will represent an input into the local economy.

Food prices are likely to rise in the short term, in line with higher income levels, but prices may subsequently fall as more people enter the business market (i.e., through in-migration or a greater take-up of commercial opportunities by locals) and bring competition and diversification. Other negative impacts to health, community cohesion, and law and order associated with an increase in income and wealth are discussed in Sections 13.6 to 13.8.

The greatest impact, in terms of the increase in store foods available, and a reduction in price, is expected to occur in the Pawaian villages, where few stores exist, and prices are currently the highest in the PAOI.

Vulnerability Considerations

Local communities highly value employment opportunities and expectations that local communities will be prioritized for employment are high. Education and relevant skills amongst local communities are limited (see Section 13.5), which limits their potential to benefit from some of the Project's employment opportunities.

Further indicators for pre-existing vulnerability are apparent across most of the PAOI including those related to health conditions, poverty, food security, housing, livelihood security and access to infrastructure. Without active measures to promote the education and employment of women, employment opportunities for women from local communities may be limited due to existing cultural gender norms and inequalities.

Initial Impact Assessment

Increased direct and indirect national and local business activity, and employment and development opportunities are expected due to Project employment and procurement (and including State financial payments and Project benefits, compensation and lease payments), which will increase income, wealth and skills in general.

The Project will contribute to Papua New Guinean gross domestic product growth, export growth and government revenue at a national, provincial and local level. Formal employment will also increase at a national and provincial level. This direct and indirect impact is expected to be experienced by the national, provincial and local level business community, and supply chain workers in the short to long term. Permanent positive impacts may also occur, hence a magnitude rating of ***Positive***. A sensitivity rating of ***Medium*** is applied, as some capacity to realize opportunities of this scale exist, albeit strained due to challenges with government administration (see Section 13.7). The initial social impact significance with regard to direct and indirect increased business activity and employment opportunities on a national level is assessed as ***Positive*** based on these ratings.

On a local scale, increased direct and indirect business activity, employment and development opportunities are expected to be experienced predominantly by Project-affected persons and Project-affected communities, and local communities in PRL-15 and along the export pipeline route, and to a lesser degree along the river transport corridor. Areas that may benefit to a greater degree include Wabo, Ura, Wabo Station, due to potential in-migration and where customary owners reside (see Table 13.1), Poroi 1, Mapaio Fish Camp, Subu, Aivai, Iuku and Mareke, as they are near construction activities, the shore crossing and where increased economic opportunities are expected or where clans claiming ownership over PRL-15 reside. Positive impacts may be felt at a regional level through targeted mitigations such as workforce training and development (see Section 13.5) that are considered in the residual significance assessment.

Greater employment opportunities are expected in the short to long term and are expected to increase income and wealth in general, which may positively impact on social development more broadly, and infrastructure and functioning, hence a magnitude rating of ***Positive*** has been applied to PRL-15, the export pipeline route and river transport corridor. A sensitivity rating of ***High*** is applied, as there is currently limited or no capacity to realize opportunities of this nature in PRL-15, and along the export pipeline route or river transport corridor. The overall initial social impact significance regarding direct and indirect increased business activity and employment opportunities on a local level is ***Positive*** based on these ratings.

13.4.2.2 Decrease in Business Activity and Employment Opportunities After the Commissioning and Decommissioning Phases

Income levels in the PAOI will likely return close to pre-Project levels after Project construction, as Project employment and business contracts will decrease and, again, after Project decommissioning. As a consequence, income from local business activities (e.g., trade stores, fuel sales and dinghy hire) will also likely decrease in PRL-15, along the export pipeline route and to a lesser degree, along the river transport corridor.

Many people are unlikely to have prepared adequately for seeking employment beyond the Project; although some people may have accumulated savings and others may have invested in sustainable economic activities such as cash crop production.

Initial Impact Assessment

A decrease in direct and indirect employment opportunities is expected when Project construction is completed, and contractors demobilize. Similarly, operations jobs will be lost following Project decommissioning. These losses in Project employment will have flow-on effects to related business contracts and other businesses locally, regionally and nationally. This impact is expected to be experienced predominantly by Project-affected persons and Project-affected communities and local communities in and around PRL-15, along the export pipeline route, and to a lesser degree, along the river transport corridor. Areas that may be impacted to a greater degree include Wabo, Ura, Wabo Station, where population is expected to increase and where customary owners reside (see Table 13.1), Poroi 1, Mapaio Fish Camp settlement, Subu, Aivai, Iuku and Mareke, as they are near the construction activities, shore crossing and where increased economic opportunities are expected or where clans claiming land ownership in PRL-15 reside (see Table 13.1). Skilled and unskilled workers and supply chain workers may also be impacted.

Without mitigation, impacts may be felt in the longer term but are potentially reversible and are; therefore, ***Medium*** in magnitude in PRL-15 and along the export pipeline route, and ***Low*** along the river transport corridor. There is currently limited or no capacity for impacted communities across the PAOI to adapt to this change; hence a ***High*** sensitivity rating has been applied, as with the potential impact related to employment opportunity.

The initial social impact significance regarding a decrease in business activity, and direct employment and development opportunities for PRL-15 and the export pipeline route, is ***Moderate***, and for the river transport corridor, is ***Minor*** based on these ratings.

13.4.2.3 Reduction in Community Cohesion

The amount of household and subsistence labor is likely to increase for women and children, as PAOI communities, and men in particular, dedicate more time to Project activities including direct employment, business development opportunities, and landowner and benefit sharing discussions. There is an additional risk that the introduction of higher cash incomes may have potential adverse impacts on families despite the Project generating direct and indirect employment. Men, unaccustomed to high levels of disposable income, may choose to spend money on prostitution (evidenced in nearby logging camps, see Chapter 9) or alcohol, e.g., leading to family disputes, and a potential increase in separation and divorce. Women are particularly vulnerable, as divorce and separation are uncommon across the PAOI and, in the case of some Pawaias, has allegedly led to repercussions including sorcery.

Impacts relating to increased income and associated changes to social and leadership structures are discussed and assessed in Section 13.7. Issues relating to the loss of a sense of community are discussed and assessed in Section 13.8, and issues relating to potential loss of intangible cultural heritage are discussed and assessed in Chapter 14.

These shifts in culture may negatively affect community cohesion amongst Project-affected communities.

Initial Impact Assessment

The wealth brought by Project employment, business development opportunities and State financial payments to some families may reduce community cohesion in some communities. This impact is expected to be experienced during construction and operations, as this is when income-earning opportunities will be highest; however, if they are unmitigated, they have the potential to be longer-term. Project-affected and local communities in and around PRL-15 and along the export pipeline route, and to a lesser extent along the river transport corridor are expected to be adversely impacted. Areas that may be impacted to a greater degree include Wabo, Ura, Wabo Station, where population may increase and where customary owners reside (see Table 13.1), Poroi 1, Mapaio Fish Camp, Subu, Aivai, Iuku and Mareke, as they are near the construction activities, shore crossing and where increased economic opportunities are expected or where clans claiming ownership over PRL-15 reside (see Table 13.1).

Impacts are not expected to be reversible without mitigation, and; therefore, are ***High*** in magnitude in PRL-15 and along the export pipeline route and ***Medium*** along the river transport corridor. A ***Medium*** sensitivity rating has been applied, as there is currently some capacity for impacted communities across the PAOI to adapt to this change. The initial social impact significance regarding adverse impacts due to changes in community cohesion in and around PRL-15, along the export pipeline route and along the river transport corridor, is ***Moderate*** based on these ratings.

13.4.2.4 Changes in Livelihood and Subsistence Practices

The Project has been designed so that facilities and infrastructure will avoid villages and gardens as far as practicable. Impacts to livelihoods (due to land access) and to subsistence practices (for provisioning ecosystems services) are discussed in Section 13.3 and Chapter 16, respectively, and therefore are not assessed further in this section.

13.4.2.5 Improved Housing and Living Conditions

The increase in income levels in the PAOI is expected to allow some people to invest in housing to improve their living conditions. Houses may be upgraded by using iron sheets for roofs or, e.g., procuring generators or solar power, installing electric lights or water tanks, or buying modern appliances, such as a refrigerator or television.

Constraints limiting investment in housing in the PAOI include the high cost of transporting materials and the lack of any commercial services (e.g., for installing electrical connections or repairing refrigerators).

The most significant changes to any housing and living conditions are expected to be associated with Project-affected persons in PRL-15 and along the onshore export pipeline, as their income levels are expected to increase the most.

Initial Impact Assessment

Improvements to housing and living conditions are expected, as indirect positive impacts of Project employment and procurement. This impact is expected to be experienced during construction and operations, as this is when State financial payments and Project benefits, compensation and lease payments are expected. Those that may be impacted are expected to be predominantly Project-affected persons in PRL-15 and along the export pipeline route. As this is seen as a positive impact in an area with low housing conditions, without any real need for mitigation and some capacity amongst receptors to realize opportunities, magnitude and sensitivity ratings of ***Positive*** and ***Medium*** are attributed respectively, hence an initial social impact significance of ***Positive***.

13.4.2.6 Summary of Identified Potential Impacts to Economic Development and Employment

The Project may cause both positive and negative impacts on economy, employment and livelihoods, including:

- Increase in business activity, and direct employment and development opportunities.
- Decrease in business activity and direct employment opportunities after the Project's commissioning and decommissioning phases.
- Reduction in community cohesion.
- Improved housing and living conditions.

Currently, the Project has not had any direct impacts to economic infrastructure, but opportunities for positive impact exist through the Project's Community Development Plan.

13.4.3 Proposed Mitigation, Management and Optimization Measures

Mitigation and optimization measures to be implemented during various Project phases to manage these impacts are described in Table 13.9.

Table 13.9 – Economic Development and Employment Mitigation and Optimization Strategies and Management Plans

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Increase in business activity and direct employment opportunities during Project construction and operations.	♦ Establish a set of local employment and procurement policies that: – Ban employment applications 'at the gate'. – Includes measures to protect the workforce, in particular to identify and avoid child labor and forced labor. – Gives priority to Project-affected persons and members of Project-affected communities (and in particular women) for local employment opportunities. – Maximizes the employment and training of national citizens including persons from project affected communities. – Includes measures for gender-fair hiring and workplace policies [SM003]. ♦ Community owned company capacity building: Provide support to governance and capacity building programs to improve business development and planning [SM005]. ♦ The Project will maximize the procurement of Goods and Services from local companies including community owned companies. Major contractors will be required to demonstrate measures and staff organization they will implement to maximize national content. The Project will support eligible small-scale enterprises through capacity building programs and advisory/mentoring services aiming, e.g., to improve business plans, to strengthen management capabilities and to facilitate access to information on project employment and business opportunities. At a local level, business development officers will be appointed to identify and assist eligible small and very small-scale businesses in the Project area [SM006]. ♦ Develop initiatives to enhance education and training of youths from the PAOI, e.g.: – A scholarship program to provide opportunities for eligible students from the project affected communities to pursue their studies. – Internships and/or training opportunities with the Project or its contractors specifically focusing on transferable, nationally recognized trade skill development [SM007].	Labor Management Plan; Community Development Plan; Stakeholder Engagement Plan; National Content Plan

Table 13.9 – Economic Development and Employment Mitigation and Optimization Strategies and Management Plans (cont'd)

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Decrease in business activity and direct employment opportunities during Project commissioning and decommissioning.	♦ Institutional capacity building: Provide support to capacity building programs aiming to enhance national and local government capacity to foster diversified economic growth and their capacity to deliver local public services [SM004]. ♦ Community owned company capacity building: Provide support to governance and capacity building programs to improve business development and planning [SM005]. ♦ Develop initiatives to enhance education and training of youths from the PAOI, e.g.: – A scholarship program to provide opportunities for eligible students from the project affected communities to pursue their studies. – Internships and/or training opportunities with the Project or its contractors specifically focusing on transferable, nationally recognized trade skill development [SM007]. ♦ Investigate options to work with local partners to support the development of sustainable ward development plans in the PRL-15 area and along the export pipeline route [SM009].	Labor Management Plan; Community Development Plan; National Content Plan.
Reduction in community cohesion.	♦ Undertake a feasibility assessment in consultation with local stakeholders on delivering capacity and resilience building programs for Project-affected communities and clan/village leaders, e.g., on financial literacy training and conflict resolution training [SM008].	Community Development Plan.
Improved housing and living conditions.	No additional strategies proposed.	Community Development Plan.

13.4.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to economic development and employment, assuming successful implementation of the proposed mitigation and optimization measures.

13.4.4.1 Increase in Business Activity and Employment Opportunities

Increased national and local, direct and indirect business activity, employment and development opportunities are expected due to Project employment and State financial payments, and will increase income, wealth and skills generally across the domestic economy.

On a macro scale, and given mitigations described above, the permanent positive impacts (particularly through increased training and development (see Section 13.5), are expected to be further maximized, thus the impact magnitude would remain ***Positive***. A sensitivity rating of ***Medium*** is applied, as there currently exists some capacity to realize opportunities of this scale, albeit strained due to challenges with government administration (see Section 13.7). The overall residual impact assessment regarding increased business activity and direct and indirect employment opportunities on a national level is ***Positive*** based on these ratings.

On a local scale, business activity, and direct employment and development opportunities resulting in increased income, wealth and skills are expected in the short to longer-term. This has the potential to also positively impact social development, infrastructure and functioning more broadly.

Ratings of ***Positive*** magnitude and ***High*** sensitivity have been applied across the PAOI, as a noticeable promotion of investment locally is expected, albeit in the absence of a skilled and experienced labor 'pool'.

13.4.4.2 Decrease in Business Activity and Employment Opportunities

Income and employment levels are expected to decrease both after Project construction, and then after operations, due to a reduction in workforce requirements. This is likely to have indirect implications for business activity that was associated with increased wealth and population. This is likely to affect Project-affected persons and communities, and local communities in and around PRL-15, along the export pipeline route and to a lesser extent along the river transport corridor, skilled and unskilled Project workers, the national business community and supply chain workers.

There is limited experience in the petroleum sector in Papua New Guinea in terms of formal planning for decommissioning; although, there is substantial experience in the mining sector, with closure plans required for all major mines at least five years before the planned closure date. Experience from mines such as Ok Tedi, Porgera and Hidden Valley indicate low savings rates amongst most landowners, limited investment in non-mining activities, and limited thought as to how people will maintain income levels following closure.

The Project shall consider supporting sustainable income diversification and growth initiatives, capacity- and resilience-building initiatives, and improving economic infrastructure where possible, to assist in overcoming adverse impacts from a decrease in direct and indirect employment opportunities.

Magnitude ratings of ***Low*** for PRL-15 and the export pipeline route, and ***Negligible*** along the river transport corridor are applied, as training and support (via mitigation measures) is expected to have long-term benefits, resulting in increased resilience to change and reversibility of potential adverse impacts. A sensitivity rating of ***Medium*** is applied across the PAOI, as it is expected that mitigations will increase capacity and resilience to changes in business activity and employment opportunities.

The impact significance regarding a decrease in direct and indirect employment opportunities for PRL-15 and the export pipeline route is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment based on these ratings. For the river transport corridor, the initial assessment of ***Minor*** is reduced to ***Negligible*** for the residual assessment.

13.4.4.3 Reduction in Community Cohesion

An indirect impact of changes to and community cohesion is expected due to Project employment and procurement for the reasons outlined in Section 13.4.2.3. This impact is expected to be experienced during construction and operations, as this is when income-earning opportunities will be highest, and, through mitigation, may have a permanent impact. Project-affected and local communities in and around PRL-15 and along the export pipeline route, and to a lesser degree along the river transport corridor are expected to be predominantly impacted.

Low magnitude impacts are expected, as they are likely to be experienced only by a few communities in the PAOI and the capacity-building and cultural programs (see Chapter 14) proposed are expected to increase the capacity of PAOI communities to adapt to changes brought on by the Project and to support cohesion through strengthened leadership and a maintenance of cultural values. A ***Medium*** sensitivity rating has been applied, as there is currently some capacity for impacted communities across the PAOI to adapt to this change.

The impact significance regarding changes to community cohesion in and around PRL-15, along the export pipeline route and along the river transport corridor is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.3.4.4 Improved Housing and Living Conditions

The initial impact was rated as positive in an area with low housing conditions and there is no real need for mitigation; however, opportunity for improvements to economic infrastructure remain. There also remains some capacity amongst receptors to realize change. Magnitude and sensitivity ratings of ***Positive*** and ***Medium*** respectively are therefore applied, hence a residual impact significance of ***Positive***.

13.4.5 Summary of Residual Economic Development and Employment Impacts

A summary of the assessment of residual impacts to economic development and employment is provided in Table 13.10, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.9.

All residual impacts are assessed to be ***Negligible*** to ***Minor*** or ***Positive.***

The most substantial and positive economic impact for local communities can be derived from effectively managing State financial payments and Project benefits. The Project cannot deliver this strategy alone, and it will be pursued in partnership with local-level, provincial and national governments.

Various options are available to improve economic infrastructure in the PAOI; although, the Project is not expected to impact directly on communications, energy, banking or credit.

Table 13.10 – Summary of Assessment for Residual Impact Significance for Economic Development and Employment

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Increased business activity and direct employment opportunities.	Direct and indirect	National business community, supply chain workers.	C, O, D	♦ SM003 ♦ SM005 ♦ SM006 ♦ SM007	Medium/ Positive	Positive
			Project workforce (both skilled and unskilled). Project-affected persons, Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.			High/ Positive	
	Decrease in business activity and direct employment opportunities.	Direct and indirect	Project workforce (both skilled and unskilled), national business community, supply chain workers. Project-affected persons, Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	O, D	♦ SM004 ♦ SM005 ♦ SM007 ♦ SM009	Medium/ Low	Minor
			Project-affected persons, Project-affected communities, and local communities along the River transport corridor.			Medium/ Negligible	Negligible
	Reduction in community cohesion.	Indirect	Project-affected persons, Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	C, O, D	♦ SM009	Medium/ Low	Minor
	Improved housing and living conditions.	Indirect	PRL-15 and export pipeline route Project-affected persons.	C, O	None	Medium/ Positive	Positive

C = Construction, O = Operations, D = Decommissioning and closure.

13.5 Education and Workforce Training

13.5.1 Context

Education infrastructure in the PAOI is poor, with low literacy and education levels evident, particularly in the more remote inland areas. Relatively few people in the PAOI have workforce skills and experience.

13.5.1.1 Education Infrastructure

Baseline surveys identified 32 functioning elementary or primary schools in the PAOI, which does not contain any secondary, tertiary or vocational schools. Most are made of very basic materials and have very limited facilities and equipment. Few schools had access to electricity, and more than half of the schools did not have adequate drinking water.

Approximately 75% of schools have received some external assistance in the past decade. This often includes the construction of a double classroom or one or more teacher's houses, but also commonly is a gift of timber, roofing iron or water tanks. The not-for-profit sector, the private sector and government have all provided some form of assistance to schools in the PAOI.

TEP PNG continues to support PAOI communities with education initiatives, such as providing classrooms at Muro, Poroi 2, Kavava and Arehava Harevavo primary schools in partnership with Digicel Foundation, and donation of various books, stationery and materials to other communities in the PAOI. TEP PNG has also recently (August 2019) provided logistical support and funding of a literacy trainer from the National Volunteer Service to assist with mentoring volunteer community tutors for two years in and around PRL-15.

13.5.1.2 Enrolment and Literacy Levels

School enrolment and attendance in the PAOI is very low, as described below:

- The majority of elementary schools in the PAOI are government-run, and a single teacher services many of these. Church agencies run most of the primary schools. None have boarding facilities. The nearest secondary schools are at Ihu, Araimiri, Kerema and Kikori.
- Ten percent of males and 21% of females aged 16 years and above from those surveyed have never attended school. This includes more than half of the females aged 16 years and above from Pawaian villages.
- In 2016, just 31% of boys and girls aged from six to 15 years were attending school. This net enrollment rate compares poorly with Department of Education estimates for Papua New Guinea (53%) and Gulf Province (42%) for 2007.
- On average, schools were attended by three teachers and approximately 70 students, with an average of 23 students per teacher and 24% of teacher positions vacant. Teacher vacancies and class size were particularly high for elementary schools.
- Women's groups have identified absent teachers as the overwhelming reason for schools either not operating year-round or being closed.
- The most frequently cited reason for poor attendance was that students were required to help at home with gardening, making sago or other work.

The low education levels reflect the distribution of elementary, primary and secondary schools in the PAOI. Approximately half of all males and females aged 16 years and above have completed between Grade 1 and Grade 6. Approximately 32% of males aged 16 years and above have completed between Grade 7 and Grade 10, compared to only 24% of females in the same age category. Very few males or females from the PAOI have completed vocational or technical schools or attended university.

A self-assessment of literacy conducted during the household survey showed that 19% of males and 33% of females aged 16 years and above cannot read or write in any language (Table 9.9). Literacy levels are an indicator of pre-existing vulnerability.

13.5.1.3 Workforce Experience and Training

Thirteen percent of males and 6% of females from those surveyed were formally employed in 2016 when baseline surveys were conducted. A total of 350 males (46%) and 98 females (14%) had previous work experience. As outlined in Section 13.4, the most common types of employment included laboring positions, logging/milling, administration/clerical, carpenters, cooks/catering, pastors and security. Additional technical positions were also identified, including plumbers, plasterers, painters and surveyors.

13.5.2 Identification and Initial Assessment of Potential Impacts

13.5.2.1 Increased Pressure on Education Services and Facilities

Education infrastructure that is already inadequate in terms of servicing the existing population in the PAOI may be placed under additional pressure as an indirect consequence of Project-induced in-migration. Overall enrolment and attendance may increase due to in-migration and population increase in general.

Increased enrolment and attendance will place additional pressure on existing schools and teachers. Schools around the PRL-15 and export pipeline route (Orokolo Bay), in particular, where a population increase is expected to be greatest (see Section 13.1), will likely be under most pressure from increased enrolment and attendance. Less of an impact may be felt in villages along the river transport corridor.

A proportion of State financial payments allocated to provincial and local-level governments (see Section 13.4), may potentially be used to improve the quality or number of education facilities in the PAOI or more broadly depending on the deliberations of the Development Forum. As noted in Section 13.7, ineffective use of government revenue may limit any improvement in school infrastructure and services in the PAOI. Effectively using government revenue to improve school infrastructure and services, particularly in more remote communities, would benefit PAOI communities, given the existing low levels of investment.

Existing poor literacy levels is a key indicator supporting pre-existing vulnerability in the PAOI. As noted during interviews with teachers during the social baseline studies, many of the teachers in the PAOI are frustrated with poor school infrastructure, poor living conditions, limited teaching resources, isolation, difficulties accessing their salaries, and lack of support by the community and provincial government. Some teachers may seek Project employment, both to alleviate the problems they face when teaching and to increase their income. This is likely to leave some schools with even more teacher vacancies than currently exist, while forcing some smaller (single teacher) schools to close. A reduction in teachers is likely to contribute to reductions in school enrolment and attendance, and consequently in lower education and literacy levels in the PAOI.

Initial Impact Assessment

Project employment and procurement has the potential to induce increased pressure on education and infrastructure, through Project-induced in-migration. Receptors that may be impacted the most include schools in villages with a high risk of in-migration in and around PRL-15 and Orokolo Bay (see Table 13.1), as these areas are expected to feel the greatest population increase. The same receptors may be impacted less along the river transport corridor where the population is not expected to increase as much.

Impacts if unmitigated, are expected to be medium-term and experienced by specific community/ies or small part of the PAOI (by less than a third of the communities in the PAOI), hence a magnitude of ***Medium*** is applied. A sensitivity rating of ***High*** is also applied, as there is limited or no capacity to adapt to increased pressure on already challenged education services and facilities, this results in an initial social impact significance of ***Moderate***.

13.5.2.2 Increased Population Workforce Skills, Training and Experience

The Project will make maximum use of existing skills present in the national labor market; however, it will be necessary to provide education and training to upskill the population workforce to meet targets on national content (see Section 13.4). The increase in the level of skills and safe working practices has the potential to contribute to an overall improvement in the skill-base of the local and national workforce. There is potential for developing a more educated and skilled workforce, likely to be experienced by men (as men typically hold most of the jobs in resource industries) and in areas where higher levels of in-migration are predicted (see Section 13.1.7). In-migration may increase the local labor pool, which has the potential to benefit other local businesses and industries. In-migrants may also bring new skills and innovations, which can improve productivity in existing businesses and lead to new business opportunities locally.

As described in Section 13.4.2.1, local communities highly value opportunities for employment (and related improvement in skills, training and experienced) and expectations that local communities will be prioritized for employment are high. Levels of education and skills amongst local communities are low and this limits their current potential to benefit from some of the Project’s employment and training opportunities.

Further, without active measures to also promote the education and employment of women, employment opportunities (and therefore skills, training and experience opportunities) for women from local communities may be limited due to existing cultural gender norms and inequalities.

Initial Impact Assessment

An increase in population workforce skills, training and experience may be experienced due to Project employment and procurement.

Without mitigation measures, this is expected to be experienced predominantly by the skilled workforce, business communities and supply chain workers, which are all well-placed to benefit from any workforce skills, training and experience opportunities, and have a high capacity for and resilience to change. Therefore, ***Positive*** magnitude and ***Low*** sensitivity ratings are applied across these receptors. This results in an initial social impact significance is ***Positive*** for skilled workers, the national business community and supply chain receptors.

Potential receptors also include the unskilled workforce, Project-affected persons, Project-affected communities, and local communities in and around PRL-15 and along the export pipeline route, as this is where in-migration may be highest, and to a lesser degree along the river transport corridor. Without mitigation and management measures, a ***Negligible*** magnitude and ***High*** sensitivity rating have been applied across these receptors. This results in an initial social impact rating of ***Negligible*** for these receptors.

13.5.2.3 Summary of Identified Impacts to Education and Workforce Training

The Project has the potential to impact on education and workforce training as follows:

- Increased pressure on education services and facilities.

- Increased population workforce skills, training and experience.

13.5.3 Proposed Mitigation, Management and Optimization Measures

Mitigation and optimization measures to be implemented during various Project phases to manage these impacts are described in Table 13.11.

Table 13.11 – Education and Workforce Training Mitigation and Optimization Strategies and Management Plans

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Increased pressure on education services and facilities.	♦ Develop initiatives to enhance education and training of youths from the PAOI, e.g.: – A scholarship program to provide opportunities for eligible students from the project affected communities to pursue their studies. – Internships and/or training opportunities with the Project or its contractors specifically focusing on transferable, nationally recognized trade skill development [SM007]. ♦ Partner with development organizations to deliver an education and awareness program (or include such awareness in other community development programs) to enhance the understanding of women’s rights, e.g., their right to work, their right to education, more equitable labor activities, and to tackle gender-based violence [SM010]. ♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve education infrastructure and capability, and to strengthen education outcomes. While having a focus on elementary and primary schools in the PAOI, secondary and vocational schools in the province might also be considered [SM011].	Community Development Plan; Stakeholder Engagement Plan
Increased workforce skills, training and experience.	♦ Establish a set of local employment and procurement policies that: – Ban employment applications 'at the gate'. – Includes measures to protect the workforce, in particular to identify and avoid child labor and forced labor. – Gives priority to project affected persons and members of project affected communities (and in particular women) for local employment opportunities. – Maximizes the employment and training of national citizens including persons from project affected communities. – Includes measures for gender-fair hiring and workplace policies [SM003]. ♦ Develop initiatives to enhance education and training of youths from the PAOI, e.g.: – A scholarship program to provide opportunities for eligible students from the project affected communities to pursue their studies. – Internships and/or training opportunities with the Project or its contractors specifically focusing on transferable, nationally recognized trade skill development [SM007].	Labor Management Plan; National Content Plan; Community Development Plan

13.5.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to education and workforce training, assuming successful implementation of the proposed mitigation and optimization measures.

13.5.4.1 Increased Pressure on Education Services and Infrastructure

As described in Section 13.5.2.1, Project employment and associated business opportunities have the potential to induce an increased pressure on education and infrastructure across the PAOI, through Project-induced in-migration. Receptors that may be impacted the most include Project-affected communities with a high risk of in-migration in and around PRL-15 and Orokolo Bay (see Section 13.1.7), as these areas are expected to feel the greatest population increase. The same receptors may be impacted less along the river transport corridor where the population is not expected to increase as much.

The Project is committing to undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve education infrastructure and capability, and to strengthen education outcomes. Further mitigations aimed at awareness raising activities and scholarships, will potentially improve education services and infrastructure receptors to be experienced beyond the life of the Project. The design of these initiatives will need the mandate for providing education services to remain with the relevant and competent institutions and development organizations to avoid dependency and create long term benefits that can outlast Project support.

Considering these mitigations measures, a ***Low*** residual impact magnitude rating is assigned. An increased capacity to realize opportunities over the short to long term is expected with mitigation, hence a reduced sensitivity rating of ***Medium*** is applied.

The impact significance regarding increased pressure on education services and infrastructure is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings*.*

13.5.4.2 Increased Workforce Skills, Training and Experience

Mitigation measures focused on local employment and capacity building are expected to realize greater workforce skills, training and experience opportunities for the unskilled workforce, Project-affected persons, communities and local communities, both in the short- (6 to 12 months) to longer-term, extending beyond the life of the Project. A further educated and skilled workforce will result, which has potential for positive national impacts, hence a ***Positive*** magnitude and ***Medium*** sensitivity rating have been applied to these receptors, resulting in a residual significance assessment of ***Positive***.

The residual significance assessment remains ***Positive*** for skilled workers, all business communities and supply chain receptors.

13.5.5 Summary of Education and Workforce Training Residual Impacts

A summary of the assessment of residual impacts to education and workforce training is provided in Table 13.12, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.11.

Both residual impacts are assessed to be ***Minor*** to ***Positive.***

Table 13.12 – Summary of Assessment for Residual Impact Significance for Education and Workforce Training

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Increased pressure on education services and facilities.	Induced	Project-affected persons, Project-affected communities, and local communities including schools in and around PRL-15, along the export pipeline route and along the river transport corridor. Baimuru and Ihu LLG. Kikori District	C, O, D	♦ SM007 ♦ SM010 ♦ SM011	Medium/ Low	Minor
	Increased workforce skills, training and experience.	Direct	Project workforce (both skilled and unskilled), national business community, supply chain workers. Project-affected persons, Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	C, O, D	♦ SM003 ♦ SM007	Medium/ Positive	Positive

C = Construction, O = Operations, D = Decommissioning and closure.

13.6 Community Health and Safety

13.6.1 Context

A high burden of disease and limited health infrastructure and services, combined with poor social determinants of health and some pre-existing vulnerability characteristics, result in poor health indicators for communities across the PAOI. Community members must often travel significant distance by boat or foot to access health services, and many continue to use traditional medicines.

The treatment of vulnerability in this chapter is described in Box 13.1

Impacts relating to community health and safety only have been assessed in this section. Workforce and relevant workforce mitigation measures have been included where it is identified that workforce may potentially contribute toward any community health and safety impacts; however, this does not constitute a workforce health and safety impact assessment.

13.6.1.1 Health Infrastructure

The 12 health facilities in the PAOI comprise one health center, one subhealth center and 10 aid posts. A number of these are closed (2) or only partially operating (3), with staff, medical supplies and equipment limited at those that are open. All health facilities are along the riverways and the coastline except for aid posts at Wabo and Poroi 2 (partially open) (see Figures 13.2 and 13.3).

Drug and medical supplies, and health professionals are inadequate across all health facilities. Access to facilities in terms of distance, time, availability and cost of transport is a barrier to attendance for those villagers not located nearby.

Kapuna Health Center, managed by Gulf Christian Services, is the only facility in the PAOI with a medical doctor on the staff. It is also the only facility to have electricity, and only half of all facilities have a safe water supply and toilet facilities. The Incentive Fund Program (Australian Aid) selected the Kapuna Health Center in 2018 to receive support to upgrade to a level 4 rural hospital. TEP PNG provides logistical support to this initiative for the transport of building materials and volunteers to the site. The Kapuna Health Centre upgrades include the following renovations and construction; outpatient department, nutrition unit, antenatal ward and kitchens, pediatric ward, adult ward, maternity ward, birthing suites, operating theatre and ICU, accidents and emergency, dental clinic and physiotherapy, drug storage and general storage, solar system and battery house, electrical grid upgrades, water infrastructure upgrades, offloading pontoon and staff housing.

The expected outcome is improved public health care services delivery to a catchment population of more than 10,600 of Baimuru LLG, Kikori District, Gulf Province (see Part 14 of Volume 2).

13.6.1.2 Illness and Disease

Part 16 of Volume 2 outlines the different illnesses and diseases that are present in the PAOI, and their status, which can be summarized as follows:

Communicable:

- Vector-related diseases in the PAOI largely comprise malaria and lymphatic filariasis; however, the area is also at risk to flaviviruses (e.g., dengue, Japanese encephalitis, zika and chikungunya) and less common alphaviruses (e.g., Ross River). Community surveys documented malaria as a notable health problem in communities and households in the PAOI; however, as outlined in Section 9.7.4, it is not uncommon for general respiratory symptoms to be conflated with malarial symptoms (e.g., InterOil studies (Cross et al., 2014) showed a less than 1% prevalence of malaria from a study on 366 people plus a further 175 people, as follow up across all ages from eight Pawaia villages).

- Respiratory disease, including tuberculosis (TB), pneumonia, pertussis (whooping cough) and measles, is the leading cause of reported morbidity across the PAOI. TB is at epidemic levels across Gulf Province and in 2016, the Gulf Provincial Health Office recorded a 767 per 100,000 case notification rate, more than double the national level. Health professionals are increasingly concerned about the TB prevalence in Papua New Guinea and the rise of drug-resistant strains of TB (i.e., MDR-TB and XDR-TB), which are difficult to treat and have a very poor prognosis. International organization supporting TB programs in Papua New Guinea include The Global Fund, Australian Government, The World Health Organization, Word Bank Group, United States Agency for International Development and Médecins Sans Frontières.
- Low immunization rates (e.g., in 2015 immunization against measles is significantly lower in Gulf Province (19%) than the national level (40%) (NDOH, 2015), high household occupancy rates and an already high burden of respiratory disease across the PAOI, particularly TB, indicates that the population is highly vulnerable to disease, with children under 5 years, adults over 65 years and those with pre-existing medical conditions being most susceptible.
- High levels of animal husbandry across the PAOI increases the risk of zoonotic disease (e.g., avian influenza). During baseline studies (Chapter 9) the lowest rates of chicken husbandry were recorded in the Pawaia (42%) and Koriki villages (48%), and the highest rates were recorded in the Kaimare villages (83%) and the Ahia village of Evara (86%). The highest rates of pig ownership (more than 60% of households) and the largest herds were reported in the Kaimare, Koriki and Maipua villages.
- While overall sexually transmitted infections (STI) data across the PAOI is sparse, health center data is generally consistent with national human immunodeficiency virus (HIV) data for rural locations (i.e., less than 1% prevalence rate (0.4% and 0.5% for Kapuna and Kerema health centers respectively). Understanding and awareness of STI transmission was mixed, with 16% of women's groups surveyed indicating that everyone knew how STIs are transmitted and 19% of women's groups surveyed reporting they were not sure how STIs were transmitted. The cultural stigma associated with STI diagnosis resulted in a high likelihood of underrepresentation in reported data. Papua New Guinea has a high prevalence, compared to developed nations of human immunodeficiency virus (HIV) and other STIs, and in 2016 recorded the highest prevalence and incidence of HIV in the Pacific (UNAIDS, 2019).

Non-communicable:

- Many people and communities in Papua New Guinea still face the threat of under-nutrition. Food- and nutrition-related issues including food security are highly relevant to communities in the PAOI, as most still live a traditional lifestyle of subsistence farming, hunting, and fishing.
- Households across the PAOI are primarily engaged in subsistence agricultural activities, which reduces the likelihood of noncommunicable diseases. Betel nut, a known human carcinogen, and alcohol, tobacco and marijuana are likely contributors to noncommunicable diseases in the PAOI.

13.6.1.3 Water and Sanitation-related Issues

Only 40% of the Papua New Guinean population has access to a safe water supply and 80% is without access to adequate water. The number of people in the PAOI with access to a safe water supply is lower than the national average.

People in most (76%) of the villages wash in a river or creek, and 34% of households indicated they used the bush, river or sea for toilets. Waste is disposed of in the environment; tins and batteries are either disposed of in the bush, sea or river or buried; and paper and plastic is burnt. These factors all lead to an increased risk of sanitation-related illnesses, such as gastrointestinal diseases.

13.6.1.4 Exposure to Potentially Hazardous Materials and Pollutants

There is currently little exposure to anthropogenic hazardous materials, as the PAOI is a predominantly rural, subsistence agricultural environment. Project-related impacts to air quality, greenhouse gases and climate change, noise, soils, water and major hazards have been identified and assessed in Chapters 11, 12, 15 and 18, and have therefore not been assessed further in this chapter.

13.6.1.5 Food Security and Nutrition

All communities in the PAOI practice a subsistence lifestyle, and this increases the likelihood of food security issues if local resources are depleted through additional demand due to population influx, contamination (i.e., via sewerage, chemicals or hydrocarbons) or natural events.

Baseline studies indicate that food availability and perceptions of food availability are not a concern to households. Food sources are seasonal, but adequate food is available (Parts 14 and 18 of Volume 2).

Despite an apparent adequacy of food and nutritional sources across the PAOI, child malnutrition rates are high. Gulf Province recorded 33% of children with moderate and severe weight-for-age malnutrition in 2016, higher than the national figure of 23% (Part 16 of Volume 2). Further, social baseline survey data suggests that almost two thirds of communities from most language groups surveyed, except the Maipua people from Apiope, had households that regularly went a day without eating. The survey also established that 30% of communities in the Iare, Koriki, Orokolo and Pawaia language groups spent more than 40% of their income on food (see Chapter 9).

Impacts related to land access impacts on natural resources and related livelihood security are discussed and assessed in Section 13.3 and Chapter 16, and impacts related to increased disputes related to food security are discussed and assessed in Section 13.8. These impacts are; therefore, not assessed further in this section.

13.6.1.6 Accidents and Injuries

Accidents and injuries from marine and river traffic or associated with daily activities are an under-appreciated morbidity burden across the PAOI and account for 5 to 10% of health center morbidity caseloads. Community surveys and observations made during field visits indicate that accidents and injuries occur from various daily activities, including clearing gardens, handling knives, encounters with snakes and crocodiles, and fighting. The perceived primary causes of accidents and injuries are often related to sorcery. Domestic violence-related injuries were commonly reported during these surveys and are likely to be underreported in health facility data.

Gulf Province has minimal emergency services, and less than 3% of health centers have an ambulance (Howes et al., 2014). None of the PAOI villages has any emergency response services.

13.6.1.7 Social Determinants of Health

The World Health Organization defines social determinants of health as the ‘conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life (WHO, 2019). They include access to education, economic and job opportunities, access to quality health care, exposure to crime and violence, literacy levels, social norms and attitudes. The following are considered in this assessment; access to and quality of education, economic and employment opportunities, exposure to crime and cultural beliefs and social structures.

The population in the PAOI is young, with a low life-expectancy and poor social determinants of health, including low education levels (see Section 13.5) and limited economic and employment opportunities (see Section 13.4), and most communities are engaged primarily in subsistence activities. Women in the PAOI also experience poorer social determinants of health, due to lower education levels, marrying at a young age, maternal morbidity and child-rearing responsibilities.

Cultural beliefs and social structures also influence health outcomes in the PAOI. Early marriage, sometimes during childhood, influences women’s health, with reproductive health issues a risk for younger women. A strong belief in sorcery can influence how health issues are identified and addressed, and behaviors such as substance abuse, violence, including gender and domestic violence, and promiscuity are also factors.

Male alcohol consumption is common and alcohol abuse is regarded as a law and order concern, as it is associated with issues such as fighting and domestic violence. Marijuana use is also reportedly widespread (Chapter 9).

Domestic violence and sexual assault are pervasive problems in the PAOI. Women from every village reported a past domestic violence incident either involving their husband or another family member. According to baseline studies (Chapter 9), women from 26 villages (87%) indicated an assault had occurred over the 12 months prior to the survey in 2016. This compares with 67% of women nationally who are believed to have been the victims of domestic violence (Amnesty International, 2010).

13.6.1.8 Cultural Health Practices

Health issues are understood in relation to strong cultural beliefs, including the belief in sorcery. Traditional medicine still features strongly in most PAOI communities, and some descriptions of traditional medicine are more reflective of ‘magic’ and superstition than medicine, which poses a risk to vulnerable people, including women and children.

13.6.2 Identification and Initial Assessment of Potential Impacts

13.6.2.1 Increased Pressure on Health Services and Facilities

Health infrastructure that is already inadequate in servicing the existing population in the PAOI and may be placed under additional pressure, as an indirect consequence of an increase in population due to Project activities and Project induced-in-migration. Services that may be particularly impacted are those in and around PRL-15, where the most drivers for in-migration occur. Community health issues may escalate in and around PRL-15, as there is only one aid post at Wabo Station, an aid post in Poroi 2 and another aid post at Evara.

A proportion of State financial payments allocated to provincial and local-level governments (see Section 13.4), may potentially be used to improve the quality or number of health facilities in the PAOI or more broadly subject to the deliberations of the Development Forum. As noted in Section 13.7, ineffective use of government revenue may limit any improvement in health infrastructure and services in the PAOI. The effective use of government revenue to improve health infrastructure and services, particularly in more remote communities, would have a beneficial impact on PAOI communities and more broadly, given the existing low levels of investment.

Initial Impact Assessment

The Project has the potential to increase pressure on the already strained health facilities due to an increase in population. This induced impact is likely to occur more in areas prone to Project-induced in-migration in and around PRL-15 (see Box 13.1), where most of the Project activities will take place and to be experienced from the Project construction phase into operations. Unmitigated, impacts are expected to be medium-term (1 to 5 years) and experienced by less than one third of the Project affected communities in the PAOI, hence a magnitude of ***Medium*** is applied. A sensitivity rating of ***High*** is applicable, as there is limited or no capacity to adapt to increased pressure on already challenged health services and facilities. This results in an initial impact significance of ***Moderate***.

13.6.2.2 Improved Access to Health Services and Infrastructure

The Project has the potential to improve health infrastructure and capacity in the PAOI. Currently, TEP PNG is working in partnership with the Digicel Foundation and the Gulf Province Administration to develop new health infrastructure projects such as providing aid posts at Evara (2018) and Poroi 2 (2019). TEP PNG is also supporting the placement of two female volunteer community health workers at Wabo and Poroi 2 aid posts respectively, two aid posts close to PRL-15, through the PNG Government's National Volunteer Services program.

TEP PNG has and continues to provide further support through donation of various medical equipment (e.g., delivery beds and a GeneXpert machine to diagnose multi-drug-resistant TB), various resource materials and medical supplies to health facilities and the distribution of 6,000 mosquito nets to communities in the PAOI.

TEP PNG has an agreement with the Kapuna Health Center to provide logistical support for their teams to carry out health patrols and to train Pawaians from communities in and around PRL-15 to become Community Health Workers.

Initial Impact Assessment

State financial payments, Project benefits, Project employment and procurement and associated business opportunities, have the potential to indirectly improve access to health services and infrastructure in the PAOI via an increase in wealth and the capacity to afford access to these services. As noted in Section 13.7; however, ineffective use of government revenue may limit any improvement in health infrastructure and services in the PAOI.

Receptors that may be impacted greatest include Project-affected communities and local communities and their associated health facilities in Kikori District, Baimuru and Ihu LLG, in and around PRL-15 and around the export pipeline route. The same receptors may be impacted less along the river transport corridor

The sensitivity of health infrastructure in the PAOI is rated as ***High***. The initial assessment of impact significance is that a ***Positive*** magnitude rating is appropriate without additional management measures given the activities already being delivered. The initial social impact significance is; therefore, ***Positive***.

13.6.2.3 Increased Frequency, Severity and Risk of Diseases

Vector-related Diseases

The Project has potential to induce an increase in vector-related diseases in the areas of the PAOI prone to Project-induced in-migration. Vector-related diseases (e.g., malaria, dengue, lymphatic filariasis) already exist in the PAOI; however, reliance on clinical diagnosis (i.e., presentation of symptoms) for malaria due to a lack of laboratory facilities in health facilities in the PAOI means that the existing level of prevalence is unknown. An increase in migrant workers, population in general and increased movement of people associated with the Project workforce may increase the frequency and/or severity of vector-related disease outbreaks. In-migration may see different disease strains brought into the PAOI, as denser living arrangements can lead to an increase in the prevalence of a disease while also introducing new mosquito breeding and harborage sites.

Project infrastructure, including workers accommodation, also has the potential to increase vector breeding and harborage. This is more likely during the construction period, when existing breeding or harborage sites are disturbed or new ones are created (e.g., pooling water in poorly drained hardstands) and when staffing numbers are high.

Initial Impact Assessment

Malaria and other vector-borne diseases are already present in the PAOI; therefore, the sensitivity rating attributed to all PAOI communities is ***Medium***. The potential magnitude of an increase in vector-borne diseases due to Project activities, in the short to medium term, is assessed as ***Low*** for Project-affected and local communities along the river transport corridor, and as ***Medium*** for Project-affected and local communities in PRL-15 and along the onshore export pipeline route. The latter communities will be closer to planned construction activities and therefore could be potentially more exposed to vector harborage sites. This provides an initial social impact significance assessment of ***Minor*** for river transport corridor Project-affected and local communities and ***Moderate*** for Project-affected and local communities around PRL-15 and along the export pipeline (e.g., Evara and Orokolo Bay communities).

The sensitivity is rated as ***Medium*** for the Project workforce that will be accommodated in camps in PRL-15, as a large percentage will be PNG workers (see Section 4.7.1.3) who will have been previously exposed to these diseases. The magnitude assigned in the absence of additional mitigation measures is ***Low***, as the level of company control over the accommodation provided for the workforce is high. This provides an initial social impact significance assessment of ***Minor***.

Respiratory Diseases

Respiratory disease rates are high in the PAOI, including epidemic-levels of TB. A population increase can introduce new disease strains and increase the spread of respiratory disease through overcrowding due to increased population density. This impact is more likely to occur during the construction phase.

Increased population and overcrowding may also lead to a greater prevalence of noncommunicable respiratory diseases associated with wood smoke, as most of the communities in the PAOI rely on burning wood for fuel (see Chapter 16).

Initial Impact Assessment

The Project has the potential to induce an increase in the incidence of respiratory disease across the PAOI, through an increase in population. Potential receptors include the Project workforce along with Project-affected communities and local communities in areas prone to Project-induced in-migration as described in Section 13.1.7. Any impacts would be permanent in the case of drug resistant TB.

An initial sensitivity rating of ***Medium*** has been assigned, given the epidemic levels of TB and other respiratory diseases already evident in the PAOI, and the limited capacity of the health system to diagnose or treat them. The initial magnitude rating is ***High***, given the potential for impacts initiated during the construction phase, to be long term, and to affect most receptors, resulting in an initial impact significance assessment of ***Moderate***.

Zoonotic Diseases

A combination of increased population and movement, potential import of goods from outside of the PAOI, and the reliance on or demand for locally sourced foods have the potential to cause a zoonotic disease outbreak (e.g., avian influenza).

Health facilities in the PAOI are not equipped to identify or treat zoonotic illness, thereby potentially increasing the impact were a disease outbreak to occur.

Initial Impact Assessment

The potential for Project-induced in-migration may induce an increase the incidence of zoonotic disease in the PAOI, through increased population, and associated movement and trade in goods and livestock. Potential receptors include project affected communities and local communities in areas prone to project-in-migration as described in Box 13.1. Any impacts would occur from the construction phase onwards, therefore short- to long-term duration.

The initial sensitivity of PAOI communities is rated as ***High,*** given the lack of capacity to address an outbreak of zoonotic diseases in the PAOI. The initial magnitude of the impact is ***Medium*** since such diseases could cause moderate impacts compared to baseline conditions due to the high levels of animal husbandry of PAOI communities, particularly those inland. The initial impact significance assessment rating is; therefore, ***Moderate***.

Sexually Transmitted Infections

Papua New Guinea has among the highest prevalence of human immunodeficiency virus (HIV), syphilis and other STIs in the Asia-Pacific region (see Part 16 of Volume 2). The virus compromises the immune systems, increasing susceptibility to infectious diseases such as TB. Mother-to-child transmission is also a risk without appropriate preventive care and treatment, which is not currently available in the PAOI. The Project may induce an increase in the prevalence of STIs, including HIV/acquired immune deficiency syndrome (AIDS), because of a combination of a population increase, workforce movements, increased income and increased high-risk behaviors including prostitution. An increase in STIs is more likely around construction camps or areas where workers could interact with local communities, and in areas where in-migration is predicted to be higher (see Table 13.1).

The transient nature (i.e., fly-in, fly-out) of the construction workforce may increase the rates of STIs, including HIV. The Project workforce will be mobilized from different locations around Papua New Guinea and internationally via Port Moresby. Human immunodeficiency virus is prevalent nationwide, with urban centers, including Port Moresby, through which workers must transit, providing access to commercial sex workers. A predominantly male workforce with increased income and rostered weeks off may increase the potential for promiscuity and commercial sex transactions, increasing the risk of STI infections, which may be transferred to communities in the PAOI and more broadly.

Low community awareness of STIs and how they are spread, combined with stigma that deters seeking treatment, may exacerbate this issue.

Initial Impact Assessment

The Project has potential to induce an increase the incidence of STIs in the PAOI, through a combination of increased income, project induced population influx and a transient workforce. The rate of sexually transmitted infections may increase in the Project workforce, along with Project-affected communities and local communities in areas prone to in-migration as described in Table 13.1.

A sensitivity rating of ***High*** is assigned, given the prevalence of STIs in communities in the PAOI, the pre-existing high levels of gender-based violence, including sexual assault and rape, the stigma around these types of diseases, and the limited capacity of the health system to diagnose or treat them. Any impacts may be short to long term. A magnitude rating of ***High*** is assigned in the absence of additional mitigation measures, which provides an initial social impact significance assessment of ***Major***.

Noncommunicable Diseases

Noncommunicable diseases (e.g., diabetes and heart disease) can arise from consuming unhealthy food and/or harmful substances (e.g., excessive alcohol). The Project has the potential to change the subsistence practices of some community members in the PAOI through an increase in income, employment and business opportunities, and the increased availability and consumption of store-bought and processed foods. An independent audit report (D'Appolonia S.p.A, 2012) on the PNG LNG Project highlights the impact of a change in diet, including for the project construction workforce, which may have contributed to an increase in obesity and lifestyle-related diseases and long-term health risks.

Changes to the consumption of store-bought and unhealthy foods causing an increase in noncommunicable diseases are likely to be minimal outside Project camps, with any impact concentrated in locations that have experienced significant in-migration (see Section 13.1.7) or in locations close to the development of commercial trading stores.

Initial Impact Assessment

The Project has potential to induce an increase noncommunicable disease in the PAOI by changing livelihood practices, including decreased reliance on bush food and increased dependence on store food with a concomitant more sedentary lifestyle.

Project-affected communities, and local, communities in the PAOI are assigned a ***Medium*** sensitivity rating, as most are already exposed to some, albeit low, extent to consumables and store-bought products. An initial magnitude rating of ***Low*** is assigned to the river transport corridor communities, as they are not expected to benefit from greater incomes over a short to medium term, and the existence of more opportunities to purchase these products in most communities is unlikely. In areas prone to Project-induced in-migration or close to the development of commercial trading stores in and around PRL-15 and around the export pipeline route; however, an initial magnitude rating of ***High*** is assigned, as this is likely to be the area where both income and population may increase (see Section 13.1.7), and impacts could be long term depending on lifestyle choices. The Project workforce may also be exposed to this magnitude due to the Project providing meals on work sites.

This provides an initial social significance impact assessment of ***Minor*** for Project-affected and local communities along the river transport corridor, and ***Moderate*** for Project-affected communities prone to in-migration in and around PRL-15 and around the export pipeline route, and the Project workforce.

Water and Sanitation-related Diseases

Village water sources, particularly for coastal villages, are shallow and highly susceptible to contamination from domestic and wild animals, latrines and chemicals. Groundwater studies (Part 4 of Volume 2) indicate widespread microbiological contamination in shallow wells in the PAOI. The physical nature of village-based water sources, combined with animal husbandry practices and limited and/or poor sanitation options, leads to a vulnerability to water-, soil- and sanitation-related issues.

A population influx, particularly during the construction phase, would exacerbate the likelihood of water- and sanitation-related health issues. Poor sanitation infrastructure and personal behaviors (e.g., hand washing) can influence the spread of diarrheal and other gastrointestinal diseases such as gastroenteritis, cholera, typhoid, acute diarrhea and dehydration. The risk to communities increases with the low immunization levels in the PAOI. Children are at particular risk, even more so in settings where health services are limited. Project-induced population influx may also place pressure on local freshwater water supplies, forcing communities to access and use less sanitary or potable sources.

Initial Impact Assessment

The Project has potential to induce an increase in water and sanitation-related diseases in the PAOI in area prone to Project-induced in-migration as described in Section 13.1. In these areas, likely receptors include project-affected communities, and local communities Any impacts would be short to long term during the Project's construction and operations phases.

Sanitation practices and water quality in shallow wells are already low in the PAOI, and the related health attribute is considered of critical importance; therefore, an initial sensitivity rating of ***High*** is assigned. Sanitation-related diseases are predicted to rise where in-migration is predicted to occur (see Table 13.1). The magnitude is rated as ***Medium*** in the absence of additional mitigation measures, since they will be experienced by specific communities, giving an initial social significance impact assessment of ***Moderate***.

13.6.2.4 Increased Malnutrition Rates due to Reduced Food Security

Despite food availability and perceptions of food availability not being a concern to households, and depending on individuals' choices, the Project may lead to or exacerbate nutritional issues due to:

- Economic displacement where loss of access to subsistence resources (e.g., food gardens, planted sago and wild plant foods) may cause food insecurity and; therefore, nutritional status (Section 13.3 and Chapter 16).
- Any changes or reduction in agricultural land or land used for subsistence resources due to an increase in population (Table 13.1 and Chapter 16).
- An increase in store food prices making store foods unaffordable (Section 13.4).

The initial impact significance to livelihoods from Project land access and any related economic displacement is assessed as ***Minor*** in and around PRL-15 and along the export pipeline route for reasons explained in Section 13.3. Loss of food gardens, planted sago and wild plant foods due to Project activities is rated ***Negligible*** in initial social impact significance for reasons explained in Section 16.5 and is not assessed further.

Some potential of decreased nutritional status from reduced food security remains if impacts are unmitigated, and based on the initial social impact significance applied to livelihoods from Project land access and any related economic displacement. Any impacts would be induced due to Project activities including construction and Project employment and procurement. Receptors would include Project-affected persons, Project-affected communities, and local communities in and around PRL-15, and to a lesser degree along the export pipeline route and along the river transport corridor. Impacts are likely to be localized and reversible since communities have capacity to access nearby alternatives, hence ***Low*** sensitivity and ***Low*** magnitude ratings are applied to the PAOI.

The initial social impact significance of increased malnutrition rates due to reduced food security is assessed as ***Minor*** based on these ratings.

13.6.2.5 Project-related Accidents and Injuries

Direct Impacts

The PAOI currently has no emergency services, so people suffering from trauma are required to transport themselves to a health facility to seek medical treatment. The inability to access immediate first aid and assistance can increase the likelihood of further injury or even mortality in the event of severe physical trauma.

The increase in river traffic, particularly large barges transporting Project materials and supplies, during the construction period, poses a risk of increased incidents involving community members who primarily travel the river in canoes or small outboard motor–powered dinghies. Accidents may occur due to large waves overturning canoes or collisions between vessels.

There are no public roads in the PAOI, so interaction between Project and public vehicles cannot occur. Project vehicles will operate in Project worksites, including the pipeline right of way, where public access will be prohibited during construction.

The export pipeline access track will be used intermittently during operations for maintenance purposes, during which time accidents may occur between vehicles and pedestrians. Risk of pedestrian/vehicle accidents will also be present during operations for Project roads in PRL-15 that may be accessed by local inhabitants.

There will also be an exclusion zone around the central processing facility (CPF) to avoid opportunistic settlements in this currently uninhabited area and further reduce the chance of Project-related accident and injuries.

Major Hazards are discussed in Chapter 18.

Indirect Impacts

In addition to an increase in barge traffic, an increase in dinghy traffic on the Purari River distributaries may occur due to increasing population and income, as local people invest their income in motorized boats. An increase in dinghy and canoe accidents causing injury or mortality may occur, given the absence of navigation aids on the Purari River and basic safety equipment, such as lights and lifejackets, in dinghies and canoes.

Initial Impact Assessment

Increased logistics and transport have the potential to directly increase Project-related accidents and injuries where Project activities take place. Likely receptors include the Project workforce, Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor. Any impacts could be short to long term and reversible to permanent depending on the individual case.

The safety of Project-affected communities and the Project workforce is of the highest importance, and the initial sensitivity rating is accordingly rated as ***High***.

A magnitude of ***High*** is assigned to potential accidents related to the Project workforce, given the standard safety controls and workplace safety systems already in place, and the potential for lost-time injuries. This results in an initial impact rating of ***Major***.

A magnitude rating of ***Very High*** is assigned to the potential seriousness of a Project-related accident that could result in loss of life, resulting in an initial significance impact assessment rating of ***Severe*** for this impact.

13.6.2.6 Impacts Associated with Social Determinants of Health

The Project may influence social determinants of health in the PAOI, causing positive and negative impacts to PAOI communities. In this section, impacts on social determinants of health specific to gender, substance abuse, violence, employment and education are addressed. A discussion on the treatment of vulnerable peoples is included in Box 13.1. Impacts relating to increased tension, and law and order issues are discussed and addressed in Section 13.8.

Women in the PAOI are particularly vulnerable to poorer social determinants of health, given their pre-existing low education levels (see Section 13.5), their high reproductive rates and the cultural expectations about social roles and responsibilities. Social investment in health services and community education focused on improving the social determinants of health of women may improve reproductive health services, improve community awareness of reproductive health, family planning, and education and awareness programs focused on gender equality issues. Furthermore, increased income in the PAOI has the potential to facilitate greater investment in individual and family health and nutrition.

A prevalent belief in sorcery influences where and how people seek health care, and can also restrict movements in an area, as people are fearful of further repercussions. It also results in violence in and between communities.

Increased income may encourage some people to misuse substances, such as alcohol, tobacco, betel nut or marijuana, thereby reducing mental and physical health, and leading to an increase in other high-risk behaviors, such as promiscuity and unprotected sex, with consequent increase in STIs or unplanned pregnancies. Substance abuse also has the potential to increase violence, including domestic violence. Risks to the community are potentially posed by the increase in population associated with people attracted to the Project area through the potential for business opportunities. Risks associated with the Project workforce are considered negligible as they will reside in closed camps or return to their place of origin while not working or once employment or contracts are complete.

Poor health could cause PAOI community members who are seeking Project employment failing the necessary pre-employment checks. This may place the local population at a disadvantage compared to candidates from outside of the PAOI, (e.g., Port Moresby) where healthcare is generally more accessible. This could limit the potential for PAOI communities to secure employment outcomes and benefit from the Project. Women are not well positioned to benefit directly from the Project through economic opportunities and may see an increase in domestic duties should the men of the family gain employment (see Section 13.4).

Better education is often associated with better health outcomes. The potential impacts on education are discussed in Section 13.5 and may have subsequent effects on health for those communities that have improved access to education services.

Initial Impact Assessment

The Project, through an increase in disposable incomes, has potential to induce a decrease social determinants of health in the PAOI, the effect of which would be compounded by increases in population in areas prone to Project-induced in-migration as described in Box 13.1. In these areas, the likely receptors include project-affected communities, and local communities.

A sensitivity rating of ***Medium*** is assigned, as social determinants of health are already low for PAOI communities but have capacity for improvement. The Project could indirectly increase the consumption of drugs and alcohol, possibly increasing crime and violence in the absence of mitigation measures. A ***High*** initial magnitude rating is assigned, as the Project could negatively affect community health indicators over the long term, causing an initial social impact significance assessment of ***Moderate***.

13.6.2.7 Impacts on Cultural Health Practices

Any disease outbreaks or accidents and injuries may be viewed as being caused by spirits or sorcery, as part of some traditional beliefs and cultural practices. A reliance on traditional medicine and health practices exists in the PAOI, and the presence of the Project and subsequent investment in health services, have the potential to improve access to better-quality health services, minimizing additional harm through further spread of disease or incorrect diagnosis or treatment causing further physical harm to an individual.

Potential impacts associated with cultural health practices include:

- An increase in perceived sorcery-related events and the associated retaliation or ostracization. This is often focused at women.
- A loss of knowledge and/or practice of traditional medicines and cultural practices (discussed in Chapter 14).
- A greater acceptance of modern health practices.

Initial Impact Assessment

The Project has potential to increase induced impacts associated with cultural health practices in the PAOI, through an increase in population. Likely receptors include Project-affected communities in areas of high-risk for Project-induced in-migration (see Section 13.1.7).

Communities in the PAOI live largely traditional lifestyles and still practice sorcery, which is often attributed by community members as causing accidents and injuries; therefore, the sensitivity of all communities to changes to cultural practices is considered ***High***.

Communities may possibly associate Project-related accidents, injuries or misfortune with sorcery. However, there are likely to be minimal changes in community practice of sorcery-perceived events compared to the current state. The initial magnitude of this impact is rated as ***Low***, which results in an initial social impact significance assessment for an increase in perceived sorcery-related events of ***Minor***.

There is expected to be greater acceptance of modern health practices as a result of Project operations in the PAOI, generating positive outcomes for Project-affected communities, Project-affected persons and local communities. The initial magnitude of this impact is rated as ***Positive***, resulting in an initial impact assessment of ***Positive***.

13.6.2.8 Summary of Potential Impacts

The Project has the potential to interact with various community-related health, safety and wellbeing aspects in the PAOI, causing positive and negative impacts as follows:

Positive Impacts

- Increased access to health services and facilities.
- Increased acceptance of modern health practices leading to better health outcomes.

Negative Impacts

- Increased pressure on local health services and infrastructure.
- An increase in frequency, severity or risk of:
  - Vector-borne disease.
  - Respiratory disease.
  - Zoonotic disease (e.g., avian influenza).
  - Sexually transmitted infections, including HIV.
  - Noncommunicable diseases.
  - Water- and sanitation-related diseases.
- Increased malnutrition rates.
- Project-related accidents or injuries.
- Impacts associated with social determinants of health specific to gender, substance abuse and violence. Impacts associated with improved employment and education are discussed in Sections 13.4 and 13.5, respectively.
- Increase in perceived sorcery related events and associated violence and injuries.

The following embedded design control addresses potential impacts on Community Health and Safety:

- The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED003].
- Continue pre-employment and ongoing health and fitness to work screening and annual medical checks for all workers working for the Project in the Project Area [ED034].
- Design Project infrastructure (including workforce accommodation) to minimize vector harborage (e.g., minimize pooling water, proper waste disposal) and human exposure (e.g., screening of doors and windows) to minimize spread of disease [ED035].

13.6.3 Proposed Mitigation, Management and Optimization Measures

Mitigation measures to be implemented during various Project phases to further manage these impacts are described in Table 13.13.

Table 13.13 – Community Health and Safety Mitigation, Optimization Strategies and Management Plans

Potential Impact	Mitigation and Optimization Strategy	Relevant Management Plan
Improved access to health services and facilities.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve health services and infrastructure, and to strengthen health outcomes [SM012].	Project-induced In-Migration Management Plan; Community Health, Safety and Security Management Plan.
Increased acceptance of modern health practices.	No additional mitigation measures proposed.	NA
Increased pressure on local health services and infrastructure.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve health services and infrastructure, and to strengthen health outcomes [SM012]. ♦ Engage with communities and local-level governments to discourage the development of informal settlements along Project access routes and near Project facilities [SM028]. ♦ Establish Project recruitment centers away from PRL-15 and construction areas to prevent in-migration [SM029]. ♦ Demobilize all Project workers to their point of hire after their shift/employment is completed [SM030].	Community Development Plan; Project-Induced In-Migration Management Plan; Community Health, Safety and Security Management Plan
Increased frequency, severity and risk of diseases.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve health services and infrastructure, and to strengthen health outcomes [SM012]. ♦ Partner with relevant organizations to develop a Health and Wellness Awareness Program for the Project workforce and Project affected communities, particularly in high-risk, in-migration areas. Topics may include preventing and managing communicable and noncommunicable diseases, women's health, nutrition, hygiene and sanitation, and transport safety [SM013]. ♦ In areas of high risk of project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives aimed at improving water, waste, sanitation and hygiene services (WASH) [SM014]. ♦ Develop a tuberculosis (TB) prevention and control program for the Project workforce, including measures to screen and confirm the medical status of TB prior to employment or assignment in the Project area. Project workers diagnosed with active TB will be demobilized to their point of hire, they will be advised to seek treatment and the government will be notified to follow-up with their immediate family members as part of the national TB program. After treatment, a medical evaluation and fitness to work certificate will be required to resume work [SM015]. ♦ Provide healthy and culturally appropriate food choices at workforce accommodation [SM017]. ♦ Restrict community access to Project sites [SM018].	Labor Management Plan; Community Development Plan; Community Health, Safety and Security Management Plan; Stakeholder Engagement Plan.

Table 13.13 – Community Health and Safety Mitigation, Optimization Strategies and Management Plans (cont'd)

Potential Impact	Mitigation and Optimization Strategy	Relevant Management Plan
Increased malnutrition rates.	See Table 13.7	Land Access Resettlement Framework; Land Access and Livelihood Development Plan; Resettlement Action Plan (if required)
Project-related accidents or injuries.	♦ In consultation with relevant stakeholders, develop a community emergency preparedness and response policy and procedure that clearly define roles of stakeholders in the event of Project-related emergencies or accidents affecting the community [SM016].	Community Health, Safety and Security Management Plan; Labor Management Plan; Traffic and Transport Management Plan; Stakeholder Engagement Plan.
Impacts associated with social determinants of health (specific to gender, substance abuse and violence).	♦ Partner with relevant organizations to develop a Health and Wellness Awareness Program for the Project workforce and Project affected communities, particularly in high-risk, in-migration areas. Topics may include preventing and managing communicable and noncommunicable diseases, women's health, nutrition, hygiene and sanitation, and transport safety [SM013]. ♦ In areas of high risk of Project-induced In-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives aimed at improving water, waste, sanitation and hygiene services (WASH) [SM014].	Community Development Plan; Community Health, Safety and Security Management Plan; Stakeholder Engagement Plan.
Increase in perceived sorcery related events.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve health services and infrastructure, and to strengthen health outcomes [SM012]. ♦ Partner with relevant organizations to develop a Health and Wellness Awareness Program for the Project workforce and Project affected communities, particularly in high-risk, in-migration areas. Topics may include preventing and managing communicable and noncommunicable diseases, women's health, nutrition, hygiene and sanitation, and transport safety [SM013]. ♦ See Table 13.17 for measures designed to support law and order in the PAOI.	Project-induced In-Migration Management Plan; Community Health, Safety and Security Management Plan.

13.6.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to community health and safety, assuming successful implementation of the proposed mitigation and optimization measures.

13.6.4.1 Increased Pressure on Health Infrastructure

The Project has potential to induce an increase pressure on health services and infrastructure in area of the PAOI prone to project-induced in-migration. Receptors that may be impacted include project affected communities in areas that are expected to feel the greatest population increase as described in section 13.1.7. The same receptors may be impacted less along the river transport corridor where the population is not expected to increase as much.

The sensitivity of health infrastructure in the PAOI remains as ***Medium***. Implementation of the mitigation measures, which are aimed at supporting sustainable priority health initiatives, combined with managing in-migration, will potentially lead to some improvement to health infrastructure when compared to baseline conditions, thus the magnitude of the potential impact of increased pressure on health infrastructure is rated as ***Low***. The impact significance regarding increased pressure on health infrastructure is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.6.4.2 Improved Access to Health Services and Infrastructure

The Project has potential to directly and indirectly improve access to health services and infrastructure in project-affected communities in the PAOI, through State financial payments; however, ineffective allocation and/or use of government revenue may limit any improvement in health infrastructure and services in the PAOI, as noted in Section 13.7.

Receptors that may be impacted the most include project affected communities in and around PRL-15 and along the export pipeline route and to a lesser degree long the river transport corridor.

Support provided to improve existing health infrastructure and to improve local capacity to deliver health services will be planned in consultation with the National Department of Health, the provincial and local governments, and other health service providers in the PAOI. The objective is to develop initiatives that are strategic, aligned with development priorities and Project policies, multi-stakeholder driven, sustainable with a viable handover strategy and with measurable outcomes. The design of these initiatives will need the mandate for providing health care to remain with the relevant and competent health services, to avoid dependency and create long term benefits that can outlast Project support.

A ***Positive*** magnitude rating and a ***Medium*** sensitivity rating are still applicable with the proposed management measures to support and improve health infrastructure, including the existing programs in Wabo and Poroi 1. The initial social impact significance assessment for improved access to health infrastructure remains ***Positive*** for the residual assessment based on these ratings.

13.6.4.3 Increased Frequency, Severity and Risk of Diseases

Preparation and planning for disease outbreaks will be undertaken in consultation with government and other health service providers to agree roles, responsibilities and resourcing requirements. The objective is to develop initiatives that are strategic, aligned with development priorities and project policies, multi-stakeholder driven, sustainable with a viable handover strategy and with measurable outcomes.

Vector-related Diseases

Project activities have potential to indirectly increase the incidence of vector-related disease. For vector-related diseases such as malaria, disturbance to or creation of vector breeding and harborage due to Project activities will be mitigated through appropriate design, such as preventing water pooling and managing waste appropriately.

The sensitivity rating attributed to all communities remains ***Medium***. Part 16 of Volume 2 highlights that WASH programs reduce the spread of preventable waterborne diseases. The Project's participation in sustainable WASH programs with local and provincial governments, and other programs to improve priority health services and facilities in the PAOI, is expected to improve the control of vector-related diseases. The potential magnitude of an increase in vector-borne diseases due to Project activities is; therefore, assessed as ***Negligible*** for Project-affected communities and local communities along the river transport corridor and as ***Low*** for Project-affected communities and local communities in and around PRL-15 and along the onshore export pipeline route after mitigation measures are implemented. The impact significance is reduced from ***Minor*** for river transport corridor Project-affected communities and local communities and ***Moderate*** for Project-affected communities and local communities around PRL-15 and along the export pipeline (e.g., Evara and Orokolo Bay communities) for the initial assessment to ***Negligible*** and ***Minor,*** respectively***,*** for the residual assessment based on these ratings.

The sensitivity remains ***Medium*** for the Project workforce. Embedded design controls on the Project facilities, such as window and door screens, can limit human exposure. Implementation of these measures reduces the magnitude to ***Negligible.*** The impact significance is reduced from ***Minor*** from the initial assessment to ***Negligible*** for the residual social impact significance assessment.

Respiratory Diseases

The Project has potential to induce an increase the incidence of respiratory disease in the PAOI, through Project-induced in-migration. Likely receptors include the Project workforce, Project-affected communities, and local communities in areas prone to in-migration as described in Section 13.1.7 in and around PRL-15, along the export pipeline route and along the river transport corridor.

Respiratory diseases represent the most significant disease burden in the PAOI, and TB is already at epidemic levels. Proposed management measures involve working with government and nongovernmental organizations to evaluate and deliver control measures in identified high risk areas in the PAOI with links to nationwide programs to facilitate TB control. The objective is to develop initiatives that are strategic, aligned with development priorities and Project policies, multi-stakeholder driven, sustainable with a viable handover strategy and with measurable outcomes.

Project infrastructure, including accommodation camps, will be designed to minimize the potential to spread respiratory disease, and community and workforce health programs will educate people about preventive behavior and how to seek treatment. In-migration management will be important in minimizing spread through informal settlements, and the TB-DOTS program will be available to the Project workforce and their families.

The sensitivity rating of ***Medium*** remains relevant for this impact. Any impact is expected to be limited when compared to baseline conditions due to measures outlined earlier and in Section 13.6.3; therefore, a magnitude rating of ***Medium*** is assigned. The initial social impact significance assessment for the increased incidence of respiratory disease remains ***Moderate*** for the residual assessment, based on these ratings.

Zoonotic Diseases

The Project has potential to induce an increase in the incidence of zoonotic disease in the PAOI, through Project-induced in-migration. Likely receptors include the Project workforce, Project-affected communities, and local communities in areas prone to in-migration as described in Box 13.1.

The sensitivity of PAOI communities remains rated as ***Medium***. The magnitude of the impact is assigned a rating of ***Low***, considering the mitigation measures outlined in 13.6.3; therefore, minimal change is expected compared to baseline conditions. The residual impact significance for the increased incidence of zoonotic disease is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

Sexually Transmitted Infections

The Project has potential to induce an increase the incidence of STIs in the PAOI in areas prone to project-induced in-migration. Sexually transmitted infections may affect the project workforce, project-affected communities, and local communities in these areas as described in Box 13.1.

At-risk Project-affected persons and communities, and the Project workforce will be made aware of sexually transmitted infection, high-risk behaviors and preventive measures. Reducing the stigma around STIs and HIV is also important to encourage people to both seek and undertake appropriate care.

A sensitivity rating of ***Medium*** was initially assigned to this impact and this remains relevant. Awareness programs will mitigate some of this risk but the causal factors cannot be fully mitigated; therefore, a magnitude rating of ***Medium*** is assigned. The impact significance for the increased incidence of STIs is reduced from ***Major*** for the initial assessment to ***Moderate*** for the residual assessment, based on these ratings.

Noncommunicable Diseases

An increased reliance on store food, a decreased reliance on bush food and a more sedentary lifestyle has the potential to induce an increase in noncommunicable disease in the PAOI. These lifestyle-related diseases may be driven by increased income from the Project, which makes store food more affordable. Papua New Guinean nationals living in Project accommodation may also experience a shift in diet and nutrition, with potentially positive (i.e., improved nutrition) and negative (i.e., increased incidence of obesity) impacts.

Communities in the PAOI were initially assigned a ***Medium*** sensitivity rating, and this remains unchanged. A magnitude rating of ***Low*** for most communities in the PAOI also remains applicable. For communities in and around PRL-15; however, a magnitude rating of ***Medium*** is assigned, as workforce and community health education programs will mitigate the negative impacts. The impact significance for the incidence of noncommunicable disease; therefore:

- Remains ***Minor*** for communities along the river transport corridor for the residual assessment.
- Is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment for communities around the onshore pipeline route.
- Remains ***Moderate*** for communities in and around PRL-15 and the Project workforce for the residual assessment.

Water- and Sanitation-related Diseases

The Project has potential to induce an increase in water and sanitation-related disease in area of high risk for Project-induced in-migration (see Section 13.1.7). Likely receptors include the Project workforce, Project-affected communities, and local communities in the areas of the PAOI prone to in-migration.

The initial sensitivity rating of ***High*** remains relevant. Community education and improved sanitation, waste and freshwater infrastructure in areas identified as high-risk for Project-induced in-migration (see Box 13.1) delivered through government or other relevant organizations partnered programs will mitigate the risk of increased sanitation-related diseases, thus the magnitude is rated as ***Low.*** The impact significance for the increase water and sanitation-related disease is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.6.4.4 Increased Malnutrition Rates due to Reduced Food Security

The residual impact significance to livelihoods from Project land access and any related economic displacement is assessed as ***Minor*** in PRL-15 and along the export pipeline route for reasons explained in Section 13.3***.***

Any risk of increased malnutrition rates due to reduced food security (rated as ***Low*** sensitivity in Section 13.6.2.4), is seen as non-appreciable when compared to baseline conditions given mitigations focused on avoiding, minimizing and compensating for any economic displacement, therefore a ***Negligible*** magnitude rating is applied to the PAOI.

The residual impact significance of increased malnutrition rates due to reduced food security is lowered from ***Minor*** for the initial assessment to ***Negligible*** for the residual assessment, based on these ratings.

13.6.4.5 Project-related Accidents and Injuries

Logistics and transport have potential to directly increase Project-related accidents and injuries in the PAOI. Likely receptors include the Project workforce, project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.

The health and safety of local communities and the Project workforce are of the highest importance, and the sensitivity rating was accordingly rated as ***High*** initially and this remains relevant. The potential for serious accidents occurring will be minimized, with the mitigation measures proposed in Section 13.6.3, hence a ***Low*** magnitude rating is applied. The potential for Project-related accidents and injuries is reduced from ***Severe*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.6.4.6 Impacts Associated with Social Determinants of Health

The Project has potential to induce a decrease in social determinants of health in the PAOI. Likely receptors include Project-affected communities, and local communities in areas prone to Project-induced in-migration as described in Section 13.1.7.

Management measures designed to mitigate the indirect effects of an increase in income and resulting antisocial behaviors are discussed in Sections 13.4 and 13.8. The potential impacts on education are discussed in Section 13.5 and sorcery related impacts are discussed further below in this section. A sensitivity rating of ***Medium***, as for the initial significance assessment, remains relevant. Based on experience in other resource projects in Papua New Guinea, even with mitigation measures in place, the Project remains likely to indirectly cause increased consumption of drugs and alcohol, and possibly a consequent increase in crime and violence (Section 13.8). Therefore, a ***Medium*** magnitude is assigned. Based on these ratings, the initial social impact significance assessment for impacts associated with social determinants of health remains ***Moderate*** for the residual assessment.

13.6.4.7 Impacts on Cultural Health Practices

The Project has potential to induce create both positive and negative impacts associated with cultural health practices in communities across the PAOI. Likely receptors include Project-affected persons, and Project-affected communities in and around PRL-15, along the export pipeline route and along the river transport corridor. Any impacts would be short to long-term and have potential to be permanent (positive).

The sensitivity of communities throughout the PAOI to an increase in perceived sorcery-related events remains ***High*** as Project-related accidents, injuries or misfortune may continue to be associated with sorcery, and retribution will be sought. Through mitigations aimed at improving health services and facilities and ensuring access to remedy is available to community members, some positive change is expected, hence a magnitude rating of ***Positive***. Based on these ratings, the initial social impact significance assessment of an increase in perceived sorcery-related events of ***Minor*** becomes ***Positive*** for the residual assessment.

The initial impact rating for a greater acceptance of modern health practices as a result of Project operations in the PAOI is rated as ***Positive*** in Section 13.6.2.7, and the residual significance rating remains ***Positive***.

13.6.4.8 Summary of Residual Community Health and Safety Impacts

A summary of the assessment of residual impacts to community health and safety is provided in Table 13.14, including when and where (in which Project phase and location) these impacts are expected to occur. The table should be read in conjunction with the specific mitigation measures provided in Table 13.13.

All residual impacts are assessed to be ***Negligible*** to ***Minor*** or ***Positive*** except for impacts described below which are assessed to have a ***Moderate*** residual impact:

- Increase in respiratory disease rates and frequency or severity of outbreaks.
- Increase in sexually transmitted infections, including HIV and AIDS.
- Increase in non-communicable diseases (for Project workforce (CPF, accommodation camps) and for Project-affected persons and Project-affected communities in and around PRL-15).
- Impacts associated with social determinants of health specific to gender, substance abuse and violence.

The Project is unlikely to significantly impact on community health with robust mitigation measures and has the potential to improve health outcomes by improving infrastructure, services and community education programs. Positive outcomes include:

- Improved access to health services.
- The potential for an increased acceptance of modern health practices and a reduction in the practice of sorcery.

Table 13.14 – Summary of Assessment of Residual Impact Significance for Community Health and Safety

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Increased pressure on local health services and infrastructure.	Induced	Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor. Kikori district, Baimuru and Ihu local level government.	C, O, D	♦ SM012 ♦ SM028 ♦ SM029 ♦ SM030	Medium/Low	Minor
	Improved access to health services and infrastructure.	Indirect	Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor., Kikori district, Baimuru and Ihu local level government.	C, O, D	♦ SM012	Medium/ Positive	Positive
Construction activities, dredging, drilling, waste generation, storage and management, discharge of surface runoff.	Increase in vector-borne disease rates, frequency and severity of outbreaks.	Induced	Project-affected communities, and local communities in and around PRL-15 and along the export pipeline route.	C, O, D	♦ SM012 ♦ SM013	Medium/Low	Low
		Induced	Project-affected communities, and local communities along the river transport corridor.			Medium/ Negligible	Negligible
		Indirect	Project workforce (skilled and unskilled).			Medium/ Negligible	Negligible

Table 13.14 – Summary of Assessment of Residual Impact Significance for Community Health and Safety (cont'd)

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Increase in respiratory disease rates and frequency or severity of outbreaks.	Induced	Project workforce. Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	C, O, D	♦ SM012 ♦ SM013 ♦ SM015 ♦ SM018	Medium/ Medium	Moderate
		Induced	Project workforce Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	C, O, D	♦ SM012 ♦ SM013	Medium/Low	Minor
	Increase in sexually transmitted infections, including HIV and AIDS.	Induced	Project workforce Project-affected communities, and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor.	C, O, D	♦ SM012 ♦ SM013 ♦ SM018	Medium/ Medium	Moderate
	Increase in non-communicable diseases.	Induced	Project workforce Project-affected communities, and local communities in and around PRL-15.	C, O, D	♦ SM013 ♦ SM017	Medium/ Medium	Moderate

Table 13.14 – Summary of Assessment of Residual Impact Significance for Community Health and Safety (cont'd)

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement (cont'd).	Increase in non-communicable diseases (cont'd).	Induced	Project-affected communities, and local communities around the export pipeline route and along the river transport corridor.	C, O, D	♦ SM013 ♦ SM017	Medium/Low	Minor
	Increase in frequency of water- and sanitation-related (e.g., gastrointestinal) disease outbreaks.	Induced	Project workforce Project-affected communities, and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor.	C, O, D	♦ SM013 ♦ SM014	High/Low	Minor
Land access.	Increased malnutrition rates resulting from reduced food security.	Induced	Project-affected persons. Project-affected communities, and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor.	C, O	♦ SM001 ♦ SM002 ♦ SEM003	Low/ Negligible	Negligible
Logistics and transport.	Project-related accidents and injuries.	Direct	Project workforce Project-affected communities, and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor.	C, O, D	♦ SM016	High/Low	Minor

Table 13.14 – Summary of Assessment of Residual Impact Significance for Community Health and Safety (cont'd)

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Impacts associated with social determinants of health (specific to gender, substance abuse and violence).	Induced	Project-affected communities, and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor.	C, O, D	♦ SM013 ♦ SM014	Medium/ Medium	Moderate
	An increase in perceived sorcery-related events.	Induced	Project workforce Project-affected communities, and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor.	C, O, D	♦ SM012 ♦ SM013 ♦ See Table 13.17 for measures designed to support law and order in the PAOI.	High/Positive	Positive

C = Construction, O = Operations, D = Decommissioning and closure.

13.7 Governance and Leadership

13.7.1 Context

Elected local government representatives currently play a limited role in local village governance. Most villages in the PAOI are largely self-governing; although, churches and some private-sector organizations assist some communities. Traditional leaders, comprising clan leaders and village elders, and religious leaders primarily govern communities in the PAOI.

13.7.1.1 Government Administration

The lack of capacity in the Papua New Guinean public service is well documented by the Lowy Institute (Hayward-Jones, 2015); and despite consistent investment, particularly by the Australian Government, the World Bank's Worldwide Governance Indicators show little overall improvement in governance in Papua New Guinea between 1998 and 2014 (World Bank, 2015).

In general, government authorities have minimal presence in PAOI villages and have limited impact on their day-to-day lives; although, government representation varies across the PAOI. Communities located along the export pipeline route and along Orokolo Bay are generally better represented by government (e.g., through ward councilors and village court magistrates) than villages in and around PRL-15. This may be due, in part, to the relative isolation and small size of Pawaian villages, particularly Poroi 1, Poroi 3, Subu and Subu 2.

While ward development committees are increasingly becoming redundant in Papua New Guinea due to a lack of funding, some members of parliament have assisted villages in the PAOI, such as installing water tanks and new health facilities, but this assistance has often been plagued by implementation problems (Part 15 of Volume 2).

13.7.1.2 Traditional Leadership

The tribal groups in the PAOI have retained and continue to practice traditional leadership. The traditional leaders are usually clan leaders and village elders. Traditional leaders have the authority to speak on behalf of their group or village; although, consultation among the group or village may be expected before decisions are made or shared with outsiders.

The role of traditional leaders in the past has been associated with resource access, including defending land and resources, and social relationships. Managing communally owned land may involve educating other members about the land boundaries and the history of the boundaries, defending the boundaries, allocating land to families or family groups (e.g., for food gardens) and overseeing any decisions that involve using land or resources in the communal area. Maintaining social relationships may involve traditional exchange, clarifying the timing of cultural rituals or other events, or maintaining peace and law and order, both between and within villages. The role of traditional leaders has changed over time, as government officials and church leaders have played more prominent roles in various aspects of village life.

Coordinated leadership tends to be weaker in PRL-15 and adjacent communities relative to other parts of the PAOI due to their isolation, nomadic origins and lack of a chieftainship system (Kinkin et al., 2008) among Pawaian communities.

13.7.1.3 Religious Leadership

Church leaders play a key role in village society, not only in terms of religion but also in maintaining the peace, resolving disputes, providing youth leadership and organizing support for the elderly and other disadvantaged[4] groups. Voluntary community work is often organized through women's, church or youth groups and is common practice in PAOI villages. Voluntary community work is an important component that contributes toward the social structure and sense of communities amongst PAOI villages in terms of maintaining health, education and church facilities, cleaning public areas, and providing care and assistance to the elderly, sick or otherwise disadvantaged individuals in the community.

All villages in the PAOI except for Poroi 1 indicated that they had church leaders; and all except for Wabo have a church group (see Part 15 of Volume 2).

13.7.1.4 Women's Involvement

Gender distinctions exist in all communities. Women and girls do not enjoy the same social status nor are they afforded the same rights or are able to exert the same influence as men and boys (see Chapter 9) but some variation exists between the more remote, inland communities and the larger, coastal communities.

Community and household surveys (Part 14 of Volume 2) showed that women's understanding of the Project and its impacts was considerably lower than that of men. This is partly due to cultural protocols making it more difficult for women to engage in Project activities than men and because men from the PAOI communities often do not readily share information about the Project with women. There are also often language constraints, as many women prefer to speak their local language, rather than *Tok Pisin* or English, and many older women only speak their local language.

TEP PNG has set-up quarterly meetings with local leaders in PRL-15 to Provide project updates and respond to concerns, and in these meetings, women are invited to participate. In particular, two female representatives of each of the following villages attend the Lidas Kibung (Wabo/Ura, Subu, Poroi 2 and Evara). Some Pawaian women have been nominated as 'clan executives' on Incorporated Land Groups, but it is unknown how this process functions in practice.

13.7.1.5 Other Organizations and Support

External support or assistance for any public good has been provided to all but five villages in the PAOI in the past, as is described in Chapter 9. By far, the most common source of external support has been for water supplies; however, assistance has also been provided for schools, health facilities and communications. According to the communities surveyed, assistance has been provided by the European Union, Department of Foreign Affairs and Trade (formerly AusAID), the Japanese International Cooperation Agency, InterOil (the previous PRL-15 operator), PNG Energy Developments Limited (no longer operating), logging companies, and the Kapuna and Muro missions.

No nongovernmental organization (NGO) has a permanent presence in the PAOI; although, Médecins Sans Frontières has recently established a base at Ihu to the east of the PAOI to implement a program to help combat tuberculosis, and aims to establish another base at Kapuna.

A full description of these and other stakeholder individuals and groups is included in Chapter 6.

4 The terms 'disadvantaged' and 'vulnerable' groups are defined and discussed in Chapter 9 and Box 13.1.

13.7.2 Identification and Initial Assessment of Potential Impacts

13.7.2.1 Increased Challenges to Government Administration

The Project's fiscal contributions to the State of Papua New Guinea are outlined in Section 13.4. Positive impacts related to State financial payments and Project benefits are also discussed in Section 13.4.

Papua New Guinea is in a period of growth, particularly in regard to resource development. With this growth also comes increased pressure on local and national government due to an increased need for their services in managing and monitoring potential resource project-related environmental and social impacts. Demand for government to engage with communities will also likely increase, adding further pressure on government capacity and resources that are currently facing challenges.

In addition, issues with accountability and transparency in the key institutions managing resource project revenues in Papua New Guinea have been described in the Papua New Guinea Extractive Industries Transparency Initiative Report (PNG EITI, 2017).

The combination of increased pressure on local and national government, with accountability and transparency issues could potentially cause perceived or real inequitable or untimely distribution of State financial payments, particularly royalty or equity entitlements, as has been experienced during the process of other large-scale resource projects in Papua New Guinea (e.g., PNG LNG, the Gobe oil projects and the Hidden Valley and Simberi mines). Based on these projects, and the difficulty that the government, landowners or courts face when resolving disputes concerning the allocation of resource project benefits (Section 13.8.1.2), there is potential that State financial payments will not increase income levels in the PAOI to the degree or in the timeframe landowners and local communities expect.

Lack of understanding, and therefore frustration, over the distribution of State financial payments can often cause increased disputes, and law and order problems, leading to a decline in community cohesiveness (see Section 13.8). Bell (2009) has documented the inequitable and untimely distribution of project benefits giving rise to new forms of social stratification and sustained conflict.

If landowner groups are unprepared to participate in the Development Forum, e.g., through weak leadership coordination (Section 13.8.1.2), or are provided with insufficient resourcing for participation, outcomes may be compromised that later also become a source of sustained tension (see Section 9.14).

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State financial payments have potential to indirectly increase challenges to government administration that would be experienced by all levels of government.

All levels of government may experience further challenges to already stretched and under-resourced capacity (short-term and widespread adverse change when compared to baseline conditions) without mitigation. The initial magnitude and sensitivity ratings of ***High*** during the construction phase and ***High*** during the operation phase have been applied, as there is currently limited capacity to realize opportunities related to this impact, which is likely to be felt most when State financial payments are expected to be distributed. This results in an initial social impact significance assessment of ***Major***.

13.7.2.2 Increased Challenges to Traditional Leadership and Community Governance

Increased pressure is likely to be placed on local community leaders due to an increased need for their services on behalf of their communities in negotiating Project benefits, monitoring Project activities, helping to manage potential Project related environmental and community impacts such as economic displacement, population influx, and managing landowner companies. Some of the elderly traditional leaders, who may not be fluent in *Tok Pisin* or English, may have difficulty engaging in Project land negotiations and the government-led benefit-sharing negotiations, and may have to rely on younger men, often those able to speak *Tok Pisin* and/or English, to participate in these Project-based discussions. Sullivan (2012) describes how younger men can see older leaders as enfeebled, unable to communicate well in either *Tok Pisin* or English, and therefore unsuitable to participate in project-based discussions.

Clan members may challenge the capacity of traditional leaders to fully engage if they perceive Project benefits to be inequitably distributed. Distrust of traditional leadership may be exacerbated if communities feel isolated from decision-making processes due to a lack of engagement. This places pressure on local leaders to undertake continued engagement with affected communities, which can be a challenge with limited capacities and resources.

Combined with these factors, increased income and wealth generated by State financial payments, Project benefits, compensation and lease payments, and employment and procurement activities leading to a transition from a subsistence to increased cash-based economy (see Section 13.4), can shift the focus away from cultural beliefs, values and traditional practices, as there is little or no historical bond, societal tie or shared value between traditional leaders and those more focused on economics. This shift, indirectly driven by State financial payments and Project benefits, compensation and lease payments, also has potential to challenge and weaken traditional governance and leadership.

Another factor contributing to the potential breakdown of traditional leadership is the case where, despite low establishment in PAOI villages (see Chapter 9), community opinion influencers such as village office holders, village officials and teachers, take up paid employment with the Project, thereby weakening the village institutions where they may have provided guidance. Increased community disputes and law and order problems can also result from weakened traditional leadership or leadership that is being challenged, leading to a decline in community cohesion (see Section 13.9). Any challenges to and resulting weakening of traditional leadership may create pressure on religious leadership to provide further support amongst Project-affected PAOI communities.

PRL-15 and adjacent communities, and parts of the export pipeline route are likely to feel the impact, as this is where potential State financial payments and induced in-migration are expected to be concentrated.

Initial Impact Assessment

Receptors including traditional leadership and Project-affected persons, project-affected communities and local communities in and around PRL-15, and around the export pipeline route may experience increased challenges to traditional leadership and governance without mitigation. There is currently limited capacity to realize Project opportunities, as traditional establishments like village courts are not functioning effectively. This impact is likely to be felt during all Project phases, as Project related discussions continue. Thus, initial magnitude and sensitivity ratings of ***Medium*** and ***High*** have been applied, respectively. This results in an initial social impact significance assessment of ***Moderate***.

13.7.2.3 Summary of Identified Potential Impacts to Governance

The Project has the potential to impact government administration and traditional leadership in the PAOI, as follows:

- Increased challenges to government administration.
- Increased challenges to traditional leadership and community governance.

The following embedded design controls address potential impacts related to governance and leadership:

- The Project Operator makes payments of taxes and royalties in an accurate and timely manner during construction and operations phases. The Project Operator reports within the PNG Extractive Industry Transparency Initiative (EITI) framework, the amounts of taxes and royalties paid, within its operated perimeter [ED036].
- The Project Operator will continue the employment and where possible the recruitment of women in community relations positions (community liaison officer, village liaison officer, etc.) to conduct specific engagements with women and ensure that women's views and interests are identified [ED037].

13.7.3 Proposed Mitigation, Management and Optimization Measures

The potential for impacts to community governance and leadership may be countered and optimized by measures designed to:

- Support the capacity building of local-level and provincial governments to improve the planning and implementation of local development plans.
- Support the inclusion of women in Project benefits and decision-making.
- Support stronger, more resilient communities that are more likely to benefit from the Project and to manage potential adverse impacts more effectively.
- Limit Project-induced in-migration to PAOI communities.

Mitigation and optimization measures to be implemented during various Project phases to further manage these impacts are described in Table 13.15.

Table 13.15 – Governance and Leadership Mitigation, Optimization Strategies and Management Plans

Potential Impact	Mitigation and Optimization Strategy	Relevant Management Plan
Increased challenges to government administration.	♦ Enhance compliance with business ethics: – The Project and its contractors will require that all direct and contracted workers undertake anti-bribery, corruption, ethics and compliance training. – The Project will establish an employee whistleblowing system, thereby providing a confidential mechanism to report, e.g., any cases of bribery and corruption, or labor rights infringements in the workforce [SM019].	Community Development Plan; National Content Plan; Stakeholder Engagement Plan.

Table 13.15 – Governance and Leadership Mitigation, Optimization Strategies and Management Plans (cont'd)

Potential Impact	Mitigation and Optimization Strategy	Relevant Management Plan
Increased challenges to traditional leadership and community governance.	♦ Develop and implement targeted engagement activities with women in the Project-affected communities to help build their knowledge of the Project so that their views and rights are considered throughout its ongoing development [SM020]. ♦ The Project will work with traditional leaders and ward councilors to encourage community volunteers to participate in the Project's social monitoring and evaluation [SM021].	Community Development Plan; Stakeholder Engagement Plan

13.7.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to governance and leadership, assuming successful implementation of the proposed mitigation.

13.7.4.1 Increased Challenges to Government Administration

There is potential that the administration of State financial payments will indirectly increase challenges to all government levels leading to further adverse impacts such as increased disputes and law and order problems (see Section 13.9). Project mitigation measures focused enhancing compliance with business ethics will assist to moderate potential impacts in the PAOI and, more broadly, at provincial and national levels (see Section 13.4).

A ***Low*** magnitude rating and a ***Medium*** sensitivity rating have been applied to the PAOI, as mitigations are expected to contribute toward short- to long-term financial investment occurring in an equitable and timely manner in the PAOI and will also increase capacity to realize opportunities in various government levels.

The impact significance regarding increased challenges to government administration is reduced from ***Major*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.7.4.2 Increased Challenges to Traditional Leadership and Community Governance

Increased challenges to traditional leadership and governance due indirectly to State financial payments, Project benefits, compensation and lease payments, and employment and procurement activities is expected to be greatest in communities in and around near PRL-15, and parts of the export pipeline route, where the impacts of increased wealth from landowner benefit payments to PRL-15 customary landowners and a population influx are already present to some degree. Potential impact may be felt in the short to longer term as Project related discussions continue and particularly by receptors including traditional leaders and Project-affected persons and project-affected communities and local communities in and around PRL-15 and around the export pipeline route.

The following is an example of increased challenges to traditional leadership due to wealth from landowner benefit payments and population influx experienced during similar projects:

> In Papa village (near the LNG plant), an international contractor had become wittingly or unwittingly entangled in village politics and contributed to the polarization of the villagers and village leadership over competing lancos – almost to the detriment of [company name's] efforts to establish an umbrella lanco. It was clear to the IESC from a relatively brief discussion that the division created in Papa remains un-reconciled. This is an unhealthy situation given the seed money and employment benefits that are about to flow. It is in no-one's interest that the village leadership be divided and unable to take advantage of the seed money that is due to it. While the

> situation is not of [company name's] making, it might consider whether there is value in seeking some third-party intervention (either from higher levels of government or through a civil society group with conflict resolution skills) to broker some reconciliation between the two sides. (D'Appolonia 2010).

Adverse indirect impacts may be experienced in the shorter term only and the degree of disruption is expected to be reversible due to mitigations focused on building capacity, raising awareness and sustainable community development. A magnitude rating of ***Low*** and sensitivity rating of ***Medium*** has been applied.

The impact significance regarding increased challenges to traditional leadership and governance for Project-affected persons and Project-affected communities and local communities in and around PRL-15 and around the export pipeline route is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment, based on these ratings.

13.7.5 Summary of Residual Governance and Leadership and Impacts

A summary of the assessment of residual impacts to governance and leadership is provided in Table 13.16, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.15.

Both residual impacts are assessed to be ***Minor***.

Significant potential exists for positive impact where State financial payments are directed toward local communities; however, strengthening technical capacity will need to be supported with increased resources provided through local and national government benefit allocation. Focus will be placed on some of the key Project impacts and mitigation measures linked to employment, procurement, in-migration, land compensation, royalties and benefits.

Table 13.16 – Summary of Assessment for Residual Impact Significance for Governance, Leadership and Social Structure

Key Sensitivity	Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
							Sensitivity/ Magnitude	Significance
Economic activity.	Project employment and procurement.	Increased challenges to government administration.	Indirect	National, provincial, district and local government/s.	C, O, D	♦ SM019	Medium/Low	Minor
Governance and leadership structures.	Project employment and procurement.	Challenges to traditional leadership and community governance.	Indirect	Traditional leaders, Project-affected persons, Project-affected communities and local communities in and around PRL-15, around the export pipeline route.	C, O, D	♦ SM020 ♦ SM021	Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure.

13.8 Law and Order

13.8.1 Context

Issues surrounding disputes and tension can be generally understood in the context of community cohesion, law and order and security issues, i.e., 'Law and order' generally describes community policing and the state's capacity to intervene to restore peace and to enforce justice in the communities. This is traditionally a challenge in the PAOI, due to poor or little Police presence (e.g., little manpower, low budget, no accommodation and poor transportation means). The government is primarily in charge of law and order. Project contributions can only assist the government to mitigate the effects of Project development on law and order.

13.8.1.1 Community Cohesion

Rapid population growth, urbanization and modernization in Papua New Guinea are causing a diminishing observance of traditional leadership practices and a greater focus on individual wealth.[5] The Project has the potential to exacerbate and accelerate these changes through the introduction of social changes,[6] economic opportunities and new migrants into remote communities, many of which have not had prior experience in managing issues of this type. These changes are often associated with increased community tension.

In Papua New Guinea, disputes associated with resource development projects may arise due to:

- The process of development and implementation of benefit sharing agreements negotiated between the State of PNG, landowners and government representatives, independent of the Project. These agreements describe how the statutory benefits will be shared with landowners, local level governments and provincial governments (see Sections 13.4 and 13.7, respectively).
- Increased income and wealth, and the introduction or expansion of a cash economy, leading to social and economic change where the focus shifts to economic benefits rather than sharing aspirations that are more valued among the customary landowners, such as the need for social development (see Sections 13.4 and 13.9). Increased income and wealth may also lead to increased antisocial behaviors (e.g., consumption of drugs and alcohol, gambling, prostitution), crime and gender-based violence (see Section 13.6).
- Pressures on natural resources and ecosystem services relied upon by rural communities for subsistence (see Section 13.3 and Chapter 16).
- Clashes involving the country's armed security forces and excessive use of force.

There is potential for Project-related tension to arise in relation to any of these issues; however, no significant security incident had been registered with TEP PNG or documented in the baseline studies.

13.8.1.2 Law and Order

There is little or no police presence in the PAOI. The ratio of number of policemen per inhabitant is 1 to 4,200 in Gulf Province, versus 1 to 1,500 in Papua New Guinea compared to 1 to 400 recommended by the UN. The provincial police headquarters is located in Kerema; and in 2016,

5 Bell (2015) presents examples of such changes and associated impacts, particularly tension with waterway communities.

6 This is particularly so when the number or power of people with historical ties and shared values has declined, allowing the boundaries of 'acceptable behaviour' to shift outward.

the provincial police had 48 regular police officers and approximately 500 reserve police and community-based constables. Police are based at Ihu, Baimuru and Kikori. The locations had one police officer each with no functioning vehicle, dinghy or radio communication during the baseline studies. At end of 2019, there is now an operational dinghy at Baimuru and the Kikori police boat engine is under maintenance repair.

Traditional and church leaders also often play a direct role in conflict resolution and/or determining compensation (as discussed in Section 13.7), as do the designated land mediators.

The main law and order problems in the PAOI include stealing (generally, the theft of garden produce), fighting and domestic violence (NSO, 2013). Crime is often associated with the consumption of alcohol or illicit drugs (predominantly marijuana), and gambling and prostitution are common.

Leaders in the Orokolo villages identified more law and order problems than those from villages in and around PRL-15, which is likely to be attributable to the involvement of village court officials in the village leader meetings and their willingness to talk openly about such problems. The main security concerns expressed by village leaders were sorcery and violence (including domestic violence and sexual assault) (see Chapter 9). Leaders often indicated that the level of security had improved in recent years, due primarily to the reintroduction and strengthening of the village court system in the PAOI; although, the majority of women surveyed indicated no change.Village leaders in Aumu, Wabo, Ura, Mareke, Ere and Kilavi, and women's groups in Evara, Kaivukavu and Larihairu reported a decline in security.

The village court system is the main mechanism in the PAOI for dealing with relatively minor crimes and disputes, as there is little or no police presence, and it is relatively active, except in the Pawaian villages. The role of the village courts is to promote peace and harmony in the communities in which they operate, and they are obliged to attempt to resolve disputes initially with mediation. Traditional and church leaders often support the village court officials. Disputes that cannot be resolved are referred to the courts in Kerema.

13.8.1.3 Security

TEP PNG has been working with the government and police forces to implement a community-policing program at Wabo Station. TEP PNG has also signed a memorandum of understanding with the Royal Papua New Guinea Constabulary, outlining the support to be provided by regular and reserve police to its activities in PRL-15 and the terms and conditions of this engagement. Specifically, this includes the requirement for security procedures and measures applied under the memorandum to be compliant with the Voluntary Principles on Security and Human Rights (VPSHR, 2000).

TEP PNG has engaged three private security providers: G4S and Black Swan in Port Moresby and Guard Dog at Herd Base, all of whom are unarmed.

No significant security incidents had been recorded on site prior to the baseline studies and is likely to be due to the remoteness of PRL-15 and the PAOI in general, combined with a sparse local population.

13.8.2 Identification and Initial Assessment of Potential Impacts

Increased tension and a decline in customary social systems may arise due to rapid social and economic change, concerns over State financial payments and competition for employment and/or local economic inequity.

13.8.2.1 Decline in Customary Social Systems

Section 13.4 discusses increased income and wealth, and the introduction or expansion of a cash economy leading to social and economic change. The key cause for tension in this scenario is when this change shifts social focus to economic benefits rather than sharing aspirations that are more valued among the customary landowners, such as the need for social development.

Various government levels are largely responsible for distributing State financial payments and disputes surrounding this issue and impacts on extractive projects and their affected communities are well documented. D'Appolonia (2016) discusses how the 'failure of the Government to meet its commitments under the Benefit Sharing Agreement (including payment of royalties) provoked Hela province landowners to attack the (PNG LNG) project in the hope of getting Government's attention', causing damage to project equipment and project delays. D'Appolonia (2016) also suggests the PNG LNG Project continues to see a decrease in security incidents; however, serious community protests have occurred and are likely to continue until government commitments are met. The best approach offered by D'Appolonia (2016) is a combination of engagement and 'good intelligence' where affected communities are made aware of the project's effort to facilitate government in meeting its commitments.

There is the potential for these challenges to government administration including past issues related to State financial payments to contribute to social stratification between landowning groups where one group may benefit more than others from State financial payments. This may lead to an increase in tension and possibly conflict between landowning groups.

Project employment and business opportunities can benefit PAOI communities, but they can also become sources of tension, particularly if migrants are seen to benefit from local employment and business opportunities more than local community members do.

Section 13.7 discusses intergenerational tensions and related opportunities for asserting leadership and associated changes to traditional governance and leadership. Coordinated leadership tends to be weaker in and around PRL-15 than in villages in Orokolo Bay (see Part 15 of Volume 2).

Communities with strong leadership are more likely to resolve disputes and grievances before they become larger problems. Those with weak leadership often experience a decline in customary social systems, sense of belonging and potentially a breakdown in social and family structures.

Further impacts to customary social systems include those relating to community health and safety, particularly an increase in anti-social behaviors, discussed in Section 13.6 and assessed in Section 13.8.2.3.

The changes listed earlier have potential to increase tension, contributing to a decline in customary social systems, which itself can lead to further disputes.

Project affected communities in and around PRL-15, and parts of the export pipeline route may feel the greatest impact, in areas prone to Project-induced in-migration and where potential State financial payments may be concentrated.

Initial Impact Assessment

A decline in customary social systems and increase disputes due to rapid social and economic change induced by State financial payments, and Project employment and procurement, may be greatest in areas where income levels are expected to increase the most substantially, where in-migration is expected to be focused (see Table 13.1), and the village courts are not functioning properly. Bell (2009) provides examples of a gradual decline in customary social systems leading to further tension due to extractive industry projects in Purari River delta communities. Any potential impact may be felt during all Project phases, as Project-related discussions and activities continue.

Potentially-affected receptors include traditional leadership, project-affected persons, project-affected communities and local communities in and around PRL-15 and around the export pipeline route, and to a lesser degree, along the river transport corridor.

Without mitigation, receptors in and around PRL-15, and along the export pipeline route may experience a potentially frequent disputes related to State financial payments and an irreversible decline in customary social systems, potentially contributing to further tensions. Initial magnitude and sensitivity ratings of ***High*** have been applied, as there is currently limited or no capacity for change related to customary social systems, which is likely to be felt most during the Project's construction and operation phases when State financial payments are expected to be distributed. Some communities along the river transport corridor may only be moderately impacted and are assessed as being ***Medium*** in magnitude, but ***High*** in sensitivity for the same reasons as stated earlier.

This results in an initial social impact significance assessment of ***Major*** for receptors in and around PRL-15 and along the export pipeline, and ***Moderate*** for river transport corridor receptors.

13.8.2.2 Disputes Due to Competition Over Natural Resources

Community cohesion is generally stronger in the smaller, more isolated communities in the PAOI, where the villagers have abundant land and resources, and limited interactions with outsiders, and where they demonstrate high levels of community work (i.e., volunteering) and leadership. Political and economic agendas that promote a more individual or segmented approach can impact on community cohesion when resources are in shorter supply.

Project-induced in-migration associated with resource projects have the potential to lead to disputes and tension over access to or competition for local resources. The possibility also exists that any migrants may not respect or conform to traditional leaders' customs or traditions and may access resources inadvertently or illegitimately or without clan approval.

Un-approved access to natural resources may occur along the onshore export pipeline access road and areas in PRL-15 that are near access roads, and along the Purari River, with potential access points provided at Aivai and Evara (i.e., via existing logging camps and tracks). This is discussed in more detail in Section 13.1.7.

Potential impacts upon land and the natural environment, and on livelihoods present a focus for grievances and have the potential to generate tensions within the communities. Any impacts on natural resources (e.g., food, water, firewood) are likely to be experienced disproportionately by women, as they generally have the primary responsibility for providing food and water for their families (see Chapter 9).

Associated pressures on natural resources and ecosystem services rural communities rely on for subsistence are assessed in Chapter 16.

Initial Impact Assessment

Increased disputes due to increased access to or competition for natural resources, as an induced impact from Project employment and procurement, and population increase, may be experienced in the PAOI for reasons outlined earlier. Any potential impact may be felt during all Project phases, particularly by receptors including Project-affected persons, Project-affected communities and local communities.

Receptors may occasionally experience this potentially reversible adverse change without mitigation. Initial magnitude and sensitivity ratings of ***Medium*** and ***High*** have been applied, respectively, to PAOI communities, as there is currently limited or no capacity for change related to this impact. This results in an initial social impact significance assessment of ***Moderate***.

13.8.2.3 An Increase in Antisocial Behavior and Crime

Antisocial behaviors in local communities, including excessive alcohol consumption, smoking marijuana, gambling and prostitution are commonly reported in resource project areas in Papua New Guinea (UNDP, 2014). These behaviors may occur due to an increase in income and wealth, and a limited local capacity to expend that income. Verifying whether local people or migrants are responsible for introducing or promoting these behaviors is difficult and may instead be due to a combination of an increase in wealth and in population more generally These behaviors, irrespective of the role played by migrants, can create rifts between local people and migrants, between the older and younger generations, and between men and women, again adversely impacting community cohesion.

Problematic behaviors toward women can include the risk of sexual violence, the spread of sexually transmitted diseases, and the pressure to engage in prostitution or marry migrant men (see Section 13.6).

Law and order problems related to antisocial behavior may be experienced most by project-affected communities and local communities in areas prone to Project-induced in-migration (see Section 13.1.7) around PRL-15 and around the export pipeline route, as this is where income levels are expected to increase the most, population is expected to be concentrated, and the village courts are not functioning effectively. A known trade in illicit drugs, such as marijuana imported from the highlands, already exists in and around PRL-15, (Bell, 2006), and the use and trade of illicit substances is likely to increase with the availability of more money in this area. Less impacts may be felt along the river transport corridor.

Initial Impact Assessment

Project-affected and local communities in areas prone to Project-induced in-migration in and around PRL-15 and around the export pipeline route may experience occasional increase in antisocial behaviour and crime without mitigation. Initial magnitude and sensitivity ratings of ***Medium*** and ***High*** have been applied, respectively, as there is currently limited or no capacity for change related to this impact. Some communities along the river transport corridor may be only moderately impacted and are assessed as being ***Low*** in magnitude, but ***High*** in sensitivity for the same reasons as stated earlier.

This results in an initial social impact significance assessment of ***Moderate*** for receptors in and around PRL-15 and export pipeline, and ***Minor*** for receptors along the river transport corridor receptors.

13.8.2.4 Potential Human Rights Abuses Committed by State and Non-state Security Forces

Excessive use of police force in Papua New Guinea is and continues to be common. Dinnen (2017) discusses the Royal Papua New Guinea Constabulary (RPNGC) human rights abuses rates and the strong informal networks that exist between private security companies and the RPNGC, with many senior industry employees having previous police or military experience in Papua New Guinea and overseas.

TEP PNG has signed a MoU with RPNGC in 2016. This MoU regulates the framework in which police intervene in PRL-15, including training for Voluntary Principles of Security and Human Rights. Enforcing this MoU has proved solid since 2016 with no violation reported, and a permanent exchange of information between TEP PNG security management and the police at provincial and regional levels has taken place.

Initial Impact Assessment

There is a potential risk of excessive use of force and confrontation with local community members particularly where anti-social behavior and crime may increase and where in-migration is expected to be focused (see Section 13.1.7), and where the village courts are not functioning effectively, without adequate training of state and non-state security personnel on the appropriate use of force. Any potential impact may be felt during all Project phases, as Project related activities continue. Key receptors include Project-affected persons, Project-affected communities and local communities in and around PRL-15, and to a lesser degree, around the export pipeline route and along the river transport corridor.

Receptors in and around PRL-15, along the export pipeline route and along the river transport corridor may experience occasional impacts due to interactions between state and non-state security personnel and identified communities. Initial magnitude and sensitivity ratings of ***Low*** and ***High*** have been applied, respectively, due to the security training arrangements already in place and the lack of violations recorded since 2016, and the limited or no capacity for communities to absorb increased conflict.

This results in an initial social impact significance assessment of ***Minor*** for all receptors.

13.8.2.5 Summary of Identified Potential Impacts to Law and Order

The Project has the potential to increase tension and decrease community cohesion, and law and order in the PAOI, causing the following potential impacts:

- A decline in customary social systems.
- Disputes due to competition over natural resources.
- An increase in antisocial behaviors and crime.
- Potential human rights abuses by security forces.

The following embedded design control addresses potential human rights abuses by security forces:

- The Project has been and will continue to work with security forces in alignment with Voluntary Principles on Security and Human Rights [ED038].

13.8.3 Proposed Mitigation, Management and Optimization Measures

Potential increase in tension and decreases in community cohesion, and law and order in the PAOI can be managed and optimized by measures designed to:

- Support stronger, resilient communities that are more likely to be able to resolve disputes and grievances before they become larger problems.
- Support traditional leaders to maintain local governance arrangements (see Section 13.7).
- Support increased landowner understanding and governance of the benefit-sharing process (see Section 13.4).

- Investigate options to work with relevant local-level and provincial governments to support sustainable law and order initiatives.
- Limit in-migration, particularly to communities in and around PRL-15 (see Section 13.1).
- Train private security forces on Voluntary Principles for Security and Human Rights (VPSHR).

Mitigation and optimization measures to be implemented during various Project phases to further manage these impacts are described in Table 13.17.

Table 13.17 – Law and Order Mitigation and Optimization Strategies and Management Plans

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Decline in sense of customary social systems.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to encourage regulation and monitoring of in-migration [SM022]. ♦ The Project will establish governance arrangements for the implementation and monitoring of community investment and development programs [SM023]. ♦ Support sustainable initiatives to strengthen village law and order organizations (e.g., village courts, local police and churches) [SM024].	Project-induced In-migration Plan; Community Development Plan.
DIsputes due to competition over natural resources.	♦ In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to encourage regulation and monitoring of in-migration [SM022]. ♦ The Project will establish governance arrangements for the implementation and monitoring of community investment and development programs [SM023]. ♦ See mitigations relevant to ecosystem services (Chapter 16) and economic displacement and livelihoods (Sections 13.3 and 13.4).	Project-induced In-migration Plan; Community Development Plan; Land Access and Livelihood Development Plan;
Increase in antisocial behaviors and crime.	♦ Support sustainable initiatives to strengthen village law and order organizations (e.g., village courts, local police and churches) [SM024].	Community Development Plan; Community Health, Safety and Security Management Plan
Potential human rights abuses committed by security forces.	♦ The Project will ensure private security personnel are screened and trained on the Voluntary Principles on Security and Human Rights [SM025].	Labor Management Plan; Community Health Safety and Security Management Plan.

13.8.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to law and order, assuming successful implementation of the proposed mitigation and optimization measures.

13.8.4.1 Decline in Customary Social Systems

A decline in customary social systems may be induced from a transition to a cash economy linked to increases in income from State financial payments, and Project employment and procurement may be felt during all Project phases. The most susceptible receptors are likely to be Project-affected persons, project-affected communities and local communities in area prone to in-migration in and around PRL-15 and along the export pipeline route, and to a lesser degree, along the river transport corridor. A decline in customary social systems is expected to be substantially attenuated, and may only be experienced by individual communities, with mitigations aimed at supporting stronger, resilient communities that are more likely to be able to resolve disputes and grievances before they become larger problems, hence the impact is rated ***Low*** in magnitude. A sensitivity rating of ***Medium*** is applied with implementation of these same mitigations.

The impact significance regarding a decline in customary social systems due to rapid social and economic change and increased disputes over State financial payments is reduced from ***Major*** for receptors in and around PRL-15, and around the export pipeline, and ***Moderate*** for receptors along river transport corridor for the initial assessment, to ***Minor*** for the residual assessment for all receptors based on these ratings.

13.8.4.2 Increase in Disputes Due to Competition Over Natural Resources

Disputes over access to, or competition for, local natural resources, as an induced impact from Project-induced in-migration in some communities (see Table 13.1) may increase. Minimal change is expected when compared to baseline conditions with mitigation aimed at building capacity and resilience, strengthening law and order services, discouraging informal settlements, and minimizing adverse impacts to ecosystems services (see Chapter 16) and the environment in general.

Any potential impacts are expected to be localized and reversible in the short term, impacting Project-affected persons, communities and local communities in and around PRL-15, around the export pipeline route and along the river transport corridor. A ***Low*** magnitude rating has; therefore, been assigned across these receptors. Mitigation is also expected to increase resilience to change, hence sensitivity is rated as ***Medium***, reduced from ***High*** in the initial assessment.

The impact significance for disputes over natural resources in the PAOI is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual significance assessment, based on these ratings.

13.8.4.3 Increase in Antisocial Behaviors and Crime

Increased income and available cash in communities, compounded by potential Project-induced in-migration may cause an increase in law and order issues associated with antisocial behavior and crime. These impacts are likely to be induced by State financial payments, and Project employment and procurement, and may be experienced particularly by traditional leadership and Project-affected persons, communities and local communities in areas prone to in-migration in and around PRL-15 and around the export pipeline route. The application of mitigation measures aimed at strengthening village law and order organizations and police services and targeting the awareness and reduction of gender-based violence and sorcery accusations is expected to result in impacts being short term. A ***Low*** magnitude rating has; therefore, been assigned and sensitivity remains ***High***.

The impact significance for an increase in antisocial behaviour and crime for receptors in and around PRL-15, and along the export pipeline is reduced from ***Moderate*** for the initial assessment to ***Minor*** for the residual assessment. The initial and residual significance assessment is ***Minor*** for receptors along the river transport corridor, based on these ratings.

13.8.4.4 Potential Human Rights Abuses by State and Non-state Security Forces

There could always be a risk of human rights violations from external police forces. The risk of human rights violations committed by Project-related security forces is remote, as the private security forces must comply with TOTAL Code of Conduct, TEP PNG’s procedure and commitment for VPSHR, and government security forces intervening on account of the Project work according to the signed MoU. Potentially impacted receptors include Project-affected communities and local communities in and around PRL-15, along the export pipeline route and along the river transport corridor. A ***Negligible*** magnitude rating has been assigned with screening and training of Project-contracted security forces, targeted engagement, and an appropriate grievance mechanism. A ***High*** sensitivity rating has been assigned to the PAOI, as no exposure to this impact has been reported previously.

The impact significance regarding an increase in tension between communities and security forces is reduced from ***Minor*** for all receptors for the initial assessment, to ***Negligible*** for all receptors based on these ratings.

13.8.5 Summary of Residual Law and Order Impacts

A summary of the assessment of residual impacts to law and order is provided in Table 13.18, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.17.

All residual impacts are assessed to be ***Minor,*** except for one impact assessed as ***Negligible***.

Avoiding a decline in community cohesion and an increase in law and order issues will be difficult (hence the predominance of ***Minor*** residual significance assessments), particularly in the communities containing licence area landowners, even with robust mitigation measures in place. Outside of the Project's responsibilities, an improvement in Government administration and timely State financial payments (and therefore any support provided by TEP PNG to both) would substantially decrease the significance of this impact.

The maintenance of law and order is the role of the Papua New Guinean Government, but TEP PNG has an opportunity to contribute toward building capacity and strengthening the resilience of PAOI communities so that they are more likely to be able to resolve disputes and grievances among themselves before they become larger problems.

Table 13.18 – Summary of Assessment for Residual Impact Significance for Law and Order

Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Project employment and procurement.	Decline in Customary Social Systems.	Induced	Traditional leadership, project-affected persons, project-affected communities and local communities in and around PRL-15, around the export pipeline route, and along the river transport corridor	C, O	♦ SM022 ♦ SM023 ♦ SM024	Medium/Low	Minor
	An increase in disputes due to competition over natural resources.	Induced	Project-affected persons, Project-affected communities and local communities in and around PRL-15, around the export pipeline route, and along the river transport corridor	C	♦ SM022 ♦ SM023 ♦ See mitigations relevant to Chapter 16 and Sections 13.3 and 13.4.	Medium/Low	Minor
	An increase in antisocial behaviors and crime.	Induced	Traditional leadership, Project-affected persons, project-affected communities and local communities in and around PRL-15, around the export pipeline route, and along the river transport corridor.	C	♦ SM024	High/Low	Minor
	Potential human rights abuses committed by state and non-state security forces.	Direct and indirect	Project-affected communities and local communities in and around PRL-15, around the export pipeline route and river transport corridor.	C, O, D	♦ SM025	High/ Negligible	Negligible

C = Construction, O = Operations, D = Decommissioning and closure.

13.9 Transport and Access

13.9.1 Context

This section discusses potential Project impacts on community transport and transport access. Commercial traffic and transport are discussed in Chapter 15.

The lack of transportation and communication infrastructure is a major constraint in the PAOI and, in particular, in the upstream area of the Purari River, inhabited by the Pawaian people. Transport around the PAOI is mainly undertaken on rivers with dugout canoes, motorized dugout canoes or dinghies. Distances between villages are great, travel costs are high, and local communities report numerous travel accidents (not involving Project vessels), both in the river and at sea.

13.9.1.1 River and Sea Travel

Most people living along the Purari River rely predominantly on dinghies and canoes for transport. Canoes are used daily when fishing, accessing garden or sago areas, attending school or accessing markets and health facilities in particular for communities which are not already equipped with community facilities.

Around one in five households in the PAOI own an outboard motor, which can be attached to a dinghy or larger canoe and used to facilitate travel over longer distances, e.g., to access markets or health facilities (Kapuna Hospital) or to travel to Baimuru or Kerema. Travel depends on weather and sea conditions, on access and affordability of fuel for motorized canoes or dinghies and can be dangerous in particular when traveling at sea, sometimes resulting in fatalities.

13.9.1.2 Roads and Walking Tracks

The only roads in the PAOI are those constructed by resource companies, i.e., the roads connecting drilling wells to Herd Base (in PRL-15) and temporary logging roads used to bring logs to current river ports (i.e., Evara and Poroi 2).

Walking is often the main form of transport for people living along Orokolo Bay or in the Muro area (i.e., where there is no access to a river). Roads constructed during the colonial era along Orokolo Bay to Ihu and inland to Muro Mission are now used as walking tracks. A well-established track connects the inland Orokolo villages of Avavu, Ere and Kilavi with Huruta, Arehava 2 and Paevera in the center with the coastal Orokolo villages of Harevavo, Kaivukavu, Marea, Larihairu and Iuku. The track is used to access health services and to trade food.

The only other significant walking tracks in the PAOI are those connecting the Pawaian villages, including Wabo, to villages in Simbu and the Eastern Highlands. Walking these tracks typically takes three to five days and is only suitable for people who are in good health.

13.9.1.3 Airstrips

The only operational airstrips in or near the PAOI are at Wabo and at the Purari Airstrip. Air travel is too expensive for most of the population in the PAOI.

13.9.2 Identification and Initial Assessment of Potential Impacts

13.9.2.1 Short-term Disturbance of Access to Community Services or Natural Resources

The Project will not impact on public road traffic in the PAOI, as there are no public roads and no private vehicles recorded in the PAOI.

The construction of the export pipeline shore crossing could cause a temporary disturbance to foot traffic access along the beach and dunes between villages either side of the shore crossing location (see Figure 13.3), as the right of way and a temporary construction area for facilities, equipment and a safe operating area (see Plate 4.8) will be present. This has the potential to disrupt Orokolo Bay communities' access to schools, health facilities and markets at Kavava for a short time, as these communities frequently use the beach and back dunes, as their primary form of access between villages. Villagers also use the beach as a way to recreate and connect with neighboring villagers.

The construction of the onshore export pipeline will cross the road/walking track (see Section 13.9.1.2) between inland and coastal Orokolo villages, and foot traffic access will be restricted in the short term, which could affect movement of Iuku and Mareke inhabitants. Construction of the pipeline between the shore crossing into the offshore area may cause short-term disturbance of the use of the inter-tidal zone for nearshore fishing by Iuku and Mereke communities.

Initial Impact Assessment

A short-term disturbance of access to community services or natural resources due to the export pipeline construction at the shore crossing may directly affect export pipeline route Project-affected communities in Orokolo Bay; (e.g., Iuku resident's access to health facilities at Kavava; Mareke resident's access to Kaivukavu markets). There is also the potential for short-term disturbance of access between inland and coastal Orokolo villages (export pipeline route local communities) due to onshore pipeline construction, where it crosses the walking track. The sensitivity rating applied is ***High***, as there is limited capacity to access alternatives to the already limited services and resources along the coastline. An initial magnitude rating of ***Low*** is assigned, as the villages closest to the export pipeline route and more broadly in this part of Orokolo Bay would experience short term, and reversible disturbance without mitigation measures. An initial social impact significance of ***Minor*** results for a disturbance of access to services for export pipeline route Project-affected communities and local communities due to onshore pipeline construction, with full access being reinstated once construction is complete.

Construction, including trenching, of the Orokolo Bay export pipeline shore crossing and offshore pipeline construction activities at the export pipeline shore crossing will be a temporary activity (i.e., several weeks) but will require an exclusion zone for safety reasons. A sensitivity rating of ***Low*** is assigned to the export pipeline route Project-affected communities in Orokolo Bay (Iuku and Mareke) inter-tidal and marine resources as these communities have the capacity the access nearby alternatives. Some localized inconvenience may be experienced compared to baseline conditions, and an initial magnitude rating of ***Negligible*** is assigned, given the temporary duration of this activity. This results in an initial social significance of ***Negligible*** for a disruption of access to inter-tidal and marine resources due to the export pipeline shore crossing construction, and therefore, this impact is not assessed further.

The main river transport route for Project logistics and transport is expected to be the Purari River; and the route will pass by Mapaio Fish Camp, Kaevaria, Evara, Aivai, Aumu and Apoiope. The Urika-Ivo River will be used for short-term periods in rare occasions when the Purari River is impassable, and river traffic would pass by Mapaio Fish Camp and Mapaio, Kairu'u and Akoma. The river is the only form of transport to and from services and resources for most of these communities, (only Evara and Aivai have access to inland established tracks), and is central to maintaining livelihoods to communities along the river transport corridor. The sensitivity of river transport corridor Project-affected communities to a disturbance of access due to an increase in barge traffic, particularly during the construction period, is therefore rated ***High.*** The majority of the river traffic will occur during the construction period (approximately five years), with fewer barges using the river during the operations phase. Use of the main river transport corridor (Purari River) for barge traffic will be frequent (i.e., daily) and re-occurring over this five-year timeframe. However, given the length of the river, at any given point in time during the day it is estimated that there will not be more than 1 barge every 50km, and at any point on the river the disturbance associated with a barge will last only a few minutes. Thus, a magnitude rating of ***Low*** is assigned. This results in an initial social impact significance of ***Minor*** for a disturbance of access to services and natural resources due to an increase in barge traffic on the Purari River, primarily during the construction phase.

13.9.2.2 Loss or Damage of Assets due to Increased River Traffic

Villages along the Purari River often store their personal belongings close to or along the river banks, making them susceptible to disturbance by waves caused by large vessels. Village leaders from communities along the Purari River identified that waves from the barges currently using the Purari River for exploration and logging activities caused loss or damage to canoes through capsizing them or breaking their moorings, and loss of cooking and eating utensils that may have been left on the river bank to dry.

Assets, such as canoes, are highly valued and central to livelihood maintenance for most people in the PAOI; therefore, loss or damage of these assets or the food or tools stored in them can be significant for the individuals involved. This is especially the case for vulnerable groups and individuals such as families with no or poor food security and households that do not receive any income.

Initial Impact Assessment

An increase in the number and frequency of barges using the Purari River for logistics and transport, particularly during the construction phase, could directly cause the loss or damage of personal assets such as canoes or fishing equipment. This could occur for river transport corridor Project-affected communities.

Barges already operate along this route and these communities have some level of exposure to barge movements and the impacts associated with wash; therefore, a sensitivity rating of ***Medium*** is assigned.

Project barges are not anticipated to be substantially larger or to travel faster than those already used to service Herd Base; therefore, any wave damage (i.e., scour of the riverbed and banks due to propeller wash and vessel wake) associated with additional barge traffic could result from increased barge frequency (Section 11.3.3.1). An initial magnitude rating of ***Medium*** is assigned, as loss or damage caused by Project barges would be localized (i.e., relevant to communities along the primary transport route), temporary (i.e., primarily restricted to the construction phase and much lower during operations) and largely reversible. This results in an initial social impact significance of ***Moderate***.

13.9.2.3 Transport-related Accidents and Injuries

Transport-related accidents and injuries are discussed under Community Health and Safety in Section 13.6 and are not assessed in this section.

13.9.2.4 Increased Access to Economic Opportunities

The onshore export pipeline access track will be near several villages in the Orokolo Bay and Muro areas, which are already connected by an established track. No villages further north will be located on or near the pipeline access track. Access will be limited to Project vehicles and anyone willing to walk along it, as private vehicle ownership is currently non-existent.

The pipeline access track is unlikely to greatly improve access between the PAOI inland, and coastal communities and Kerema, as the track ends at Orokolo Bay.

Initial Impact Assessment

Transportation and communication infrastructure in the PAOI is currently very poor, with limited connectivity between villages and a heavy reliance on walking and canoe transport; therefore, a sensitivity rating of ***High*** is assigned to all Project-affected communities in the PAOI. The new onshore export pipeline access track could improve access and associated economic opportunities for some communities in the PAOI (e.g., the nearest villages to the track outside the Orokolo Bay area will be Aivai and Evara, where access tracks will connect the river to the track); however, it is unlikely that these opportunities will be taken up, due to the long travel distances required and the lack of markets inside the PAOI.

No appreciable change compared to baseline conditions is predicted, and an initial magnitude rating of ***Negligible*** is assigned. This provides an initial social significance of ***Negligible*** for an increase in access and economic opportunities associated with the export pipeline access track, and therefore this impact is not assessed further.

13.9.2.5 Summary of Potential Impacts

The Project has the potential to cause the following impacts associated with traffic and transport:

- Short-term disturbance of access to community services and natural resources.
- Loss or damage to assets due to increased river barge traffic.

13.9.3 Proposed Mitigation, Management and Optimization Measures

The potential impacts relating to Project activities will be managed and optimized by measures designed to:

- Maintain foot traffic and access between inland and coastal Orokolo villages during pipeline construction.
- Minimize the loss or damage of assets associated with an increased number of barges along the Purari River.

Mitigation, optimization and management measures to be implemented during various Project phases are described in Table 13.19.

Table 13.19 – Transport and Access Mitigation and Optimization Strategies and Management Plans

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Short-term disturbance of access to community services and natural resources.	♦ Maintain designated crossing locations during construction of the onshore export pipeline and shore crossing to enable community access [SM026]. ♦ See mitigations listed in Chapter 15 (Table 15.41) and Chapter 11 (Table 11.22).	Traffic and Transport Management Plan; Stakeholder Engagement Plan; Land Access and Livelihood Development Plan; Community Development Plan

Table 13.19 – Transport and Access Mitigation and Optimization Strategies and Management Plans (cont'd)

Potential Impact	Mitigation or Optimization Strategy	Relevant Management Plan
Loss or damage to assets as a result of increased river barge traffic.	♦ Engage with communities potentially affected by barging operations about the barge movements and define a community development program recognizing the inconvenience that waterway communities may experience [SM027]. ♦ See mitigations listed in Section 13.3. ♦ See mitigations listed in Chapter 15 (Table 15.41) and Chapter 11 (Table 11.22).	Land Access and Livelihood Development Plan; Community Development Plan; Stakeholder Engagement Plan; Traffic and Transport Management Plan.

13.9.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to transport and access, assuming successful implementation of the proposed mitigation and optimization measures.

13.9.4.1 Short-term Disturbance of Access to Community Services or Natural Resources

Early engagement with project-affected communities in Orokolo Bay will be undertaken so that appropriate measures can be implemented to maintain access along the beach or dunes, while managing community safety and with minimal inconvenience to villagers.

The sensitivity of export pipeline route Project-affected communities in Orokolo Bay was assessed as ***High*** due to limited capacity to access alternatives to the already limited services and resources along the coastline. Once mitigation measures are applied, alternative access to key services and resources will be maintained at all times during the construction of the onshore export pipeline and shore crossing, thus a magnitude rating of ***Negligible*** is assigned. The impact significance for access to community services or natural resources is reduced from ***Minor*** for the initial assessment to ***Negligible,*** for the residual assessment, for the short-term disturbance of access to community services and natural resources for export pipeline route Project-affected communities and local communities, respectively.

The sensitivity of Project-affected communities along the primary and secondary river transport routes was assessed as ***High,*** as the river is the only transport route to and from services and resources for most of these communities and is central to maintaining livelihoods. Community use of the river may be influenced by the perception that additional barge traffic heightens the danger associated with travel in dinghies or canoes (see Section 13.6).

The mitigation measures in Section 13.9.3 are expected to have very localized change in inconvenience compared to baseline conditions. As these changed conditions will extend during Project construction, i.e., for the medium term, a residual magnitude rating of ***Negligible*** is assigned. Based on these ratings, the short-term disturbance of access to community services or natural resources for residents of Project-affected communities along the main river transport corridor during construction is reduced from ***Minor*** for the initial assessment to ***Negligible*** for the residual assessment.

13.9.4.2 Loss or Damage to Assets due to Increased River Traffic

Early engagement with residents of Mapaio Fish Camp, Kaevaria, Evara, Aivai, Aumu and Apoiope about the barging schedule and potential impacts during the Project construction phase will support community resilience to the potential for loss or damage to assets. Lower barge speeds in sensitive areas (see Table 11.22) will minimize the wash associated with passage and the potential for damage to canoes or loss of cooking utensils. When barges do cause loss or damage of an asset, the processes set out in the Grievance Mechanism and, where relevant, in the Land Access and Resettlement Framework will be followed to record the grievance, assess the damage caused by Project activities and identify the eligible parties for compensation.

A residual magnitude rating of ***Low*** is assigned, as the loss or damage of assets will be temporary and completely reversible. Given the ***Medium*** sensitivity rating assigned (see Section 13.9.2.2), the initial assessment of ***Moderate*** is reduced to ***Minor*** for the residual assessment for the loss or damage to assets due to increased barge traffic for river transport corridor Project-affected communities during the construction and operations phases.

13.9.5 Summary of Residual Impact Assessment for Transport and Access Impacts

A summary of the assessment of residual impacts to community transport and access is provided in Table 13.20, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Table 13.19.

All residual impacts are assessed as ***Negligible*** to ***Minor***.

Table 13.20 – Summary of Assessment for Residual Impact Significance for Transport and Access

Main Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Impact/ Receptor	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Onshore pipeline construction; construction, including trenching, of Orokolo Bay export pipeline shore crossing.	Short-term disturbance of access to community services, and natural resources	Direct	Project-affected and local communities around the Export pipeline route in Orokolo Bay and along the main river transport corridor	C, O, D	♦ SM026 ♦ See mitigations listed in Chapter 15 (Table 15.41) and Chapter 11 (Table 11.22).	High/ Negligible	Negligible
Logistics and transport (barging along the Purari River).		Direct	Project affected communities and local communities.	C, O, D		High/ Negligible	Negligible
	Loss or damage to assets as a result of increased river traffic.	Direct	Project affected communities along the main river transport corridor.	C, O, D	♦ SM027 ♦ See mitigations listed in Section 13.3. ♦ See mitigations listed in Chapter 15 (Table 15.41) and Chapter 11 (Table 11.22).	Medium/Low	Minor

C = Construction, O = Operations, D = Decommissioning and closure.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 14: Impacts - Cultural Heritage

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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14. Impacts: Cultural Heritage

14.1 Context

The Papua New Guinean National Museum and Art Gallery (NMAG) recently introduced a two-phase cultural heritage permitting system, requiring project proponents to first undertake cultural heritage mapping under the conditions of a Cultural Heritage Mapping Permit. Information obtained is then expected to inform targeted archaeological ground surveys conducted under the conditions of a second permit, ‘Permit for Archaeological Survey in Papua New Guinea’[1].

Project cultural heritage mapping was conducted under conditions described in “Cultural Heritage Mapping Permit” (Number 001) issued by NMAG. The permit conditions allow cultural heritage researchers to conduct; (a) oral documentation of spatial arrangements of cultural properties, and (b) cultural heritage landscape mapping. The baseline studies adhered to permit conditions, and included cultural heritage mapping, involving interviews with local community representatives and field visits to accessible cultural heritage sites of interest. No targeted archaeological surveys were conducted during baseline studies. The information obtained during cultural heritage mapping; however, has and will continue to inform the second phase of cultural heritage impact mitigation carried out under the conditions of a ‘Permit for Archaeological Survey in Papua New Guinea’ (Phase two permitting).

All sites identified in and close to the Project area of influence (PAOI) are considered part of the culturally connected landscape[2] for the this cultural heritage impact assessment and; therefore, are a representative sample of site types that are present inside the PAOI in the absence of full archaeological surveys being undertaken at this time; however, a cultural heritage item, attribute or quality that is not in the direct Project footprint, is not directly assessed in this cultural heritage impact assessment.

Both tangible and intangible cultural heritage values were documented during baseline characterization (Chapter 9 and Part 17 of Volume 2). These results were based on cultural heritage mapping surveys being carried out in consultation with senior key informants representing 34 communities in the PAOI (see Part 17 of Volume 2).

Fourteen tangible cultural heritage sites were formally recorded during baseline mapping in the study area. These include ancestral village sites, spirit sites and one archaeological site. A further spirit site, given the name PRL-15 oxbow wetlands, was identified based on oral testimony but not formally recorded due to logistical constraints (e.g. aerial imagery was used to determine site dimensions).

Table 14.1 and Figures 14.1 and 14.2 show those tangible heritage sites as they relate to PRL-15, the river transport corridor and the export pipeline route.

1 Archaeological ground surveys involve systematically surveying infrastructure footprints and related areas to identify tangible cultural properties (e.g. archaeological sites), prior to the project construction phase.

2 In the context of this cultural heritage impact assessment, a culturally connected landscape is characterized as a living landscape, changing as the culture, climate and natural surroundings change in and around it. The character of the cultural landscape thus reflects the values of the people who have shaped it, and who continue to live in it.

Table 14.1 – Identified Tangible Cultural Heritage Sites

Site Name	Site Type	Location to Boundary*	Formally Recorded[3]	Assessed in this EIS
In and Around PRL-15				
Sasmeia	Spirit/ritual site	Outside	Yes	No
Wabo Kai Seiro	Spirit/ritual site	Outside	Yes	No
Subuia	Spirit/ritual site	Outside	Yes	No
PRL-15 oxbow wetlands	Spirit/ritual site	Inside	No	Yes
Moiwailedsa	Women's site	Outside	No	No
Pini sopu peido/Henaru tujemino	Spirit/ritual site	Inside	Yes	Yes
Sene Sopu Jono	Old Burial Platform site (not in use)	Inside	Yes	Yes
Sene Sopu Tou	Old Burial Platform site (not in use)	Inside	Yes	Yes
Sohopu Tepi	Spirit/ritual site	Inside	Yes	Yes
Peneturo	Spirit/ritual site	Inside	Yes	Yes
Urowai peido	Spirit/ritual site	Inside	Yes	Yes
Bwepolai peido	Spirit/ritual site	Inside	Yes	Yes
Saheilo	Ceremonial site	Inside	Yes	Yes
Tipeino/Tijana peido	Landmark	Inside	Yes	Yes
Mount Aioyu	Spirit/ritual site	Inside	Yes	Yes
River Transport Corridor				
Haralua	Ancestral village	Outside	Yes	No
Vaii Vavere	Ancestral village	Inside (Purari River banks)	Yes	Yes
Kauri Nu Poke	Ancestral village	Outside	No	No
Old Iare	Ancestral village	Inside (Purari River banks)	No	Yes
Mae	Spirit/ritual site	Outside	Yes	No
Lavi	Spirit/ritual site	Outside	Yes	No
Vaii Veruku	Spirit/ritual site	Outside	Yes	No
Vaukaea	Spirit/ritual site	Outside	Yes	No
Yemelavi	Spirit/ritual site	Outside	No	No
Alau Kaipu	Spirit/ritual site	Inside (Ivo-Uriko River banks)	No	Yes
Aua Euao	Spirit/ritual site	Inside (Ivo-Uriko River banks)	No	Yes
Akia Ini Laua complex, including Eere	Spirit/ritual site	Inside (Purari River banks)	Yes	Yes
Mairi Vaara	Spirit/ritual site	Inside (Purari River banks)	No	Yes

3 Tangible cultural heritage sites were recorded using standard site record sheets that document environmental settings and site characteristics. Site locations were recorded using handheld Garmin GPS units (WGS84 datum).

Table 14.1 – Identified Tangible Cultural Heritage Sites (cont'd)

Site Name	Site Type	Location to Boundary*	Formally Recorded[4]	Assessed in this EIS
Export Pipeline Route				
JP11 Pottery Sherd Scatter	Archaeological site	Outside	Yes	Yes (as part of Orokolo Bay culturally sensitive area)
Heve Hill cultural complex including JP11 Pottery Sherd Scatter and Nipa Stand Heve (spiritual)	Archaeological site	Outside	Yes	Yes (as part of Orokolo Bay culturally sensitive area)
Ape Ohoro	Spirit/ritual site	Outside	No	No
Kaukpa Horo	Ancestral Village	Outside	No	No
Irapuipiarumirie	Ancestral village	Outside	No	No
Popo	Ancestral village	Outside	Yes	Yes (as part of Orokolo Bay culturally sensitive area)
Maiaro	Ancestral village	To be confirmed	No	Yes (as part of Orokolo Bay culturally sensitive area)
Pottery sherds/stone tools	Archaeological site	Outside	Yes	Yes (as part of Orokolo Bay culturally sensitive area)

* Denotes the locations of sites in relation to the boundaries of PRL-15, the river transport corridor and the export pipeline route (see Figures 14.1 and 14.2).

Fifteen types of intangible cultural heritage values have been recorded under the classifications of language, oral traditions, spirit oral traditions, traditional song and dance, traditional dress, traditional subsistence knowledge and traditional medicines. Nineteen villages reported keeping ancestral heirlooms.

Baseline studies identified the PRL-15 oxbow wetlands spirit site, the Heve spirit site complex and the ancestral village of Popo as the three most significant tangible cultural heritage values inside the PAOI (see Chapter 9 and Part 17 of Volume 2). A review of archaeological research informed by geographic modeling suggests that the Muro Mission area in Orokolo Bay has the potential to contain internationally significant archaeological sites dating to the late Holocene. The export pipeline has been carefully routed to avoid these four culturally sensitive areas.

NMAG issued a permit for archaeological survey after baseline studies, with the following surveys being conducted:

1. Pre-reconnaissance cultural heritage mapping surveys in parts of Orokolo Bay, as reported in Muke et al. (2018). No cultural heritage sites were documented on the export pipeline route.

4 Tangible cultural heritage sites were recorded using standard site record sheets that document environmental settings and site characteristics. Site locations were recorded using handheld Garmin GPS units (WGS84 datum).

TANGIBLE CULTURAL HERITAGE SITES IN AND AROUND PRL-15

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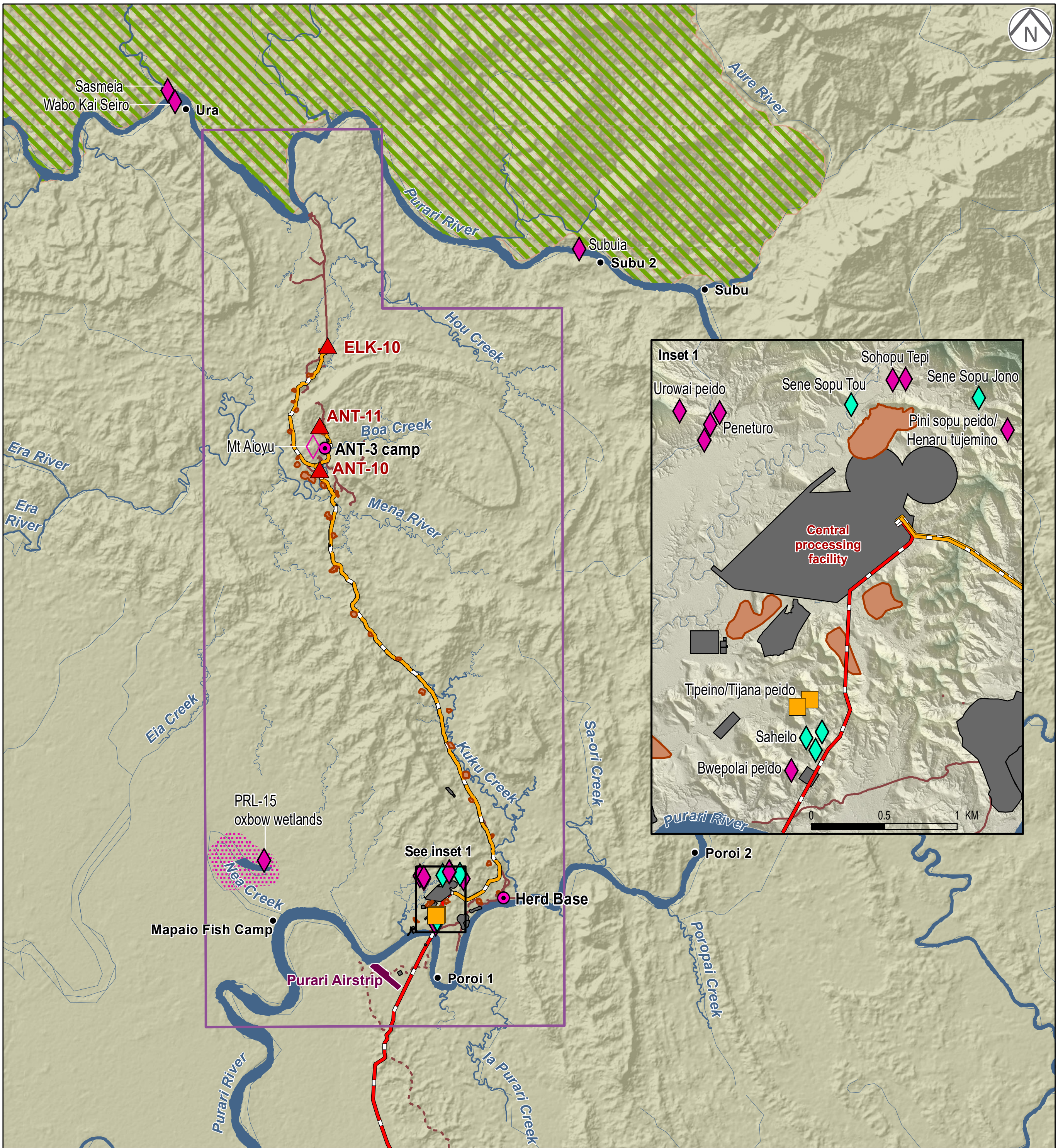
FIGURE 14.1



SCALE: 1:300,000 @ A4 | 0 2.5 5 10 15 KM | COORDINATE SYSTEM: PNG94 UTM Zone 55S

- Town or village
- Existing road
- Former logging road
- Waterway
- Waterbody or major river
- PRL-15
- Base camp
- Wellpad
- Export pipeline route
- Trunkline/flowline route (gathering system)
- Proposed Project arrangement (See Figure 4.4 for detail)
- Spoil disposal site
- Crater Mountain Wildlife Management Area
- Oxbow wetlands spiritual and traditional resource clan area (indicative)

Cultural Sites - Community-Level Social Baseline Study

- Spirit/ritual Site
- Spirit/Ritual Site (unrecorded)
- Ceremonial Site/ Burial Platform
- Landmark

01215B_23_Ch14_GIS002_v2_7

TANGIBLE CULTURAL HERITAGE SITES (RIVER TRANSPORT CORRIDOR/EXPORT PIPELINE ROUTE)

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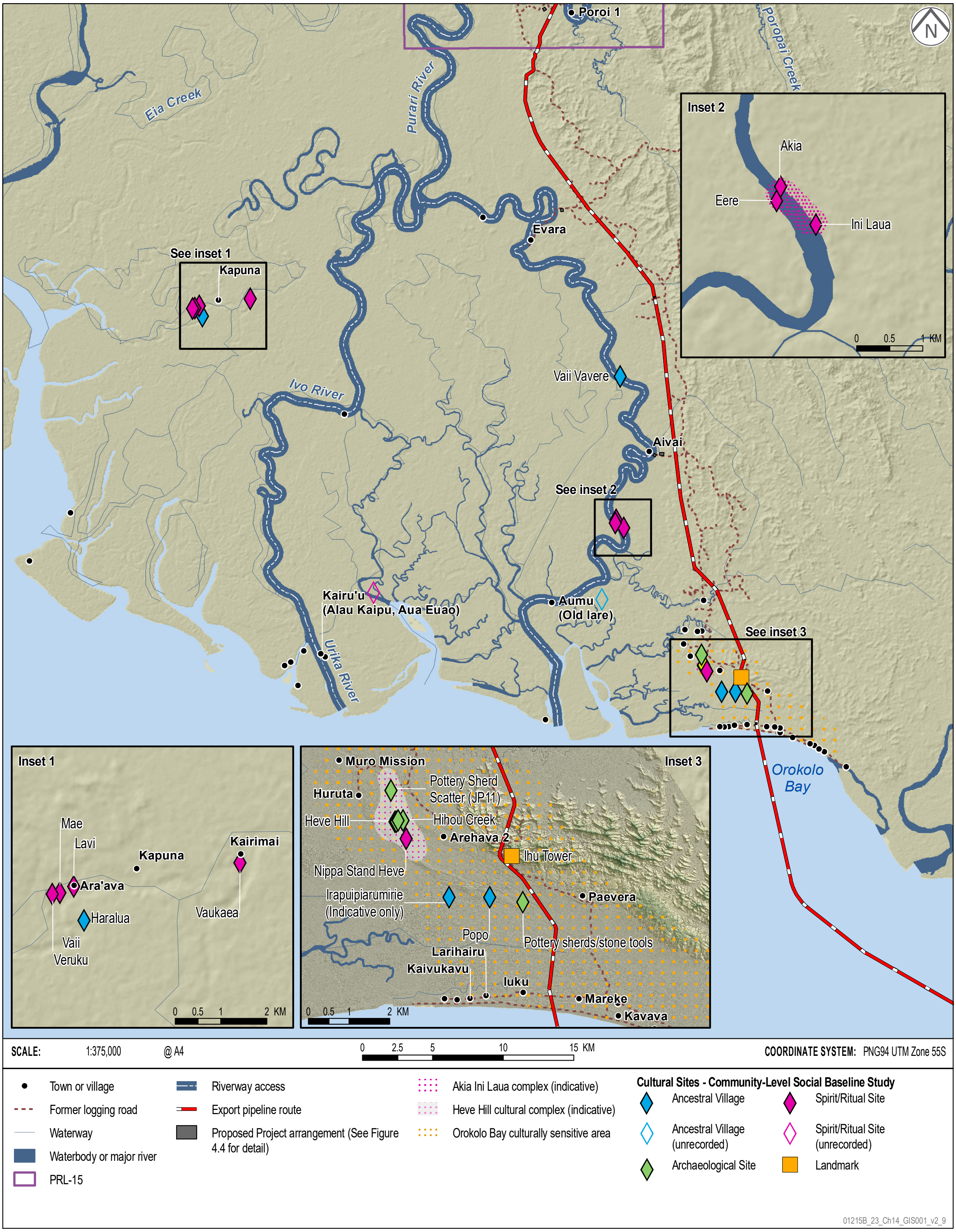
FIGURE 14.2



2. Archaeological surveys in the exclusion area including the proposed central processing facility (CPF) in PRL-15, with nine cultural heritage sites adjacent to the actual footprint of the proposed CPF being recorded (see Figure 14.1), as reported in Sepe et al. (2017).

The Project has developed a Cultural Heritage and Chance Finds Procedure in anticipation of potential impacts associated with ground altering work activities and to prevent any damage and/or destruction of potentially sensitive cultural heritage and archaeological sites and objects. This procedure will guide company, contractors' and sub-contractors' employees on how to address tangible cultural heritage properties prior to and during works. The procedure describes the recommended actions, in the case of a chance find in the Project's footprint, with priority given to avoiding sites identified as highly sensitive and important.

14.2 Cultural Heritage Impact Assessment Method

The principal objective of the cultural heritage impact assessment is to provide an assessment of potentially positive and negative impacts on tangible and intangible cultural heritage arising from Project activities, and to identify measures to manage these impacts. This chapter identifies and assesses impacts based on:

- The regulatory framework presented in Chapter 2.
- Definitions of direct, indirect and induced impacts provided in Chapter 3.
- The Project description and associated activities presented in Chapter 4.
- The alternatives analysis which described how cultural sites were considered in Project design in Chapter 5.
- Interaction between the Project and the cultural heritage and archaeological environment described in Chapter 9 and Part 17 of Volume 2.
- Assessment of impacts to terrestrial and social environments, and ecosystems services described in Chapters 11, 13 and 16 respectively, and how these may influence cultural heritage impacts.

This chapter has been structured to be consistent with onshore Project activities that occur in three areas, as defined in Chapter 1, i.e., in and around PRL-15, the export pipeline route and the river transport corridor[5], and according to definitions of tangible and intangible cultural heritage as follows.

International Finance Corporation's Performance Standard 8 (IFC, 2012) defines tangible cultural heritage as:

(i) Tangible forms of cultural heritage, such as tangible moveable or immovable objects, property, sites, structures, or groups of structures, having archaeological (prehistoric), paleontological, historical, cultural, artistic, and religious values.

(ii) Unique natural features or tangible objects that embody cultural values, such as groves, rocks, lakes, and waterfalls.

Intangible cultural heritage is defined as the practices, representations, expressions, knowledge and skills and the instruments, objects, artefacts and cultural spaces associated therewith that

5 Collectively these areas are referred to as the onshore Project area and occur in the Project Area of Influence (PAOI).

communities, groups and, in some cases, individuals recognize as part of their cultural heritage (United Nations Educational, Scientific and Cultural Organization (UNESCO, 2003).

The cultural heritage impact assessment has been conducted by firstly understanding receptors relevant to cultural heritage and the importance of cultural heritage values and then by assessing potential Project impacts whilst considering the magnitude of these potential impacts and the sensitivity of the cultural heritage receptor as described in the following sections.

14.2.1 Cultural Heritage Receptors

Social receptors relevant to cultural heritage are the individuals, communities or groups that can be affected by Project activities. Receptors in this cultural heritage impact assessment are defined according to the groups presented in Table 14.2.

Table 14.2 – Cultural Heritage Receptors

Receptor	Description
All Areas	
Unidentified tangible cultural heritage	Through Phase 2 permitting, unidentified tangible cultural heritage may be identified including (but not limited to) spirit, ancestral and archaeological sites, material culture and heirlooms (such as stone tools, shell valuables, clay pots and artefacts for example).
In and Around PRL-15	
Identified cultural heritage - PRL-15 oxbow wetlands	The PRL-15 oxbow wetlands is a spirit/ritual site that is traditionally accessed by communities from Poroi 2 (and others from Poroi 1 and 3 when permission is granted from Poroi 2), as a subsistence resource, particularly in times of food shortage and famine. The site is seen as part of the Poroi 2 community's culturally connected landscape (Part 17 of Volume 2).
Identified cultural heritage sites near the proposed CPF	The cultural heritage sites comprise spirit/ritual and potential ancestral village sites of significance to PRL-15 project affected communities.
Project-Affected Persons	Individuals or groups with legal or customary rights to land or physical assets in the Project footprint area, and whose cultural heritage could be affected by the Project land access.
Project-Affected Communities	Communities in or around PRL-15 whose cultural heritage could be affected by Project activities, including: Wabo, Wabo Station, Ura, Subu, Subu 2, Poroi 1, 2 and 3 and Mapaio Fish Camp.
River Transport Corridor	
Identified cultural heritage - Vaii Vaivere, Old Iare, Akia Ini Laua, Alau Kaipu and Aua Euao, and Mairi Vaara	Ancestral village sites Vaii Vaivere and Old Iare, and spirit sites Mairi Vaara and the Akia Ini Laua complex are located on/near the Purari River. The Alau Kaipu and Aua Euao spirit sites are located on the Ivo-Uriko River.
Vaii Vaivere, Old Iare, Akia Ini Laua, Alau Kaipu and Aua Euao, and Mairi Vaara Project-affected persons	Individuals or groups of persons who live in/near to or have legal or customary rights to land and assets in Vaii Vaivere, Old Iare, Akia Ini Laua, Alau Kaipu and Aua Euao, and Mairi Vaara and whose cultural heritage could be affected, directly or indirectly or through induced impacts due to Project activities.
Project-Affected Communities	Communities located along the Purari and Urika-Ivo rivers (the primary and secondary transport corridors) where their cultural heritage sites could be affected by barging activities, including: Apiope, Aumu, Aivai, Evara, Kaevaria along the Purari River, and Mapaio, Kairu'u, Akoma, Ikinu, along the Urika-Ivo River. Mapaio Fish Camp settlement and Poroi 1 are common to both distributaries on the river transport corridor.

Table 14.2 – Cultural Heritage Receptors (cont'd)

Receptor	Description
Export Pipeline Route	
Orokolo Bay culturally sensitive area	A prospective cultural heritage landscape with known archaeological sites of local, regional, national and international significance. It is viewed in this impact assessment, as representing a culturally connected landscape for the Orokolo Bay communities.
Project Affected Persons	Individuals or groups with legal or customary rights to land or physical assets in the Project footprint area, and whose cultural heritage could be affected by the Project land access.
Project-Affected Communities	Communities who live adjacent to the export pipeline route with cultural heritage that could be directly affected by Project activities, including: Hepere, Arehava 2, Paevera, Iuku and Mareke.

14.2.2 Cultural Heritage Value Importance

Cultural heritage property is protected under the *National Cultural Property (Preservation) Act 1965*; however, the degree to which importance is applied to cultural heritage varies greatly. International Finance Corporation (IFC, 2012) suggests as cultural heritage is not always documented or protected by law (and is mostly only understood through the knowledge held by relevant communities in the first instance), consultation with knowledgeable communities is an important means of identifying cultural heritage, documenting its presence and significance, assessing potential impacts and exploring mitigation options. Only when the significance of a cultural heritage value has been determined is it possible to determine how that value is best managed (Pearson & Sullivan, 1995).

Cultural heritage is not always documented; therefore, the importance of cultural heritage values has been assessed through a defined method which firstly considers value ratings provided by Project-affected communities during baseline consultation that attributed low, medium or high significance to their cultural heritage values. This is consistent with good international industry practice, whereby consultation is an important mechanism to obtain relevant information when cultural heritage has not been appropriately documented (IFC, 2012).

Table 14.3 provides a description of local importance ratings used by Project-affected communities.

Table 14.3 – Cultural Heritage Value Importance Ratings

Category	Description
High	The value likely plays a key role in defining and maintaining community identity and would be passed from generation to generation.
Medium	The value likely has a declining role in maintaining community identity and may not be passed from generation to generation.
Low	The value likely no longer contributes to maintaining community identity and is likely to be fading from community memory.

Local value categorization cannot always be the primary factor when determining the importance of cultural heritage value, as people who live near an intangible value may be (unconsciously) biased about the significance of that value (Ellis, 2011). For example, during baseline consultation some informants attributed low importance to language; however, language is attributed high importance at national and international scales.

Categorizing archaeological sites acknowledges their cultural context, with sites being given greater importance in this assessment, when they are known in oral traditions. A site that is unknown in oral traditions and has low local importance may; however, have research potential that makes that site important at regional, national or international scales. Additional key factors that determine archaeological site importance are rarity of the particular site type, representativeness of an historic period, the potential for the site to be scientifically informative, the preservation state and whether the site is vulnerable to destruction (Bowdler, 1984).

For this reason, local value categorization has been considered in determining regional, national and international importance based on shared multi-village recognition, previously published anthropological or archaeological sources (including both Australia International Council on Monuments and Sites (ICOMOS, 2000 and UNESCO, 1972). Assessment at these different geographic scales captures aspects that may not be recognized locally.

Once geographic scales have been captured, cultural heritage values have been reassessed considering whether the cultural heritage value is non-replicable, replicable or critical based on the definitions in Table 14.4, which were sourced from IFC (2012).

Table 14.4 – IFC Cultural Heritage Value

Category	Description
Non-replicable	Non-replicable cultural heritage may relate to the social, economic, cultural, environmental, and climatic conditions of past peoples, their evolving ecologies, adaptive strategies, and early forms of environmental management, where the (i) cultural heritage is unique or relatively unique for the period it represents or (ii) cultural heritage is unique or relatively unique in linking several periods in the same site.
Replicable	Replicable cultural heritage is defined as tangible forms of cultural heritage that can themselves be moved to another location or that can be replaced by a similar structure or natural features to which the cultural values can be transferred by appropriate measures. Archaeological or historical sites may be considered replicable where the particular eras and cultural values they represent are well represented by other sites and/or structures.
Critical	Critical cultural heritage consists of one or both of the following types of cultural heritage: (i) the internationally recognized heritage of communities who use or have used within living memory the cultural heritage for long-standing cultural purposes or (ii) legally protected cultural heritage areas, including those proposed by host governments for such designation.

The Papua New Guinean National Museum and Art Gallery (NMAG) will review this defined method of determining value importance (Figure 14.3) for its robustness and transparency in understanding the value importance of cultural heritage.

METHOD FOR DETERMINING CULTURAL HERITAGE VALUE IMPORTANCE

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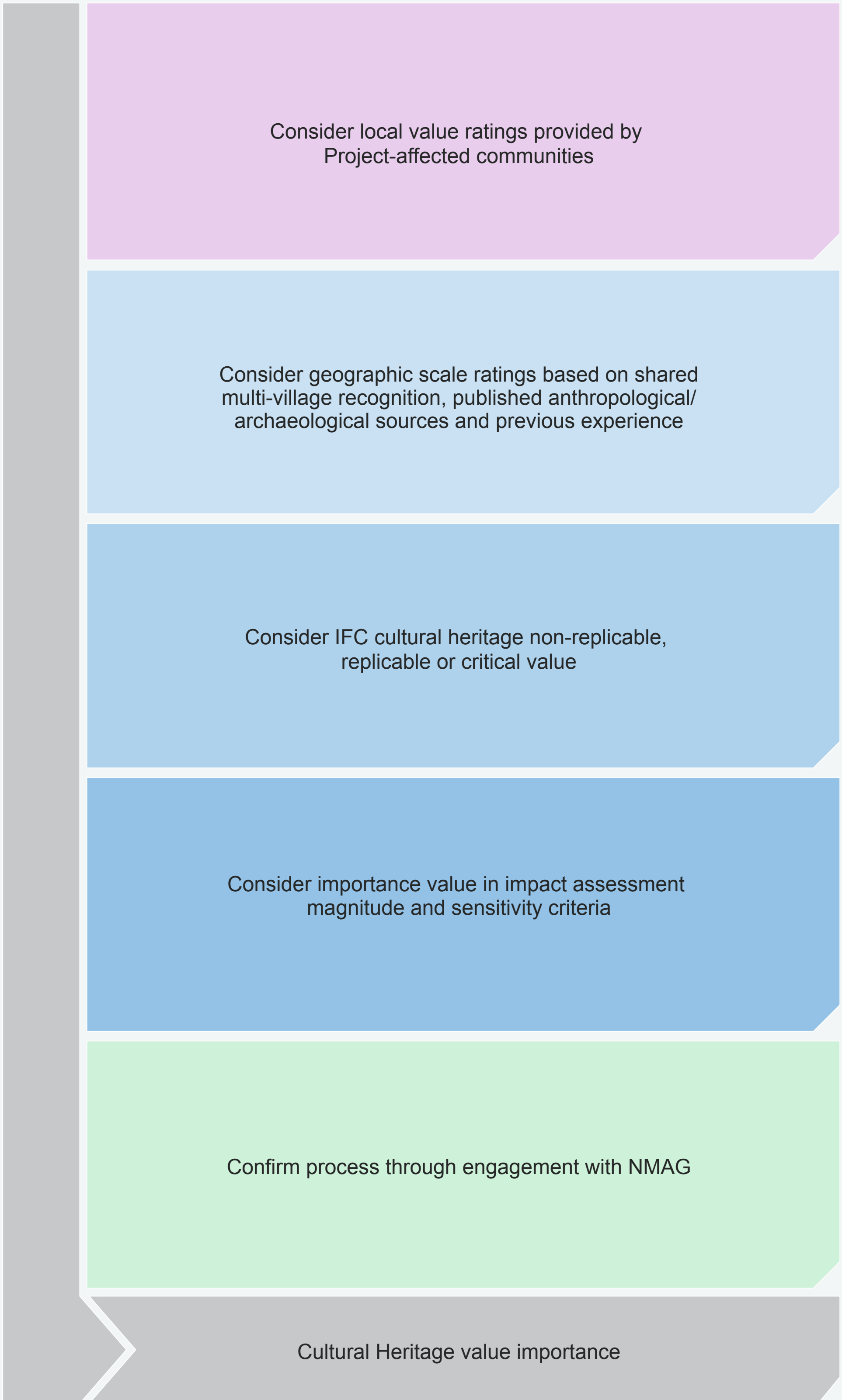
FIGURE 14.3



IFC = International Finance Corporation
NMAG = National Museum and Art Gallery

14.2.3 Cultural Heritage Impact Assessment Magnitude and Sensitivity

The value importance criteria described in Section 14.2.2 have been considered and used to define the magnitude and sensitivity criteria in Tables 14.5 and 14.6, respectively.

Table 14.5 – Cultural Heritage Impact Assessment Magnitude Criteria

Category	Description
Very High	♦ Irreversible and significant negative change, damage, loss or destruction to cultural heritage, compared to baseline conditions. ♦ Permanent and irreversible loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance is likely to be destroyed. ♦ Intangible cultural heritage and its value importance is likely to be permanently lost from community memory.
High	♦ Noticeable adverse change, damage, loss or destruction to cultural heritage, compared to baseline conditions. ♦ Permanent and irreversible loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance is likely to be damaged or partially destroyed, with some reinstatement possible through standard mitigation and management measures (Section 14.4). ♦ Intangible value importance is likely to be diminished, with some reinstatement possible through community-based management initiatives.
Medium	♦ Localized or limited change or damage to cultural heritage, compared to baseline conditions. ♦ Long term loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance may be damaged, with reinstatement possible through standard mitigation and management measures (Section 14.4), or as required under the Chance Find Procedure. ♦ Intangible value importance may be diminished, with reinstatement possible through community-based cultural heritage management initiatives.
Low	♦ Insignificant change to cultural heritage compared to baseline conditions. ♦ Temporary loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance will not be physically impacted but may be indirectly impacted (e.g., through loss of ancestral knowledge). ♦ Intangible value importance is maintained, consistent with local traditional practices and/or standard mitigation measures.
Negligible	♦ No impact to cultural heritage, compared to baseline conditions. ♦ No loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance will not be physically or indirectly impacted. No Project impact can be reasonably expected or anticipated. ♦ Intangible value importance will not be impacted. No Project impact can be reasonably expected or anticipated.
Positive	♦ Noticeable improvement to cultural heritage, compared to baseline conditions. ♦ No loss of access to sites that are used by Project-affected communities. ♦ Tangible value importance is enhanced through local village or community-based management initiatives that enhance intangible heritage values directly related to the tangible value. Archaeological excavations and analyses provide scientific knowledge to complement oral histories. ♦ Intangible value importance enhanced through village or community initiatives.

Table 14.6 – Cultural Heritage Impact Assessment Sensitivity Criteria

Category	Description
High	♦ Limited or no capacity to adapt to change. ♦ High vulnerability to changes in natural conditions (e.g. erosion, flooding, wave movement), to changes in environmental conditions (flora and fauna impacts), to changes in anthropogenic conditions (human interference, vehicular and recreational use). ♦ The item, attribute or quality is considered very important or is highly valued by the relevant community. ♦ Tangible value importance of international or national significance. Value that is *critical* or *non-replicable*, as defined in IFC (2012), and has high scientific value. ♦ Intangible value importance that is essential to maintaining cultural identity, is used by most community members and is being actively transferred to the next generation.
Medium	♦ Some resilience to changes in natural conditions (e.g. erosion, flooding, wave movement), to changes in environmental conditions (flora and fauna impacts), to changes in anthropogenic conditions (human interference, vehicular and recreational use). ♦ The item, attribute or quality is considered of medium value importance by the relevant community. ♦ Tangible value importance that is *replicable,* as defined in IFC (2012), and has medium scientific value. ♦ Intangible value importance that contributes to maintaining cultural identity, is used by most of the community or is being transferred to the next generation.
Low	♦ High resilience to changes in natural conditions (e.g. where relevant erosion, flooding, wave movement), to changes in environmental conditions (flora and fauna impacts), to changes in anthropogenic conditions (human interference, vehicular and recreational use). ♦ The item, attribute or quality is considered of low value importance by the relevant community. ♦ Tangible value importance that is *replicable,* as defined in IFC (2012), and has minimal or no scientific value. ♦ Intangible value importance acknowledged by some members of a community that is not always being transferred to the next generation.

Table 14.7 identifies tangible heritage sites discussed in the impact assessment and the sensitivity ratings applied based on sensitivity criteria defined in Table 14.6. Discussion on how the sensitivity rating was assessed for the individual sites is given in Section 14.3.1.1 for sites in and around PRL-15, Section 14.3.1.2 for sites in the river transport corridor, and Section 14.3.1.3 in the export pipeline route.

Table 14.7 – Sensitivity of Tangible Cultural Heritage Sites

Site Name	Site Type	Sensitivity
In and Around PRL-15		
PRL-15 oxbow wetlands	Spirit/ritual site	Medium
Pini sopu peido/Henaru tujemino	Spirit/ritual site	Medium
Sene Sopu Jono	Old Burial Platform site (not in use)	Medium
Sene Sopu Tou	Old Burial Platform site (not in use)	Medium
Sohopu Tepi	Spirit/ritual site	Medium
Peneturo	Spirit/ritual site	Medium
Urowai peido	Spirit/ritual site	Medium

Table 14.7 – Sensitivity of Tangible Cultural Heritage Sites (cont'd)

Site Name	Site Type	Sensitivity
Bwepolai peido	Spirit/ritual site	Medium
Saheilo	Ceremonial site	Medium
Tipeino/Tijana peido	Landmark	Medium
Mount Aioyu	Spirit/ritual site	Medium
River Transport Corridor		
Vaii Vavere	Ancestral village	Medium
Old Iare	Ancestral village	Medium
Alau Kaipu	Spirit/ritual site	Medium
Aua Euao	Spirit/ritual site	Medium
Akia Ini Laua complex, including Eere	Spirit/ritual site	Medium
Mairi Vaara	Spirit/ritual site	Medium
Export Pipeline Route		
Orokolo Bay culturally sensitive area (unidentified and not recorded) including pottery sherds/stone tools	Archaeological site	High
Maiaro (not recorded)	Ancestral village	High

A matrix combining the magnitude of impact category with the sensitivity of value category (Table 14.8) then determines the significance of the impacts on cultural heritage due to the Project's activities, consistent with the impact assessment process outlined in Chapter 3.

Table 14.8 – Impact Significance Matrix for Cultural Heritage

Magnitude of Impact	Sensitivity of Value		
	High	Medium	Low
Very High	Severe	Major	Moderate
High	Major	Moderate	Moderate
Medium	Moderate	Moderate	Minor
Low	Moderate	Minor	Minor
Negligible	Minor	Negligible	Negligible
Positive	Positive	Positive	Positive

14.3 Identification and Initial Assessment of Potential Impacts

Potential impacts to cultural heritage can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013]. For example, the Project footprint avoids culturally sensitive areas identified during baseline surveys, including the PRL-15 oxbow wetlands and Heve Hill cultural complex, the ancestral village of Popo and the Muro Mission area (see Figures 14.1 and 14.2).

Specific embedded design controls are identified throughout this section where they address potential impacts.

14.3.1 Tangible Cultural Heritage

14.3.1.1 In and Around PRL-15

Fifteen tangible cultural heritage sites (see Table 14.1) were identified in and around PRL-15. The PRL-15 oxbow wetlands (Poroi 2[6]) are located approximately 2 km northwest of the Purari River. The wetlands connect intermittently to the Purari River via Nea Creek, a former and now silting cut-off meander of the Purari River. As described in Section 5.7.1, the initial preferred site for the new airstrip north of the Purari River was rejected, as it carried potential significant adverse social, cultural and environmental impacts due to its closeness to the PRL-15 oxbow wetlands. This site is well beyond the Project disturbance areas in PRL-15 and will not be impacted. Barge Project construction activities for the wharf and barge movements will not restrict or change access to the site for Project-affected persons and communities.

The nine tangible cultural heritage sites recorded near the proposed CPF area comprised spirit (5), ceremonial (3) and landmark (1) sites. The proposed Project footprint avoids all these sites. Nonetheless, as three of these sites are located within 1 to 5 km of the export pipeline route and condensate valve station 1, there is potential, although unlikely, for indirect impacts (i.e., access/interference) to these identified tangible cultural heritage sites due to Project earthwork and related activities.

Further archaeological surveys were undertaken to the baseline studies reported in Part 17 of Volume 2, as reported in Sepe (2017) and Muke et al. (2018). No archaeological sites were found in the proposed Project footprint during surveys in the Elk-1 and ANT-3 gas field areas (Sepe, 2017).

PRL-15 has most likely always been sparsely populated; although, archaeological sites will not be entirely absent, as evidenced by the sites recorded around the CPF area. There is potential for sites to be discovered during the Project construction or operations phases. The Project has developed a Cultural Heritage and Chance Finds Procedure describing the recommended actions to implement in case of a chance find.

Project-affected persons and Project-affected communities in villages in and around PRL-15[7] maintain heirlooms that are significant material reminders of their ancestral pasts. The Project may lead to induced impacts to material culture and ancestral heirlooms if they become commodified in a cash economy due to Project employment and procurement potentially related to Project-induced influx and Project workers (including contractors).

Importance Ratings

Tangible cultural heritage value importance, relevant to PRL-15, is presented in Table 14.9.

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6 The PRL-15 oxbow wetlands spirit site is traditionally accessed by communities from Poroi 2 (and others from Poroi 1 and 3 when permission is granted from Poroi 2), as a subsistence resource, particularly in times of food shortage and famine. The site is seen as part of the Poroi 2 community's culturally connected landscape (Part 17 of Volume 2).

7 Baseline surveys were conducted in villages including Ura, Wabo, Subu 2 and Poroi 2 (Part 17 of Volume 2).

Table 14.9 – In and Around PRL-15: Tangible Cultural Heritage Value Importance

Cultural Heritage Value	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
PRL-15 oxbow wetlands	High	Low	Low	Low	N/A	N/A	No
Pini sopu peido/Henaru tujemino; Sene Sopu Jono; Sene Sopu Tou; Sohopu Tepi; Peneturo; Urowai peido; Bwepolai peido; Saheilo; Tipeino/Tijana peido	High	Low	Low	Low	N/A	N/A	No
Mount Aioyu	High	Low	Low	Low	N/A	N/A	No
Ancestral heirlooms	High	Low	Low	Low	No	Yes	No

N/A: Not applicable.

Initial Impact Assessment

None of the identified sites in and around PRL-15 are in the Project footprint and therefore are not expected to be directly impacted by the Project.

The local Project-affected persons and communities, notably Poroi 1, have assigned high tangible cultural heritage valued importance to the nine sites in the vicinity of the proposed CPF area. These sites have some resilience to change, including the three sites (Tipeino/Tijana peido, Saheilo and Bwepolai peido) located closest to the proposed footprint (see Figure 14.1). Thus, the overall sensitivity ratings for the sites are assessed as ***Medium***. The Project footprint avoids all nine sites and they are not directly affected, but they could be indirectly disturbed by Project activities given their proximity to the Project footprint; therefore, a ***Low*** impact magnitude rating has been applied for all sites.

The PRL-15 oxbow wetlands site is considered to have some resilience to change, thus the overall sensitivity rating is assessed as ***Medium***. The site is completely avoided by the proposed development; therefore, an initial magnitude rating of ***Negligible*** is assigned.

The Mount Aioyu area located north of Woh Creek is considered to have some resilience to change, thus the overall sensitivity rating is assessed as ***Medium***. The site is completely avoided by the proposed development; therefore, an initial magnitude rating of ***Negligible*** is assigned.

Any loss of material culture, ancestral heirlooms and inventories through induced impacts related to Project employment and procurement, such as an increase in a cash economy leading to commodification of such material culture, is considered to be ***Medium*** in magnitude, as this would result in localized change from baseline conditions. Project-affected persons and communities, and local communities would remain somewhat vulnerable to this impact with no mitigation or management measures in place to prevent any such loss, hence a ***Medium*** sensitivity rating has been applied.

In summary, the initial impact assessment regarding tangible cultural heritage sites in PRL-15, based on these ratings, is as follows:

- Potential disturbance, loss, damage or restricted/changed access to tangible heritage sites in the vicinity of the CPF – ***Minor***
- Potential disturbance, loss, damage or restricted/changed access to PRL-15 oxbow wetlands – ***Negligible***.

- Potential disturbance, loss, damage or restricted/changed access to Mount Aioyu – ***Negligible***.
- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Moderate***.

14.3.1.2 River Transport Corridor

Two ancestral village sites known through ethnographic accounts or oral traditions were identified on the banks of riverways. These are Vaii Vaivere (Aivai village) and Old Iare (with possible ancestral links to Aumu village) on the Purari River, with the latter not formally recorded (see Figure 14.2).

Four spirit sites were also identified during baseline surveys, one of which was formally recorded; these are Akia Ini Laua and Eere (Aivai village) and Mairi Vaara (Poroi 1, 2 and 3 villages) on the Purari River, and Alau Kaipu and Aua Euao on the Ivo-Uriko River (see Figure 14.2).

Regarding tangible site occurrence generally in the waterways, there are likely to have been many short-term ancestral settlement sites close to the river transport corridor; however, no villagers reported finding archaeological materials during gardening activities. The lack of archaeological finds by villagers is likely either due to rapid rates of siltation causing archaeological materials that may be present on riverways to be deeply buried or else eroded by the river currents and washed downstream. Thus, unknown archaeological materials are unlikely to be uncovered during Project activities. There is also little potential for unknown spirit sites to be encountered during Project activities, as traditional spiritual values have declined in importance among river transport corridor villagers since the 1950s.

Those in the river transport corridor maintain heirlooms that are significant material reminders of their ancestral pasts. The Project may lead to induced impacts on material culture and ancestral heirlooms if they become commodified in a cash economy due to Project employment and procurement. Impacts of any such commodification would likely be indirectly felt by river transport corridor Project-affected communities, and local communities.

Further, increased barge movements associated with the construction phase have the potential to increase wash effects that could destabilize and cause erosion of the riverbanks thereby impacting the integrity of sites.

Importance Ratings

Tangible cultural heritage value importance relevant to the river transport corridor is presented in Table 14.10.

Table 14.10 – River Transport Corridor: Tangible Cultural Heritage Value Importance

Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Ancestral village – Vaii Vaivere (Aivai)	High	Medium	Low	Low	No	Yes	No
Ancestral village – Old Iare (Aumu)	High	High	Medium	Low	No	Yes	No
Spirit site – Akia Ini Laua and Eere	High	Low	Low	Low	N/A	N/A	No

Table 14.10 – River Transport Corridor: Tangible Cultural Heritage Value Importance (cont'd)

Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Spirit site – Alau Kaipu – Kairu'u	High	Low	Low	Low	N/A	N/A	No
Spirit site – Aua Euao – Kairu'u	High	Low	Low	Low	N/A	N/A	No
Spirit site – Mairi Vaara – Poroi 1, 2, 3	High	Low	Low	Low	N/A	N/A	No
Ancestral heirlooms	High	Low	Low	Low	No	Yes	No

N/A: Not applicable.

Initial Impact Assessment

Any loss of material culture, ancestral heirlooms and inventories through induced impacts related to Project employment and procurement, such as an increase in a cash economy leading to commodification of such material culture, is considered to be ***Medium*** in magnitude as this would result in localized change from baseline conditions. Project-affected persons and communities, and local communities would remain somewhat vulnerable to this impact with no mitigation or management measures in place to prevent any such loss, hence a ***Medium*** sensitivity rating has been applied.

The Project will increase the volume of barge traffic on the Purari River and, if needed, the Ivo-Uriko River, during construction, operations and decommissioning. Increased vessel wash has the potential to increase river bank erosion and may directly impact cultural heritages sites that are located on the river banks through damage and or loss of materials and site integrity. Any loss or damage to sites will impact the Project-affected communities use and/or connection to these sites. A ***Medium*** impact magnitude rating is applied, as any damage or loss is expected to cause potential localized adverse change from baseline conditions. The sites are considered to have some resilience to change, given the natural variation of the river levels throughout the years, even though the precise nature and location of most of these sites are unknown, hence a ***Medium*** sensitivity rating has been applied.

In summary, the initial impact assessment regarding river transport corridor tangible cultural heritage, based on these ratings, is as follows:

- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Moderate***.
- Potential disturbance to, loss or damage to ancestral village sites Vaii Vaivere (Aivai village) and Old Iare (Aumu) and the spirit sites Mairi Vaara (Poroi 1, 2 and 3 villages), Akia Ini Laua complex (Aivai), and the Alau Kaipu and Aua Euao (Kairu'u village) sites – ***Moderate.***

14.3.1.3 Export Pipeline Route

No cultural heritage sites were recorded along most of the export pipeline route. While no sites were recorded along the route itself, numerous and significant archaeological and cultural heritage sites have been found in the landscape surrounding the route in Orokolo Bay. Although these sites were carefully avoided during the design of the route and are therefore outside the Project disturbance footprint, an appreciation of their nature and significance, which follows here, is necessary to understanding the identification of potential cultural heritage impacts in the Orokolo Bay area.

Orokolo Bay contains landscapes with high archaeological potential. Informants from all 15 Orokolo villages reported regularly uncovering pieces of pottery when working in their gardens. Orokolo Bay has not been previously subjected to systematic archaeological surveys, and only three archaeological sites have been documented thus far, i.e., the Popo ancestral village, the JP11 Pottery Sherd Scatter, and archaeological materials inside the Heve cultural site complex (see Chapter 9). Popo ancestral village site is located approximately 2.7 km inland from the coast and some 860 m to the west of the export pipeline route and is known through ethnographic and archaeological research. It is possible that unknown archaeological sites related to or from the same period as Popo may be found inside the export pipeline route at a similar distance inland from the coast.

The Irapuipiarumirie ancestral village, which was described as being approximately 1 km west of Popo and thus 1.5 km west of the export pipeline route (see Figure 14.2). The Heve spirit site complex is approximately 1,950 m west of the export pipeline route and is considered highly significant to all 15 Orokolo Bay village communities. Consultation with community informants suggest cultural connections between this site and the Pottery Sherd Scatter (JP11) archaeological site approximately 750 m to its north and the Nippa Stand Heve spirit site approximately 500 m to its south (see Figure 14.2). The Irapuipiarumirie ancestral village, which was described as being approximately 1 km west of Popo and thus 1.5 km west of the export pipeline route (see Figure 14.2). The export pipeline route has been designed to avoid disturbance to all these sites (Chapter 5). Another ancestral village is Maiaro (not recorded), which was identified through consultations with informants from Larihairu and Kaivaku, however, its precise location is yet to be confirmed.

As described in Part 17 of Volume 2, modelling suggests that the coastline in Orokolo Bay has extended (prograded) to the south over the past few thousand years as the sediment bed-load carried by the Purari River has been deposited offshore. The archaeological implications of coastal progradation are that formerly beach-fronting ancestral villages occupied by seafaring communities over the past 3000 years are now at varying distances inland from the coast. The predictive mapping suggests that ancient habitation of and inland of Orokolo Bay was most likely associated with the Araimiri (beach ridges) and Malalaua (beach plains) land systems that parallel the coast and extend inland to Muro Mission (Part 17 of Volume 2, Section 4.3).

It is foreseen that deflated dunes some 1 to 2 km inland from the coast would have provided beach fronting settlement options during a period of heightened coastal seafaring 350 to 600 years ago. Archaeological sites from this period are likely to be ancestral *hiri* settlement sites. The *hiri* has become symbolic for Papua New Guinean national identity, and archaeological sites that contribute to understanding *hiri* origins can be nationally significant. Depending on site content and what that may contribute to understanding the ancestral *hiri* period, an ancestral *hiri* site may be replicable or non-replicable (see Table 14.4). Sites in the coastal hills further inland are most likely to be on hilltops. Any sites located in coastal hills will likely date to between 1,200 and 800 years ago. These remain poorly understood periods in Papuan history, and archaeological sites from the period could therefore have national significance. The unrecorded Maiaro ancestral village site, recalled in oral traditions, may be one such site. Deflated dunes along the base of the hills may contain archaeological sites from the same period and could also contain Lapita[8] sites dating to 2,600 and 2,900 years ago. Although Lapita finds are possible along the northern edge of Orokolo Bay, landscape modeling suggests that the most likely place for Lapita sites to be found is on beach plains near Muro Mission, some 3.6 km west of the export pipeline route. Archaeological sites dating to the Lapita period would have national and international significance. Any Lapita site that may be discovered on the northern fringe of Orokolo Bay would be non-replicable.

Cultural heritage investigations in near-neighboring areas suggest that archaeological materials may be found where the export pipeline route traverses inland coastal hills and enters Orokolo Bay, an area described in this impact assessment as ‘Orokolo Bay culturally sensitive area’ (see Figure 14.2). This area is highly likely to have previously unidentified cultural heritage sites and thus is the main subject of impact assessment in this part of the Project area.

Any unidentified archaeological sites potentially within the export pipeline route may be at risk of loss, disturbance or damage from pipeline construction earthworks and vegetation clearance[9] leading to direct, indirect or induced impacts to Project-affected persons, communities and/or local communities in and around the export pipeline route.

The Project may lead to induced impacts on material culture and ancestral heirlooms if they become commodified in a cash economy due to Project employment and procurement. Impacts of any such commodification would likely be indirectly felt by export pipeline route Project-affected persons and communities along with local communities.

Importance Ratings

Tangible cultural heritage value importance relevant to the export pipeline route is presented in Table 14.11.

Table 14.11 – Export Pipeline Route: Tangible Cultural Heritage Value Importance

Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Ancestral village – Popo	High	High	High	Low	No	Yes	No
Heve Hill cultural complex	High	High	High	Low	No	Yes	No
Orokolo Bay culturally sensitive area	High	TBC	TBC	TBC	TBC	TBC	TBC
Ancestral village – Maiaro	High	TBC	TBC	TBC	TBC	TBC	TBC
Ancestral heirlooms	High	Low	Low	Low	No	Yes	No

TBC = to be confirmed.

8 There have been three major increases in cultural activity on the south coast of Papua New Guinea during the past 3,000 years. The earliest involved the arrival of Oceanic seafarers known as Lapita people who occupied beach-fronting locations along the south coast 2,600 to 2,900 years ago.

9 Understanding that forest area here is already disturbed due to existing logging activities.

Initial Impact Assessment

All identified ancestral village sites are outside of the export pipeline route and will not be materially impacted by the Project. The exact location of the ancestral village of Maiaro is yet to be determined.

Archaeological investigations in near-neighboring areas suggest that archaeological materials may be found where the export pipeline route traverses the landscape in the ‘Orokolo Bay culturally sensitive area’; therefore, it is possible that currently unidentified cultural heritage sites could be potentially directly impacted during earthworks and vegetation clearance for the onshore pipeline construction in this area. Any such potential impacts could affect both Project-affected and local communities in and around the export pipeline corridor, particularly those near Orokolo Bay.

Currently unidentified, potential tangible cultural heritage value may be damaged; therefore, a ***Medium*** magnitude rating has been applied, as any damage to existing tangible cultural heritage would be an adverse change from baseline conditions. These potential unidentified sites could be related to either ancient *hiri* and Lapita periods, and could have national and international significance. Such sites or finds are deemed non-replicable, and highly valued by the local communities, thus cultural heritage would be highly vulnerable to impacts, hence a ***High*** sensitivity rating is applied. The same impact assessment magnitude and sensitivity criteria are applied to the Maiaro ancestral village site which has not yet been located.

Any loss of material culture, ancestral heirlooms and inventories through induced impacts related to Project employment, such as an increase in a cash economy leading to commodification of such material culture, is considered to be ***Medium*** in magnitude, as this would result in localized change from baseline conditions. Project-affected persons and communities, and local communities would remain vulnerable to this impact with no mitigation or management measures in place to prevent any such loss, hence a ***Medium*** sensitivity rating has been applied.

In summary, the initial impact assessment regarding export pipeline route tangible cultural heritage, based on these ratings, is as follows:

- Potential disturbance, loss, damage to Maiaro (not recorded) – ***Moderate***.
- Potential disturbance, loss or damage to unidentified tangible cultural heritage sites in the ‘Orokolo Bay culturally sensitive area’ – ***Moderate.***
- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Moderate***.

14.3.1.4 Summary of Identified Potential Impacts to Tangible Cultural Heritage

Based on the impact assessment magnitude and site sensitivity ratings, the main impacts and their overall initial impact assessment with regard to tangible cultural heritage is as follows:

- Potential disturbance, loss, damage or restricted/changed access to sites in the vicinity of the CPF.
- Potential disturbance, loss or damage to ancestral village sites Vaii Vaivere (Aivai village) and Old Iare (Aumu) and the spirit sites Mairi Vaara (Poroi 1, 2 and 3 villages), Akia Ini Laua complex (Aivai), and the Alau Kaipu and Aua Euao (Kairu’u village) sites.
- Potential disturbance, loss or damage to unidentified tangible cultural heritage sites in the ‘Orokolo Bay culturally sensitive area’.
- Potential disturbance, loss, damage or restricted/changed access to Maiaro (not recorded).
- Potential loss of material culture, ancestral heirlooms and inventories through commodification.

14.3.2 Intangible Cultural Heritage

14.3.2.1 In and Around PRL-15

Project-affected persons and communities in and around PRL-15 (Poroi 1, 2 and 3, Mapaio Fish Camp, Purari Airstrip house, Wabo, Wabo Station, Ura, Subu, Subu 2) maintain intangible cultural heritage values in the form of the Pawaia and (some) Iare languages (see Figure 9.2), oral traditions, oral histories, ritual practices, traditional knowledge about medicines and knowledge of the physical world related to subsistence activities.

Project-affected persons and communities in and around PRL-15 maintain a strong cultural identity based on the shared use of Pawaia and Iare languages, which are being actively taught to the next generation in all PRL-15 villages surveyed. The promise of economic opportunity could be expected to stimulate in-migration, leading to increased use of *Tok Pisin* and a corresponding decline in the use of the Pawaia language, as happened during planning phases for the Purari River (Wabo) Dam Site and Reservoir Project in the 1970s (Egloff et al., 1978).

Traditional song and dance are attributed low local importance, as these heritage values are not being taught to the next generation and were not active during the baseline studies.

Oral traditions, particularly those with historical content, are attributed high local importance, as they contribute to cultural identify and justify ancestral rights to land. They are being actively taught to the next generation in all Project-affected communities in and around PRL-15 surveyed during baseline studies. Oral traditions are rated low on a regional, national and international scale, as the values are unknown outside local villages.

Traditional knowledge related to subsistence activities and medicines is attributed high local and low regional, national and international importance. People openly welcome economic development; although, they remain skeptical about the material benefits of economic change; and traditional knowledge related to subsistence practices is highly valued for providing 'insurance' against its unknown consequences and for maintaining independence from reliance on external economic factors.

Project-affected communities in and around PRL-15 surveyed have had limited historical contact with missionaries; consequently, intangible heritage values may be less resilient to Project impacts than values maintained in the river transport corridor or export pipeline route, which have experienced greater contact in the past. Intangible heritage values are particularly vulnerable to induced impacts from Project employment and procurement including in-migration, increased population mobility and economic change (see Chapter 13). These induced impacts have potential to occur during all Project phases.

Importance Ratings

Intangible cultural heritage value importance in and around PRL-15 is presented in Table 14.12.

Table 14.12 – In and around PRL-15: Intangible Cultural Heritage Value Importance

In and Around PRL-15 Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Languages – Pawaia and Iare	High	High	High	High	N/A	N/A	Yes
Oral traditions	High	Low	Low	Low	N/A	N/A	No
Traditional song and dance	Low	Low	Low	Low	N/A	N/A	No
Traditional medicines	High	Low	Low	Low	N/A	N/A	No
Traditional knowledge related to subsistence activities	High	Low	Low	Low	N/A	N/A	No

N/A: Not applicable.

Initial Impact Assessment

Project-affected persons, communities and local communities in and around PRL-15 may experience a decline in the use of Pawaia language, as a potential impact of Project-induced in-migration and without mitigation. The Pawaia language is assessed as having high vulnerability to change, is actively used and passed between generations, has a 'high' international importance, and can be considered 'critical' under IFC Performance Standard 8; therefore, a ***High*** sensitivity rating has been applied.

For the same reasons, the initial assessment of the significance of Project impacts to other forms of intangible cultural heritage (e.g., oral traditions, ritual practices, traditional practices, traditional medicines and traditional knowledge related to subsistence activities) are assessed as being ***Medium*** in magnitude and ***High*** in sensitivity. The exception is the ***Low*** sensitivity of traditional song and dance, which has already experienced a decline in practice.

In summary, the initial impact significance regarding PRL-15 intangible cultural heritage, based on these ratings, is as follows:

- A potential decline in the use of local languages and increased use of *Tok Pisin* – ***Moderate***.
- Potential changed traditional site use or access and; therefore, loss of ancestral knowledge related to identified and unidentified cultural heritage sites – ***Moderate***.
- A potential decline in the proportion of the population that is familiar with local cultural practices and subsistence activities – ***Moderate***.
- Potential disruption to or loss of the intergenerational transfer of local cultural knowledge, traditions and practices – ***Moderate***.
- A potential further decline in the proportion of the population that is familiar with local traditional song and dance – ***Minor***.

14.3.2.2 River Transport Corridor

River transport corridor communities maintain intangible cultural heritage values, as the languages, oral traditions, oral histories, ritual practices, traditional knowledge about medicines and the physical world related to subsistence activities.

Communities along the river transport corridor speak five languages belonging to the Trans-New Guinea family (i.e. Koriki, Iare, Ahia, Kaimare and Maipua (see Figure 9.2)). All communities, except for Evara, attribute high local importance to their languages. Informants representing

Evara attributed low importance to language, which may reflect the nearness of a logging camp. All languages are rated of high importance on a regional, national and international scale.

Previous historic contact and other external factors have already led to an increase in the use of *Tok Pisin* among river transport corridor communities, particularly among young people, many of whom regularly travel away from their villages for education or employment. All river transport corridor communities are passing on local languages to the next generation; although, increased in-migration may potentially cause an induced impact on the maintenance of these languages.

Traditional song and dance maintain medium to high local importance and are being actively taught to the next generation among most river transport corridor communities. Traditional song and dance are rated as low importance on a regional, national and international scale, as the values are unknown outside local villages.

Oral traditions, particularly those with historical content, are attributed high local importance, as they contribute to cultural identity and land ownership. Oral traditions are being actively taught to the next generation in communities along the river transport corridor and are rated low on a regional, national and international scale, as the values are unknown outside local villages.

Traditional knowledge related to subsistence activities and traditional medicines is attributed high local and low regional, national and international importance. These values are also being actively taught to the next generation; although, to a lesser extent than Project-affected communities in and around PRL-15.

The linguistic diversity of riverways communities where five separate indigenous languages are spoken results in these communities being potentially more vulnerable to Project impacts than Project-affected communities in and around PRL-15, and the export pipeline route communities where largely one or two local languages are spoken. Project impacts to local languages may be due to increased population mobility and social interactions that lead to increased use of *Tok Pisin*.

Importance Ratings

Intangible cultural heritage value importance relevant to the river transport corridor is presented in Table 14.13.

Table 14.13 – River Transport Corridor: Intangible Cultural Heritage Value Importance

River Transport Corridor Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Languages - Koriki, Iare, Ahia, Kaimare and Maipua	High	High	High	High	N/A	N/A	Yes
Oral traditions	High	Low	Low	Low	N/A	N/A	No
Traditional song and dance	Medium to High	Low	Low	Low	N/A	N/A	No
Traditional medicines	High	Low	Low	Low	N/A	N/A	No
Traditional knowledge related to subsistence activities	High	Low	Low	Low	N/A	N/A	No

N/A: Not applicable.

Initial Impact Assessment

Aivai and Apiope communities on the Purari river transport corridor may experience a decline in the use of local languages from induced impacts from Project induced in-migration; therefore, a ***Medium*** magnitude is applied. The Aivai community is in the Iare language group and the Apiope community is in the Maipua language group. A ***High*** sensitivity rating has been assigned, as these languages are assessed as having high vulnerability to change, are actively used and passed between generations, have a 'high' international importance, and can be considered 'critical' under IFC Performance Standard 8.

Intangible cultural heritage in the river transport corridor communities is actively being transferred to the next generation. The initial significance assessment of Project induced impacts to other forms of intangible cultural heritage (e.g., oral traditions, ritual practices, traditional practices, traditional medicines and traditional knowledge related to subsistence activities) are assessed as being ***Medium*** in both magnitude and sensitivity.

In summary, the initial assessment of impact significance without mitigation regarding river transport corridor intangible cultural heritage, based on these ratings, is as follows:

- A potential decline in the use of local languages and increased use of *Tok Pisin* – ***Moderate***.
- Potential disruption to or loss of the intergenerational transfer of cultural knowledge and practices – ***Moderate***.

14.3.2.3 Export Pipeline Route

The Orokolo Bay[10] communities extend from the coast inland to Hepere and are the only communities located along the export pipeline route. These communities maintain intangible cultural heritage values in the form of Orokolo language (see Figure 9.2), oral traditions, oral histories, ritual practices, traditional practices, traditional knowledge about medicines and knowledge of the physical world related to subsistence activities.

Orokolo language is rated high in importance to all Orokolo Bay communities, and on a regional, national and international scale. Orokolo villagers travel regionally for business purposes and many villagers permanently or temporarily reside outside of Orokolo Bay. Despite this, Orokolo communities are conscious of maintaining language and use Orokolo in all interactions with fellow speakers.

Traditional song and dance maintain medium-high local value and is being passed on to the next generation among most of Orokolo Bay communities. Traditional song and dance are rated as low importance on a regional, national and international scale, as the values are unknown outside local villages.

As described in Section 14.3.1.3, the coastline in Orokolo Bay has prograded to the south over the past few thousand years. The ethnographic effects of coastal progradation are regularly recalled in oral traditions of these coastal communities where formerly beach-fronting ancestral villages occupied by seafaring communities over the past 3,000 years are now at varying distances inland from the coast. Oral traditions are therefore attributed high local importance, as these values are important for clan identity and justify rights to land. Oral traditions are rated low on a regional, national and international scale, as the values are unknown outside local villages.

10 From a cultural heritage perspective, communities in the export pipeline corridor footprint identify as Orokolo Bay communities with their own cultural heritage identity (Part 17 of Volume 2).

Traditional knowledge related to subsistence activities and traditional medicines is attributed medium-high local and low regional, national and international importance. These values are being passed to the next generation in most villages.

Orokolo Bay villagers have demonstrated a cultural resilience to social and economic change compared to communities in and around PRL-15, and along the river transport corridor, and this is particularly evident in the maintenance of the Orokolo language.

Intangible heritage values maintained in Orokolo Bay and along the export pipeline route are potentially less vulnerable to Project impacts mentioned in this chapter, than those of the communities along the river transport corridor or in and around PRL-15, as Orokolo Bay villagers have experienced cultural change through seafaring exchange relationships for many centuries.

Orokolo Bay villagers have also demonstrated a cultural resilience to social and economic change that is particularly evident in the maintenance of the Orokolo language.

Importance Ratings

Intangible cultural heritage value importance relevant to the export pipeline route is presented in Table 14.14.

Table 14.14 – Export Pipeline Route: Intangible Cultural Heritage Value

Export Pipeline Route Cultural Heritage	Importance				IFC Standard 8 Value		
	Local	Regional	National	International	Non-replicable	Replicable	Critical
Language - Orokolo	High	High	High	High	N/A	N/A	Yes
Oral traditions	High	Low	Low	Low	N/A	N/A	No
Traditional song and dance	Medium	Low	Low	Low	N/A	N/A	No
Traditional medicines	High	Low	Low	Low	N/A	N/A	No
Traditional knowledge related to subsistence activities	High	Low	Low	Low	N/A	N/A	No

N/A: Not applicable.

Initial Impact Assessment

Interactions between Project construction activities and Orokolo Bay communities will be transitory and limited to a few months, as the onshore export pipeline and shore crossing are constructed in this area. Project effects on communities will likely relate to induced impacts from Project employment and procurement, including in-migration, increased population mobility and economic change. The initial significance assessment of these impacts to the maintenance of the Orokolo language is that Project-affected persons, communities and local communities around the export pipeline corridor will likely experience a limited change in the use of the Orokolo language without mitigation; therefore, a ***Medium*** magnitude has been applied. An initial ***High*** sensitivity rating has been applied; as the Orokolo language has already demonstrated some resilience to change.

The initial significance assessment of Project impacts to other forms of intangible cultural heritage (e.g. oral traditions, ritual practices, traditional practices, traditional medicines and traditional knowledge related to subsistence activities) are assessed as being ***Medium*** in both magnitude and sensitivity for the same reasons.

In summary, the initial impact significance without mitigation regarding export pipeline route intangible cultural heritage, based on these ratings, is as follows:

- A potential decline in the use of local language and increased use of *Tok Pisin* – ***Moderate***.
- A potential decline in the proportion of the population that is familiar with local cultural practices and subsistence activities – ***Moderate***.

14.3.2.4 Summary of Identified Potential Impacts to Intangible Cultural Heritage

The Project has the potential to adversely impact intangible cultural heritage as follows:

- A potential decline in the use of local languages and increased use of *Tok Pisin*.
- Potential changed traditional site use or access and therefore loss of ancestral knowledge related to identified and unidentified cultural heritage sites.
- A potential decline in the proportion of the population that is familiar with local cultural practices and subsistence activities.
- Potential disruption to or loss of the intergenerational transfer of local cultural knowledge and practices.

14.4 Proposed Mitigation and Management Measures

14.4.1 Tangible Cultural Heritage

Table 14.15 describes mitigation and management measures to reduce impacts to identified and unidentified tangible cultural heritage.

Table 14.15 – Tangible Cultural Heritage Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan
Loss of material culture, ancestral heirlooms and inventories through commodification.	♦ Develop and implement archaeological clearance procedures related to all early works and construction activities. This will include: – Establishment of a buffer area around identified sensitive sites near the planned project facilities, prior to early works and construction activities, to avoid accidental or inadvertent impacts. – Management of potential direct impact to any known site where impact is unavoidable, in consultation with local affected communities. – A Chance Finds Procedure for managing the discovery of ancestral remains, burial sites, and human remains. – Other measures, e.g. on site-specific recording, marking, erosion prevention, relocation, clearance distances and monitoring.	Cultural Heritage Management Plan

Table 14.15 – Tangible Cultural Heritage Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategy	Relevant Management Plan
Disturbance, loss or damage to identified and unidentified tangible cultural heritage sites.	♦ Provisions for notification of relevant parties in case of chance finds, and the notification of relevant parties in case of direct impacts to any known site [CHM001]. ♦ Develop and enforce the Project Material Culture Policy, which prohibits Project workforce from obtaining items of material culture from local communities through purchase or by way of a gratuity [CHM002]. ♦ Maintain traditional access to significant cultural places through consultation with relevant communities [CHM003]. ♦ Appoint a Project cultural heritage officer during the construction phase to oversee the implementation of the chance finds procedure, to conduct training as appropriate and to act as key contact for Project workers and contractors on all matters related to cultural heritage [CHM004]. ♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001] ♦ All Project personnel, workers, contractors and 3rd party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking. – Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028]. ♦ See also waterway erosion mitigations in particularly Table 11.22.	Cultural Heritage Management Plan

14.4.2 Intangible Cultural Heritage

Table 14.16 lists further management measures for potential impacts to intangible cultural heritage.

Table 14.16 – Intangible Cultural Heritage Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategies	Relevant Management Plan
A decline in the use of local language and increased use of *Tok Pisin*.	♦ Develop intangible cultural heritage workshops in collaboration with relevant Project-affected communities, with guidance and oversight provided by cultural heritage specialists [CHM005]. ♦ All Project personnel, workers, contractors and 3rd party operators will be educated during inductions and safety training about: – Fire risks, including the heightened risk during extreme drought years and smoking.	Cultural Heritage Management Plan
Changed traditional site use or access and therefore loss of ancestral knowledge related to cultural heritage sites (identified and unidentified).		

Table 14.16 – Intangible Cultural Heritage Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Strategies	Relevant Management Plan
A decline in the proportion of the population that is familiar with local cultural practices and subsistence activities. Disruption to or loss of the intergenerational transfer of cultural knowledge and practices.	– Wildlife values. – Weed, pathogen and animal pest hygiene and control measures. – Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure [EM028]. ♦ See also in-migration mitigations in Chapter 13.	Cultural Heritage Management Plan

14.4.3 Stakeholder Engagement

Community consultations were completed for the cultural heritage baseline characterization, consistent with IFC (2012) (see Part 17 of Volume 2). Engagement will continue as part of ongoing cultural heritage management during the Project, as described in Tables 14.14 and 14.15 and further detailed in Chapter 6.

14.5 Assessment of Residual Impacts

The following section provides the assessment of residual impacts to landform and soils subject to the embedded design control in Section 14.3 and the successful implementation of the proposed mitigation and management measures in Section 14.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

14.5.1 Tangible Cultural Heritage

14.5.1.1 In and Around PRL-15

As described in Section 14.3.1.1, none of the identified sites in and around PRL-15 are in the Project footprint; however, several sites (rated as ***Medium*** sensitivity in Section 14.3.1.1) are located close to the footprints of the proposed CPF, export pipeline route and condensate valve station 1. The mitigation measures outlined in Table 14.15, implemented in consultation with the Project-affected communities and NMAG, will avoid any potential indirect impacts. The resultant impact magnitude rating applied is therefore ***Negligible***.

Any loss of material culture, ancestral heirlooms and inventories (rated as ***Medium*** sensitivity in Section 14.3.1.1) through induced impacts related to Project employment and procurement, such as an increase in a cash economy leading to commodification of such material culture, will be mitigated with the implementation of a Cultural Heritage Management Plan in addition to cultural heritage induction and awareness programs to employees and contractors. These specific mitigations and the others described earlier are designed to reduce the risks of material culture loss. The residual impact magnitude rating applied is ***Low.***

The residual impact significance regarding tangible cultural heritage in and around PRL-15, based on these ratings, is as follows:

- Potential disturbance, loss, damage or restricted/changed access to tangible sites around the CPF – ***Negligible***.
- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Minor***.

14.5.1.2 River Transport Corridor

The possibility remains that the currently identified Vaii Vaivere (Aivai village) and Akia Ini Laua complex and non-formally identified sites of Mairi Vaara (Poroi 1, 2, and 3), Old Iare (Aumu) and Alau Kaipu and Ava Euao (Kairu'u) sites (all rated as ***Medium*** sensitivity in Section 14.3.1.2) may be impacted by increased Project barging activities during all Project phases for reasons described previously. The potential resultant impacts may damage and erode sites due to wash from vessel movements. Section 11.3 describes the proposed mitigations to reduce riverbank erosion from vessel movements. These proposed mitigations, the cultural heritage mitigations described in Table 14.15, and particularly the archaeological clearance and community consultation to be implemented, as the Project development planning progresses, is expected to mitigate all potential impacts. The resultant impact magnitude rating applied is therefore ***Negligible***.

Any loss of material culture, ancestral heirlooms and inventories through induced impacts related to Project employment and procurement, such as an increase in a cash economy leading to commodification of such material culture, is now considered to be ***Low*** in magnitude and sensitivity with prohibition mitigation measures. Project-affected persons and communities along the riverways transport corridor are expected to be less vulnerable to this impact and in fact, may become adaptable to any change with measures implemented to prevent any such loss, hence a ***Low*** sensitivity rating has been applied.

The residual impact significance regarding river transport corridor tangible cultural heritage, based on these ratings, is as follows:

- Potential disturbance, loss, damage or restricted/changed access to Vaii Vaivere (Aivai village) and Akia Ini Laua complex and non-formally identified sites of Mairi Vaara (Poroi 1, 2, and 3), Old Iare (Aumu), and Alau Kaipu and Ava Euao (Kairu'u) sites – ***Negligible***.
- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Minor***.

14.5.1.3 Export Pipeline Route

The final approach of the export pipeline route to the coast crosses the Orokolo Bay culturally sensitive area that is assessed as being of ***High*** sensitivity due to the extent and importance of known and potentially unknown sites in the area at local, regional, national and potentially international levels. The likelihood exists that vegetation clearance and earthworks for onshore pipeline construction will intersect and disturb currently unknown sites in this area whose antiquity could potentially extend back to *hiri* and or Lapita periods based on the presence of known sites and the expected likely occurrence of other unknown sites from artifacts frequently uncovered by Project-affected communities. Proposed mitigation and management measures, notably pre-construction surveys in consultation with Orokolo Project-affected communities and NMAG, and the chance finds procedure, will focus on identifying any sites, to avoid and/or salvage. Nonetheless potential remains for localized damage to tangible cultural heritage, thus, a ***Low*** residual impact magnitude rating is given, until such time that archaeological survey is complete. The same impact assessment magnitude and sensitivity criteria are applied to the yet unknown Maiaro ancestral village site.

Project pre-construction surveys for archaeological clearance will include consultation with Orokolo Bay Project-affected communities to determine if possible, the location of the yet unknown Maiaro ancestral village site in relation to the export pipeline route footprint. Due consideration will be given to avoiding potential impact on the site during Project FEED and detailed design if the site is in or near the disturbance footprint. This site cannot be assessed further, until the archaeological survey is complete.

Mitigation measures designed to educate and prohibit the Project workforce from procuring items of material culture from local communities will reduce the potential for loss of material culture, ancestral heirlooms and inventories (rated as ***Medium*** sensitivity in Section 14.3.1.3) through induced impacts related to Project employment and procurement, such as an increase in a cash economy leading to commodification of such material culture. This results in a ***Low*** magnitude rating, as any impact would represent a localized change from baseline conditions.

The residual impact significance regarding export pipeline corridor tangible cultural heritage, based on these ratings, is as follows:

- Potential disturbance, loss or damage to unidentified tangible cultural heritage sites in the Orokolo Bay culturally sensitive area – ***Moderate***.
- Potential disturbance, loss, damage or restricted/changed access to Maiaro ancestral village – ***Moderate***.
- Potential loss of material culture, ancestral heirlooms and inventories through commodification – ***Minor***.

14.5.2 Intangible Cultural Heritage

14.5.2.1 In and Around PRL-15

The possibility remains for various impacts on intangible cultural heritage to occur in and around the PRL-15 area due to social and economic reasons outlined in previous sections. The application of proposed measures in Table 14.16 is expected to minimize the declining use of the Pawaia and Iare languages among the Project-affected communities. Nonetheless, over time, the likely improvements in living standards of these communities afforded by State financial payments and increased employment (see Chapter 13) may encourage families to send their children to Port Moresby or other urban locations for schooling and advanced education.

The current generation of Pawaian and Iare speakers will continue to speak their traditional language; however, it can be foreseen that the next and future generations either educated or born in Port Moresby or other locations will struggle to speak their local language. While this decline in use is likely over time for Project-affected communities, the Pawaian language is unlikely to decline overall in the region, as it is spoken in other villages outside of the PAOI.

The decline in use of these languages in Project-affected communities has been rated ***Medium*** magnitude; and a ***High*** sensitivity rating has been applied (Section 14.3.2.1). All other intangible cultural heritage impacts are expected to be reduced through application of proposed mitigation measures and may be enhanced through increased engagement and documentation over time; hence, it has been rated ***Low*** in magnitude. A ***Medium*** sensitivity rating has been applied, as intangible cultural heritage is being transferred to the next generation. The residual impact significance regarding intangible cultural heritage in and around PRL-15, based on these ratings, is as follows:

- A potential decline in the use of local language and increased use of *Tok Pisin* – ***Moderate***.
- Potential changed traditional site use or access and; therefore, loss of ancestral knowledge related to identified and unidentified cultural heritage sites – ***Minor***.
- Potential disruption to or loss of the intergenerational transfer of cultural knowledge and practices – ***Minor***.

14.5.2.2 River Transport Corridor

The possibility remains for various impacts on intangible cultural heritage to occur in the river transport corridor area due to social and economic reasons outlined in previous sections. The preservation local languages among the river transport corridor communities is expected to be assisted with the application of proposed mitigation measures. Nonetheless, as two languages are currently spoken respectively by the Aivai and Apiope communities, it can be expected that Project employment and procurement would promote an increased adoption of *Tok Pisin,* as the favored language amongst these communities and with outsiders, thus, a ***Medium*** impact magnitude rating to language decline has been retained. A ***High*** sensitivity rating has been applied (Section 14.3.2.2).

All other intangible cultural heritage impacts to other forms of intangible cultural heritage (rated as ***Medium*** sensitivity in Section 14.3.2.2) are expected to be reduced through implementation of cultural heritage workshops and some may be enhanced with increased engagement and documentation over time; hence, this has been rated ***Low*** in magnitude.

The residual impact significance regarding river transport corridor intangible cultural heritage, based on these ratings, is as follows:

- A potential decline in the use of local languages and increased use of *Tok Pisin* – ***Moderate***.
- Potential disruption to or loss of the intergenerational transfer of cultural knowledge and practices – ***Minor***.

14.5.2.3 Export Pipeline Route

The possibility remains for various impacts to occur on intangible cultural heritage along the export pipeline route due to social and economic reasons outlined in previous sections. The decline in use of the Orokolo language; however, has been rated as ***Negligible*** magnitude, which is lower than in and around PRL-15 and river transport corridor areas, as the area currently maintains its local language despite existing changes. This is expected to continue with the application of relevant mitigation measures. ***High*** sensitivity has been applied (Section 14.3.2.3).

All other intangible cultural heritage impacts to other forms of intangible cultural heritage (rated as ***Medium*** sensitivity in Section 14.3.2.3) are expected to be reduced or avoided with application of proposed mitigation measures and may be enhanced with increased engagement and documentation over time; hence have been rated ***Negligible*** in magnitude.

The residual impact significance regarding the export pipeline route intangible cultural heritage, based on these ratings, is as follows:

- A potential decline in the use of local language and increased use of *Tok Pisin* – ***Minor***
- Potential disruption to or loss of the intergenerational transfer of cultural knowledge and practices – ***Negligible***.

14.6 Summary of Residual Cultural Heritage Impacts

A summary of the assessment of residual impacts to tangible and intangible cultural heritage is provided in Table 14.17, including in which Project phase and location these impacts are expected to occur. The table should be read with the specific mitigation measures provided in Tables 14.15 and 14.16.

All residual risk ratings are rated as either ***Minor*** or ***Negligible*** except for potential disturbance, loss or damage to unidentified tangible cultural heritage sites in the export pipeline corridor in the Orokolo Bay culturally sensitive area, and the potential loss of languages in and around PRL-15 and river transport corridor communities, which have both been rated as ***Moderate,*** after management and mitigation measures have been applied or implemented.

Project-related investment in cultural heritage may improve the retention of cultural knowledge in the Project area. This is not only a mitigation measure to minimize adverse impacts but can become a positive outcome compared with the current situation where such knowledge is poorly documented.

Table 14.17 – Summary of Assessment of Residual Impact Significance for Cultural Heritage

Key Sensitivity	Main Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Activity/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
							Sensitivity/ Magnitude	Significance
Tangible Cultural Heritage								
Identified cultural heritage sites in the vicinity of CPF.	Earthworks, vegetation clearance	Potential disturbance, loss, damage or restricted/changed access to identified or unidentified tangible cultural heritage sites.	Direct	In and around PRL-15 Project-affected communities.	C, O, D	♦ CHM001 ♦ CHM002 ♦ CHM003 ♦ CHM004 ♦ EM001 ♦ EM028 ♦ See mitigations in Table 11.22.	Medium/ Negligible	Negligible
River transport corridor Vaii Vaivere, Akia Ini Laua complex, Mairi Vaara, Old Iare, Alau Kaipu, Ava Euao.	Logistics and transport – barges			River transport corridor Project-affected communities.	C, O		Medium/ Negligible	Negligible
Orokolo Bay culturally sensitive area sites and Maiaro ancestral village.	Earthworks, vegetation clearance			Export pipeline route Project-affected communities.	C, O		High/Low	Moderate
Ancestral heirlooms.	Project employment and procurement	Potential loss of material culture, ancestral heirlooms and inventories through commodification as an induced impact of Project employment and procurement.	Induced	In and around PRL-15 and export pipeline route Project-affected persons, Project-affected communities and local communities.	C, O, D	♦ CHM002 ♦ EM028	Medium/Low	Minor

Table 14.17 – Summary of Assessment of Residual Impact Significance for Cultural Heritage (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Activity/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
							Sensitivity/ Magnitude	Significance
Ancestral heirlooms (cont'd)	Project employment and procurement	Potential loss of material culture etc.	Induced	River transport corridor Project-affected persons, Project-affected communities and local communities.	C, O, D	♦ CHM002 ♦ EM028	Low/Low	Minor
Intangible Cultural Heritage								
Language: Pawaia	Project employment and procurement	A potential decline in the use of local language and increased use of *Tok Pisin.*	Induced	In and around PRL-15 Project-affected persons, Project-affected communities and local communities.	C, O, D	♦ CHM005 ♦ EM028 ♦ See also in-migration mitigations in Chapter 13.	High/Medium	Moderate
Language: Koriki, Iare, Ahia, Kaimare, Maipua				River transport corridor Project-affected persons, Project-affected communities and local communities.			High/Medium	Moderate
Language: Orokolo				Export pipeline route Project-affected persons, Project-affected communities and local communities.			High/ Negligible	Minor
Cultural practices and subsistence activities	Project employment and procurement	Potential changed traditional site use or access and; therefore, loss of ancestral knowledge related to identified and unidentified cultural heritage sites.	Induced	In and around PRL-15 Project-affected persons, Project-affected communities and local communities.	C, O, D	♦ CHM005	Medium/Low	Minor

Table 14.17 – Summary of Assessment of Residual Impact Significance for Cultural Heritage (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Direct/ Indirect/ Induced	Location of Activity/ Receptor	Project Phase	Mitigation and Management	Residual Assessment	
							Sensitivity/ Magnitude	Significance
Cultural practices and subsistence activities	Project employment and procurement	Potential disruption to or loss of the intergenerational transfer of cultural knowledge and practices.	Induced	In and around PRL-15 and river transport corridor Project-affected persons, Project-affected communities and local communities.	C, O, D	♦ CHM005	Medium/Low	Minor
				Export pipeline route Project-affected persons, Project-affected communities and local communities.			Medium/ Negligible	Negligible

C = Construction, O = Operations, and D = Decommissioning and closure.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 15: Impacts - Amenity and Climate Change

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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15. Impacts: Amenity and Climate Change

15.1 Air Quality

15.1.1 Context

15.1.1.1 Existing Air Quality

As identified in the Upstream Air Quality Baseline Report (Part 19 of Volume 2, summarized in Section 10.2 of this report), the Project area of influence (PAOI) is remote from existing industrial pollution sources, with minimal anthropogenic development. The ambient air quality across the PAOI is therefore assumed to be generally good and would be regarded as a 'non-degraded' airshed in relation to International Finance Corporation (IFC) assessment requirements. Baseline concentrations of gaseous pollutants (i.e., nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and volatile organic compounds (VOCs)) would be negligible, and background levels of particulate matter (total suspended particulate matter (TSP), particulate matter with an aerodynamic diameter of 10 µm or less (PM_{10}) and particulate matter with an aerodynamic diameter of 2.5 µm or less ($PM_{2.5}$)) are expected to be low given the high rainfall, low wind speeds and dense vegetation in the area.

Similar to other air quality impact assessments performed in the region (e.g., PNG Biomass Project (SLR, 2017), Hidden Valley Gold Mine (RHA, 2004) and PNG LNG Project (upstream) (HAS, 2009)), background concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) have been estimated based on monitoring data from baseline monitoring programs for other projects, i.e., Wafi-Golpu Project, and with consideration given to the local land use and high rainfall in the onshore Project area. These levels are below the relevant international guidelines for particulate matter and are considered to be applicable across the onshore Project area. Baseline gaseous pollutant concentrations have been assumed to be negligible compared to international ambient air quality criteria.

Air emissions from the existing PNG LNG Facilities will influence air quality at the Caution Bay landfall approach. Air emissions from shipping, industrial and commercial activities in and around Port Moresby (14 km to the southeast) may also cause slight increases in background concentrations of both gaseous pollutants and particulate matter at the landfall compared to the onshore Project area. As air emissions associated with the Project activities proposed at the Caution Bay landfall approach will be limited to construction of the offshore export pipeline and air emissions during the operations phase of the pipeline will be negligible, further analysis of the baseline air quality at Caution Bay has not been undertaken.

15.1.1.2 Sensitive Receptors

15.1.1.2.1 Human Receptors

PRL-15 is situated in a remote location with just five small settlement or village areas located in the surrounding area. The CPF is situated approximately 1.7 km northeast of the Purari River and the proposed Logistics Base, and approximately 3 km west of the existing Herd Base. Poroi 1, approximately 4 km to the south, is the village closest to the proposed CPF and the associated operations accommodation camp. Mapaio Fish Camp is located approximately 8 km west of the CPF. A single residence is located approximately 5 km southwest on the southern bank of the Purari River adjacent to the Purari Airstrip. Other villages are located along the Purari River; however, these are all more than 8 km from the CPF. The wellpads are located in dense tropical rainforest far from any existing settlements.

The housing density increases at the coast near the southern end of the onshore export pipeline and the pipeline shore crossing construction area.

The locations of existing villages near proposed Project infrastructure are summarized in Table 15.1. In addition to these human receptors, potential adverse impacts of Project-related air emissions on the surrounding vegetation have also been considered.

Table 15.1 – Identified Sensitive Human Receptors

Village	Separation Distance
Receptors Located Near Major Project Infrastructure	
Subu 2	14.5 km northeast of ELK-10
Poroi 1	3.9 km south of the CPF 2.4 km east of the Purari Airstrip 2.6 km south-southeast of the Logistics Base 5 km south-southwest of Herd Base
Mapaio Fish Camp	7.9 km west-southwest of the CPF 5.6 km northwest of the Purari Airstrip 6.9 km west of the Logistics Base 11.5 km west of Herd Base
Purari Airstrip House	190 m northeast of the northern end of the existing airstrip 1.3 km northeast of the extension area at the southern end of the airstrip 85 m northeast of the proposed perimeter road at the north end of the airstrip 4.8 km southwest of the CPF 2.6 km southwest of the Logistics Base 7.4 km southwest of Herd Base
Receptors Located Within 5 km of the Onshore Export Pipeline Route and Associated Infrastructure	
Poroi 1	1.2 km from the export pipeline route 1.8 km from pipe yard 2
Evara	4.5 km from the export pipeline route 2.8 km from pipe yard 3
Aivai	1.8 km from the export pipeline route 260 m from pipe yard 4 700 m from the pipeline construction camp
Hepere	1.1 km from the export pipeline route
Kilavi	1.8 km from the export pipeline route
Ere	2.2 km from the export pipeline route
Muro Mission	3.5 km from the export pipeline route
Huruta	3.4 km from the export pipeline route
Arehava 2	1 km from the export pipeline route
Paevera	640 m from the export pipeline route
Houses on the coast: a) Mareke, Iuku, Hururu, Larihairu, Mirimurua, Kavava and Kaivukavu b) Marea, Harevavo, Miha Kavava, Lariau, Oru, Hiloi and Herekela	a) Located within 2 km east and west of the export pipeline route. The closest villages are Iuku and Mareke, approximately 460 m and 300 m from the pipeline route, respectively, with approximately 10 houses within 350 m. b) Located within 5 km east and west of the export pipeline route

Table 15.1 – Identified Sensitive Human Receptors (cont'd)

Village	Separation Distance
Villages Located on Banks of Rivers Proposed for Barge Access	
Lower Purari River Route	***Ivo River Route (alternative if Lower Purari River Route cannot be used)***
Poroi 1 Mapaio Fish Camp Kaevaria Evara Aivai Aumu Apiope	Poroi 1 Mapaio Fish Camp Mapaio Kairu'u Akoma

15.1.1.2.2 Ecological Receptors

Project infrastructure will be surrounded by terrestrial ecological systems as described in Chapter 7. While a preliminary assessment of some ecological impacts is provided in this chapter, Chapter 11 describes the potential impacts resulting from a reduction in air quality due to construction and operational activities.

15.1.2 Discipline-specific Impact Assessment Method

The air quality impact assessment has been performed using a combination of quantitative and qualitative assessment techniques, as detailed in Part 2 of Volume 3 and summarized below.

The emissions to air from CPF operations were estimated based on design data and process modeling information. An atmospheric dispersion modeling study was performed to simulate the dispersion of these emissions downwind of the CPF, considering the local topography and meteorology, to estimate maximum ground-level concentrations at nearby sensitive receptors and to assess compliance against international air quality guidelines and standards. The method used in the air dispersion modeling study is outlined in Section 15.1.2.1, and the air quality criteria used to assess compliance are summarized in Section 15.1.2.2. The estimated emissions (i.e., in-stack pollutant concentrations) have also been assessed for compliance with emission limit values in relevant international air quality guideline documents, as summarized in Section 15.1.2.3.

Activities with a lower potential for impacts on local air quality have been assessed qualitatively. To assess the potential for impacts from construction dust, the Institute of Air Quality Management (IAQM) Guidance on the Assessment of Dust from Demolition and Construction (Holman et al., 2014) has been used to provide a risk-based approach to assess the potential for these activities to cause any non-compliances with relevant air quality criteria (see Section 15.1.2.4). For other potential emission sources, e.g., air emissions associated with barging, a qualitative assessment of potential air quality impacts has been performed based on the nature and scale of activities proposed, and the distance to sensitive receptors.

15.1.2.1 Air Dispersion Modeling Method

Details of the meteorological modeling method and the air dispersion modeling method used to assess potential off-site impacts from the CPF operations phase are provided in Part 19 of Volume 2 and Part 2 of Volume 3, respectively. The meteorological modeling method used the Weather Research and Forecasting Model and the US EPA–approved CALMET meteorological model, followed by dispersion modeling using the US EPA–approved CALPUFF model. The Weather Research and Forecasting, and CALMET models were used to compile a one-year, hourly meteorological data file based on the 2015 calendar year, suitable for use in the CALPUFF model.

The modeling was performed using a 15 km by 15 km modeling domain, centered over the CPF site. Four discrete receptors were included in the model to represent the existing Herd Base site and the nearest identified sensitive receptor locations in the surrounding area: Poroi 1, Mapaio Fish Camp and the house near the Purari Airstrip.

The operational scenarios selected for modeling were chosen to represent normal operations at different stages in the life of the Project as follows:

- High pressure (HP)/incineration: HP mode without acid gas injection, and no additional compression of product gas, with transport of the gas to the PNG LNG Plant by gravity.
- MP/low pressure (LP) and acid gas injection: Acid gas injection into Elk reservoir with additional gas compression for transport, and thermal oxidizer on standby.

The stack and emission data used in the modeling for this scenario were based on a pre-FEED design option of using a sulfur recovery unit to remove 95% of the hydrogen sulfide (H_2S) from the acid gas prior to incineration in the thermal oxidizer which would then convert the remaining 5% of the H_2S to SO_2 before emission to the atmosphere. The design for this phase of operations now being considered is the acid gases first being incinerated using a thermal oxidizer to convert all of the H_2S to SO_2, with the exhaust gases then undergoing treatment with a caustic soda wash to remove SO_2 from the flue gas prior to discharge to the atmosphere; however, various concepts are being investigated further as indicated in Chapter 5, Project Options and Analysis.

A revised design may change the exhaust gas flowrate and stack conditions (e.g., temperature, moisture content and exit velocity) compared to the values used in the modeling. The implications of these changes on the modeling results presented for this scenario are discussed in Section 15.1.5.

The pollutants modeled included oxides of nitrogen (i.e., NO_X, to predict off-site NO_2 concentrations), SO_2, CO and VOCs (i.e., benzene, toluene, ethylbenzene and xylenes (BTEX)); and the total estimated site emissions for each scenario are summarized in Table 15.2 Background concentrations of these pollutants were assumed to be negligible given the absence of any significant combustion or industrial sources in the region surrounding the CPF (see Section 15.1.1.1).

Table 15.2 – Total Site Emissions Used in the Dispersion Modeling Study for the CPF

Scenario	Total Site Mass Emission Rate (kg/hr)			
	NO_X	SO_2	CO	VOC
HP/incineration	115.7	35.7	16.6	27.3
MP/LP and acid gas injection	169.2	6.4	43.7	70.4

15.1.2.2 Ambient Air Quality Guidelines

The Conservation and Environment Protection Authority's (CEPA's) Technical Guideline (Additional Information) for Air Discharges (DEC, 2004) sets out the information that should be provided as part of an application for an environment permit to discharge waste, where air emissions may be generated. This includes:

- Details of the source, nature, composition and rate of air emissions.
- Information on emissions control equipment and proposed methods to minimize air discharges (specific information for fabric filters, afterburners and wet scrubbers is requested).
- Maintenance procedures and contingency procedures to avoid air discharges from process failure and shut down.

- Stack emission details.
- Calculated ground-level concentrations of pollutants proposed to be discharged to air under normal and maximum operating conditions, and start up and shutdown conditions.
- An assessment of the impact of the proposal on the environment.

Part 2 of Volume 3 presents the above information on the operations phase air emission sources at the CPF, as relevant. Emissions control equipment, proposed methods to minimize air discharges, and procedures to avoid air discharges from process failures and shut downs are discussed in Section 15.1.4.

Papua New Guinea does not currently have any statutory ambient air quality standards, nor are any specified in DEC (2004). A review of relevant air quality criteria and guidelines set by other agencies was therefore performed as part of the Upstream Air Quality Baseline Report (Part 19 of Volume 2), including (in order of priority):

- General Environmental, Health and Safety Guidelines (IFC, 2007a).
- Air quality guidelines (WHO, 2000, 2005; EU, 2010).
- National air quality standards (US EPA, 2016, 2017).
- Effects screening levels for individual VOC compounds (TCEQ, 2018).

Table 15.3 summarizes the ambient air quality criteria identified for the Project based on this review. The most stringent criteria have been used where multiple guidelines are available from different agencies. The TCEQ effective screening levels have been used for individual VOCs where standards are not available from other agencies.

Table 15.3 – Ambient Air Quality Criteria Used in this Assessment

Pollutants	Averaging Period	Limit (µg/m^3)	Source
NO_2	1-hour	200	IFC (2007), WHO (2005), EU (2010)
	Annual	40	IFC (2007), WHO (2005), EU (2010)
SO_2	10-minute	500	IFC (2007), WHO (2005)
	1-hour	200	US EPA (2016)
	24-hour	20	IFC (2007), WHO (2005)
CO	1-hour	30,000	WHO (2000), EU (2010)
	8-hour	10,000	EU (2010)
Benzene	1-hour	170	TCEQ (2018)
	Annual	4.5	TCEQ (2018)
Toluene	1-hour	4,500	TCEQ (2018)
	Annual	1,200	TCEQ (2018)
Ethylbenzene	1-hour	26,000	TCEQ (2018)
	Annual	570	TCEQ (2018)
Xylenes	1-hour	2,200	TCEQ (2018)
	Annual	180	TCEQ (2018)
TSP*	24-hour	150	US EPA (2017)
	Annual	60	US EPA (2017)
PM_{10}	24-hour	50	WHO (2005)
	Annual	20	WHO (2005)
$PM_{2.5}$	24-hour	25	WHO (2005)
	Annual	10	WHO (2005)

* Replaced by PM_{10} standards in 1987, included here to assess nuisance effects.

The United Nations Economic Commission for Europe has identified ’critical levels’ for various air pollutants to protect vegetation, with those for SO_2 listed in Table 15.4 (ICP, 2017). These European-based guidelines may have limited relevance to the types of vegetation and the growing conditions that exist in PRL-15 (i.e., warm temperatures and high rainfall), particularly given that SO_2 impacts on vegetation are exacerbated by cold temperatures (Ashmore et al., 2003); however, in the absence of local guidelines or data, they have been used to provide guidance on the potential for adverse impacts on vegetation due to SO_2 emissions from the Project.

Table 15.4 – Critical Levels for SO_2 by Vegetation Category

Vegetation Type	Critical SO_2 Level (µg/m^3)	Averaging Period
Cyanobacterial lichens	10	Annual mean
Forest ecosystems	20	Annual mean and half-year mean (Oct to Mar)
(Semi-) natural	20	Annual mean and half-year mean (Oct to Mar)
Agricultural crops	30	Annual mean and half-year mean (Oct to Mar)

15.1.2.3 Emission Limit Values

Papua New Guinea does not currently have any statutory stack emission limits, nor are any specified in DEC (2004). The in-stack pollutant concentrations reported in Part 2 of Volume 3 for the main emission sources at the CPF have therefore been compared to relevant emission limit values in the relevant IFC Environmental, Health and Safety guidelines (IFC, 2007a, 2008) and TOTAL’s general specification covering environmental requirements for exploration and production activities (TOTAL, 2015). The relevant emission limit values are shown in Tables 15.5 and 15.6 for the IFC and TOTAL, respectively.

Table 15.5 – Relevant IFC Emission Limit Values

Relevant Sources	IFC Plant Category	Emission Limit Value	Source
Heating boilers (3 x 40 MW)	Gas boilers >50 MWth	240 mg/Nm^3 * NO_X *Dry, 3% O_2, 273 K, 101.3 kPa*	IFC (2008)
Power gas turbines (4 x 23 MW) Medium-pressure compressors (5 x 23 MW)	Turbine burning natural gas, 15 to 50 MWth	25 ppm # NO_X *Dry, 15% O_2*	IFC (2007a)

Notes: * Equivalent to 118 ppm. # Equivalent to 51 mg/Nm^3 at 273 K, 101.3 kPa.

Table 15.6 – Relevant TOTAL Emission Limit Values

Source	TOTAL Plant Category	Emission Limit Value	Source
Power gas turbines (4 x 23 MW) Medium-pressure compressors (5 x 23 MW)	Used for power generation or mechanical drive purposes (capacity unspecified)	37 ppm/75 mg/Nm^3 NO_X *Dry, 273 K, 101.3 kPa, 15% O_2*	TOTAL (2011)

15.1.2.4 Construction Dust Impact Assessment Method

Constructing the access roads, laydown areas, wellpads, the Purari Airstrip extension, quarries, CPF, Logistics Base and pipelines will generate fugitive dust emissions, which have the potential to cause elevated TSP concentrations and dust deposition rates near the works.

Due to the high rainfall and dense vegetation present in the onshore Project area, published fugitive dust (i.e., TSP) emission factors are unlikely to be representative of the dust emissions from construction activities in Papua New Guinea. In addition, dust emission modeling of construction projects is generally inappropriate, as emission rates can vary depending on a combination of the construction activity and prevailing meteorological conditions (e.g., rainfall and wind speed), which cannot be reliably predicted.

For this assessment, IAQM Guidance on the Assessment of Dust from Demolition and Construction (Holman et al., 2014) has been used to provide a qualitative approach to assessing the potential for these activities to cause non-compliances with relevant air quality criteria for particulate matter. The IAQM method has been developed for an urbanized environment and has limitations in its applicability to a remote undeveloped location, such as the onshore Project area; however, it is anticipated to provide a conservative assessment of the potential risks and is the method adopted in other PNG air quality impact assessments (e.g., construction phase assessments for the PNG Biomass Project and the Wafi-Golpu Project).

The IAQM method (Holman et al., 2014) uses a four-step process for assessing dust impacts from construction activities and is based on distance to the nearest sensitive receptor, whereby the sensitivity to dust deposition of, and human health and ecological impacts to, the identified sensitive receptors are determined. The risk of dust effects from activities is assessed by considering the sensitivity of the area, surrounding dust-generating activities, and the scale and nature of the works, which determines the potential dust emission magnitude. The required level of mitigation can then be identified based on the potential risk of off-site impacts.

The detailed assessment is presented in Part 2 of Volume 3 and takes into account:

- The specific sensitivities that identified sensitive receptors have to dust deposition and human health impacts.
- The proximity and number of those receptors.
- In the case of PM_{10}, the local background concentration.
- Other site-specific factors, such as whether natural shelters, e.g., trees, are present, to reduce the risk of wind-blown dust.

15.1.3 Identification of Potential Impacts

Proposed Project activities with the greatest potential for adverse off-site air quality impacts, i.e., decline in human health, amenity or vegetation condition, at the nearest sensitive receptors, have been assessed as part of this study. Potential human health, amenity or vegetation impacts include:

- Human health impacts, where:
  - Finer inhalable particulate matter (i.e., PM_{10} and $PM_{2.5}$), which is associated more with fuel combustion processes, are small enough to penetrate the thoracic region of the respiratory system. The health effects of inhalable particulate matter include the aggravation of asthma and other respiratory symptoms, and an increased incidence of cardiovascular and respiratory diseases and lung cancer.
  - Emissions of NOX, CO, and SO2 from the combustion of fuel gas and diesel can adversely impact human health by irritating the airways of the lungs, also aggravating asthma and other existing respiratory illnesses, and increasing the incidence of acute respiratory illness in children.
  - Chronic long-term exposure to elevated concentrations of VOCs, can adversely impact human health including cancer, central nervous system disorders, liver and kidney damage, reproductive disorders and birth defects. Many VOCs are also highly odorous and can adversely impact on amenity values due to odor nuisance.
- Amenity impacts: Nuisance impacts due to the larger-sized particles of fugitive dust settling rapidly, close to the source, and soiling of surfaces in and around properties.

- Vegetation impacts: Larger-sized particles of fugitive dust settling into leaves, blocking sunlight and disrupting photosynthesis, and acid rain (see Section 11.6.3.3), thereby damaging nearby vegetation.

Construction Phase

Earthworks and Fugitive Dust from Construction

- Construction of the CPF, Logistics Base and the Purari Airstrip extension: Clearing, earthworks and construction activities that have the potential to emit dust (i.e., TSP and PM_{10} predominantly, with small amounts of $PM_{2.5}$) from operation of vehicles, machinery and equipment movement will occur at these sites for an extended period. These emissions have been assessed for their potential to cause adverse human health, amenity and vegetation impacts.

  Construction of the onshore export pipeline and access roads, including the pipeline shore crossing at Orokolo Bay, which is close to coastal settlements: Clearing, earthworks and construction activities have the potential to emit dust (TSP and PM_{10} predominantly, with small amounts of $PM_{2.5}$) from operation of vehicles, machinery and equipment movement as activity progresses along the pipeline route and road alignments. These emissions have been assessed for their potential adverse human health, amenity and vegetation impacts.

River Transport

- Marine and river transport: Potential adverse human health impacts associated with exhaust emissions (e.g., NO_X, CO, SO_2, PM_{10} and $PM_{2.5}$, and VOCs) from fuel consumption have been assessed from the barges along the marine and river transport routes, focusing on the construction phase as a worst case, given that the barging frequency will be lower during the operations phase. As of 1 January 2020, TEP PNG will require vessels to burn fuel with a sulfur content of no more than 0.5%. This is consistent with TOTAL's commitment to meet the International Marine Organization's new regulation that comes into effect on that date for a 0.5% global sulfur cap for marine fuels

Road Use

- Road transport: Potential adverse human health impacts associated with engine emissions (e.g., NO_X, CO, SO_2, PM_{10} and $PM_{2.5}$, and VOCs) from fuel consumption during road use for the construction phase. This includes light and heavy vehicle movements between the main Project facilities (e.g., the CPF, the Logistics Base, Herd Base and the wellpads), and the transport and disposal of excess spoil.

Aircraft Transport

- Air transport: Potential adverse human health impacts associated with aircraft engine emissions (e.g., NO_X, CO, SO_2, PM_{10} and $PM_{2.5}$, and VOCs) from fuel consumption, with the construction phase as a worst case, given that the flight frequency will be lower during the operations phase.

Quarry Operations

- Quarry operations: Potential adverse human health, amenity and vegetation impacts associated with fugitive dust emissions and from blasting.

Waste Disposal

- Waste disposal: Potential adverse human health impacts associated with combustion emissions (e.g., NO_X, CO, SO_2, PM_{10} and $PM_{2.5,}$ and VOCs, and traces of heavy metals, acid gases, dioxins and furans) from the proposed waste incinerator.

Operations Phase

- CPF operations: Air emissions from gas processing and fuel gas combustion at the CPF. The key pollutants requiring assessment due to potential adverse human health impacts are NO_X, CO, SO_2 and VOCs.
- CPF operations: Sulfur dioxide emissions from the acid gas removal unit. Potential adverse vegetation and fauna impacts from acid rain or acidification associated with SO_2 emissions from the CPF.

A number of embedded design controls address impacts to air quality:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- The Project will design its plant to meet the applicable emission standards and relevant ambient air quality criteria beyond the proposed facility boundary [ED002].
- During the first years of production when it is not possible to dispose of acid gas by injection, a sulfur recovery unit will be installed and operated at the CPF to remove sulfur-containing compounds from the acid gas after it has passed through a thermal oxidizer [ED024].
- Once the Elk reservoir has been depleted, acid gas removed from the raw gas using the AGRU will be disposed of by injecting it into the reservoir [ED025].
- The sulfur recovery unit will remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible [ED026].
- All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer’s specifications; defective items will be removed from service until they are repaired [ED019].
- Fixed or mobile equipment will be used and/or located in consideration of people and other sensitive receptors [ED030].
- Vessels will comply with applicable IMO requirements related to fuel to minimize related atmospheric emissions [ED001].
- The flares will be used only for safety flaring in alignment with the TOTAL no routine flaring policy [ED023].
- The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

The following identified potential air emissions are inherently addressed by the above embedded design controls or have been concluded to be negligible, with no significant potential for adverse off-site air quality impacts, and therefore have not been considered further in the assessment:

- Fuel combustion in construction equipment: NO_X, CO and SO_2 emissions from fuel combustion in construction vehicles, and other mobile and fixed equipment at construction sites and quarries will occur over relatively large areas and will rapidly disperse. They therefore do not have potential to give rise to any exceedances of the ambient concentrations off-site and would not adversely impact air quality at the nearest sensitive receptors.
- Emissions from wellpad and trunkline/flowline construction:
  - Dust from wellpad construction: ANT-10 is a new wellpad, but the ELK-10 and ANT-11 wellpads will be established on the existing Elk-1 and ANT-1 wellpads that were developed during the exploration and appraisal phases. Consequently, site preparation works will be of a smaller scale than if three new wellpads were required to be developed. The scale of the works is such that it is unlikely that dust would have an adverse impact beyond a hundred meters from the work area and there would be no impact at the nearest human receptors, which are much further away (14.5 km for ELK-10).
  - Dust emissions from trunkline/flowline construction: Clearing, earthworks and construction activities have the potential to emit dust (i.e., TSP and PM_{10} predominantly, with small amounts of $PM_{2.5}$) from operation of vehicles, machinery and equipment movement along the pipeline routes; however, approximately 77%, 35% and 68% of the Antelope trunkline, Elk flowline and water injection flowline follow existing tracks, respectively, reducing the land disturbance and hence earthworks required. Additionally, the area is surrounded by dense forest that would minimize dust dispersion.
  - Exhaust emissions from diesel-powered equipment, in particular, from diesel generators that will predominantly be used to power the drilling rig: A screening assessment of emissions from similar diesel generators proposed for the drilling operations at the PNG LNG Project operation indicated that the predicted downwind NO_2, CO, VOCs, PM_{10} and $PM_{2.5}$ concentrations were all below their respective assessment criteria (HAS, 2009). This screening assessment showed that, considering a release height of 7 m above ground, and an exit velocity of 20 m/s, air quality assessment criteria will not be exceeded.
  - On this basis, and given that the wellpads, trunkline and flowlines will be located more than 14 km from the nearest sensitive receptors, it is concluded that constructing the wellpads and trunkline/flowlines will not adversely impact air quality at the nearest sensitive receptors.
- Emissions from burning vegetation: Potential adverse human health effects or nuisance effects can occur due to particulates in smoke from open burning. Vegetation cleared for Project facilities will be used to stabilize earthworks and areas requiring rehabilitation. Small trees will be mulched. TEP PNG will avoid burning as far as practicable. By implementing these mitigation measures, TEP PNG does not expect emissions from burning vegetation to have any potential for impacts on air quality at the nearest sensitive receptors.
- Emissions from wellpad operations: Emissions from the wellpads during operations will consist predominantly of intermittent methane and VOC emissions associated with maintenance and inspection operations such as pig launching and retrieval. Dispersion

modeling undertaken for the Hides Gas Conditioning Plant study (URS, 2011) included emissions of VOCs from wellpads, and the results of this modeling did not predict any exceedances of relevant assessment criteria (URS, 2011). Given that the wellpads will be located more than 14 km from the nearest sensitive receptors, it is concluded that operations activities at the wellpads will not have the potential for impacts on air quality at the nearest sensitive receptors.

- Emissions from construction of the offshore export pipeline and pipeline landfall approach at Caution Bay: Emissions of NO_X, CO and SO_2 associated with fuel combustion in the vessels used during construction of the offshore export pipeline will occur over relatively large areas and will rapidly disperse. Except for works near the coastline, which will only occur for a limited duration, these emissions will occur at significant distances from any sensitive receptors. They therefore do not have the potential to adversely impact on air quality at the nearest sensitive receptors. Pipeline landfall approach construction activities at Caution Bay, covered by this assessment, are limited to works up to the PNG LNG lease boundary. These activities are expected to include some trenching and probably rock armoring; however, the works will be in the water and would not have any potential for significant air emissions.
- Fugitive VOC emissions from CPF operations: The fugitive nature of VOC emissions from the CPF means the quantification and characterization of these emissions for input into an air dispersion model is uncertain. In addition, dispersion modeling undertaken for the Hides Gas Conditioning Plant included estimated emissions of fugitive VOCs and concluded that they did not have the potential to exceed relevant screening-level assessment criteria at the nearest sensitive receptors (URS, 2011). The quantity and composition of non-methane fugitive VOC emissions from the CPF will differ to some extent from those estimated for the Hides Gas Conditioning Plant due to different gas compositions and different numbers of connectors and valves at the two plants; however, no adverse air quality impacts from these emissions would be anticipated on or off site. Given that flares will be used to combust any major gas releases from the facility in the event of upset operating conditions, VOC emissions from the CPF operations are not anticipated to have the potential for impacts on air quality at the nearest sensitive receptors and have not been considered further.
- Emissions from road, river and air transport activities during operations: The number of transport movements by barge, road and air during the Project's operations phase will be lower than during the construction phase; therefore, emissions to air from operations phase transport will be much lower than construction phase transport which will represent the worst case scenario in relation to emissions from transport activities for the Project.
- Other potential emissions: Emissions to air of VOCs from the storage and transfer of fuels, odor and dust from landfilling activities, odor from sewage treatment facilities and dust, VOCs and products of fuel combustion from workshops are expected to be minor due to the scale and nature of the activities, the small volumes or areas involved, and the distances to the nearest sensitive receptors and have not been considered further.
- Emissions associated with decommissioning activities have also not been considered further, given the uncertainty regarding the nature and scale of activities likely to be undertaken.

Emissions of CO_2 and other greenhouse gases are addressed separately in Section 15.2.

15.1.4 Proposed Mitigation and Management Measures

Table 15.7 describes proposed mitigation to be implemented to further reduce impacts to air quality.

Table 15.7 – Air Quality Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plans
Adverse human health, nuisance effects and vegetation effects due to fugitive dust from construction activities, quarry operations, and roads.	♦ Implement dust control, where required [EM041]. ♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape, e.g., – Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g., rip the substrate, replace topsoil, apply mulch. – Rehabilitate Pandanus habitats, e.g., recreate mounds, re-instate the intertidal surface between Pandanus mounds. – Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion. – Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration. – Use native vegetation to revegetate sites when active rehabilitation measures are required [EM029].	Air Emissions and GHG Management Plan
Adverse human health and nuisance effects due to fuel combustion emissions from operation of vehicles, machinery, fixed and mobile plant and equipment, and marine, river and air transport.	♦ Use low sulfur fuel, as far as practicable [EM042].	Air Emissions and GHG Management Plan
Adverse human health effects from combustion emissions of air pollutants associated with waste incineration.	♦ Waste incineration shall: – Use appropriately designed incinerators commensurate with proposed inventory. – Be considered for waste that will effectively combust. – Be operated within the required specification and by competent personnel [EM043].	Air Emissions and GHG Management Plan; Waste Management Plan
Adverse human health and vegetation effects from air emissions at the CPF.	No additional mitigations measures are proposed.	Air Emissions and GHG Management Plan
Community complaints associated with actual or perceived air quality effects from construction or operations.	No additional mitigations measures are proposed.	Air Emissions and GHG Management Plan; Stakeholder Engagement Plan

15.1.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to air quality subject to the embedded design controls in Section 15.1.3 and the successful implementation of the mitigation and management measures in Section 15.1.4. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

15.1.5.1 Construction Phase

As outlined in Section 15.1.3, the construction phase activities identified as requiring assessment are:

- Earthworks and fugitive dust emissions from constructing the CPF, Logistics Base, terrestrial pipelines (including the shore crossing area at Orokolo Bay), access roads and Purari Airstrip extension.
- River transport.
- Road use including spoil disposal.
- Aircraft transport.
- Quarry operations.
- Waste disposal.

The potential air quality impacts associated with each of these activities are discussed in the following sections.

Earthworks and Fugitive Dust from Construction

The screening and assessment of dust emission magnitude was undertaken as per steps 1, 2a and 2b of the IAQM guidance, and is detailed in Part 2 of Volume 3. Based on the area sensitivities and dust emission magnitudes, the resulting risk of air quality impacts from fugitive dust has been derived for each construction activity using the impact matrix in Part 2 of Volume 3, the results of which are presented in Table 15.8. As per the IAQM guidance, the risk of air quality impacts assumes no mitigation is applied, to identify what level of control may be required to mitigate potential off-site impacts.

Based on the risk categories derived using the IAQM method, it is concluded that there is a ***Negligible*** or ***Low*** risk of human health or dust nuisance impacts associated with the earthworks and construction activities proposed as part of the Project, even if no dust mitigation measures were to be implemented. This is due to the separation distances between the worksites and the nearest inhabited areas (see Section 5.2.1 of Part 2 of Volume 3).

The risks of any potential ecological impacts are also concluded to be ***Low***, even if no dust mitigation measures were to be implemented, except for the pipeline and access road earthworks and for the Purari Airstrip extension earthworks and construction activities, which are indicated to have a medium risk of impacts. The implementation of dust controls during construction will reduce the risks of any off-site ecological impacts occurring to ***Low*** for all Project components; however, the above assessment indicates that particular care should be taken to reduce dust emissions during the pipeline and access road earthworks, and the Purari Airstrip extension earthworks and construction. Any residual impacts for the road and pipeline alignments would be highly localized to the area immediately adjacent to these activities and will move along as the works progress. For the airstrip, vegetation clearing will be maintained for safety reasons.

Table 15.8 – Assessment of Potential Fugitive Dust Impacts from Construction Prior to Mitigation

Value	Construction Activity	Sensitivity of the Area	Magnitude of Dust Emissions		Risk of Air Quality impacts	
			Earthworks	Construction	Earthworks	Construction
Dust soiling Human heath	CPF site	Low	Large	Large	Low	Low
	Logistics Base	Low	Large	Large	Low	Low
	Export pipeline route	Low	Medium	Small	Low	Negligible
	Export pipeline shore crossing site at Orokolo Bay	Low	Medium	Small	Low	Negligible
	Access roads	Low	Medium	-	Low	-
	Purari Airstrip extension	Low	Large	Medium	Low	Low
Ecology	CPF site	Low	Large	Large	Low	Low
	Logistics Base	Low	Large	Large	Low	Low
	Export pipeline route	Medium	Medium	Small	Medium	Low
	Export pipeline landfall site at Orokolo Bay	Low	Medium	Small	Low	Negligible
	Access roads	Medium	Medium	-	Medium	-
	Purari Airstrip extension	Medium	Large	Medium	Medium	Medium

Note: While pre-mitigation risk assessment is not generally applied in this EIS, an exception is made in this instance due to application of the IAQM method.

River Transport

Section 4.9.2.1 summarizes the anticipated frequency of barging movements during the Project's construction phase. Six barges per day are likely to pass villages along the river transport corridors during the first year of construction, accounting for up-river and down-river movements for each barge delivery. During the second year, this may increase to eight passes per day depending on timing of the weekly supply barges. The number of daily passes will progressively decrease over the remainder of the construction period.

Air emissions from the barge engines will occur near the center of the river while the barge is in transit, and each barge will be near each village for only a short time as it travels past. Given the low number of passes, the potential for these emissions to cause a decline in the health of local people is negligible.

The Logistics Base and Herd Base are located more than 2 km from the nearest village, which is Poroi 1 (see Table 15.1). Air emissions from the barges and cargo handling equipment have no potential to cause a decline in the health of local people at these distances. The family resident in the house at the Purari Airstrip will be near the unloading area for the barges delivering aggregate from Herd Base to the airstrip construction site during the second year of construction; however, these activities will only occur for four months. The number of daily vessel movements is minimal and air quality criteria in the surrounding area would not be exceeded.

Road Use

Once constructed, light and heavy vehicle movements on access roads between the CPF, Logistics Base, wellpads and Herd Base will emit wheel-generated dust and exhaust fumes.

These emissions will peak during the construction phase and will occur to a much lesser extent during the operations phase.

If the road surface is highly erodible, nuisance dust impacts may occur in the areas immediately adjacent to the road in dry conditions; however, given the high rainfall in the region which will act to suppress dust emissions, the potential for impacts due to construction traffic will be minimal.

As noted in Table 15.1, no human receptors are located within 350 m of the access roads associated with the Project. Poroi 1, the nearest sensitive receptor, is located more than 2 km from any Project road. At this distance, dust and exhaust fumes from vehicle movements have no potential to give rise to adverse health impacts.

Aircraft Transport

The number of aircraft movements from Port Moresby to Purari Airstrip during construction is anticipated to be between five to seven flights per day (ATR42, Twin Otter or Dash 8 type aircraft). The low flight frequency means that these activities are unlikely to exceed ambient air quality criteria at the nearest sensitive receptor (i.e., the house approximately 200 m northwest of the northern end of the runway), and they have not been considered further.

Quarry Operations

The quarries that the Project shall use are described in Section 4.8.4 and shown in Figure 4.11. All of these quarries are more than 4 km from the identified sensitive human receptors and would therefore not have any potential for adverse impacts on air quality at these distances.

Waste Disposal

A new high-temperature waste incinerator will be installed and operated at the general waste landfill site, approximately 245 m west of the operations accommodation camp, for the disposal of solid waste generated during the Project’s construction, operations and decommissioning phases. This incinerator is likely to be a multi-chamber incinerator designed to destroy a wide variety of wet and dry waste materials. These types of incinerators are designed to maintain a secondary chamber operating temperature of not less than 1,000ºC with a secondary chamber gas retention time of not less than one second so that VOCs are destroyed and to meet international air emissions standards for dioxin and furan destruction.

The incinerator’s size and the proposed waste volumes to be incinerated are unknown at this stage. Air dispersion modeling studies for waste incinerators for similar projects have shown that air pollutant concentrations at sensitive receptors at a separation distance of 150 m would be well below the relevant ambient air quality criteria. The Poroi 1 community is the closest sensitive receptor to the proposed incinerator and is more than 3.5 km away. The operations accommodation camp is also beyond this separation distance.

Waste management procedures will be implemented so that the appropriate waste streams are disposed of in the incinerator and that personnel are appropriately trained to operate the unit.

Based on the above, it is concluded that there is no risk of air quality impacts due to emissions from the incinerator, provided it is operated in accordance with the manufacturer’s instructions.

15.1.5.2 Operations Phase

As outlined in Section 15.1.4, the only operations phase activity identified as requiring assessment is air emissions from the CPF. All other operational activities (i.e., barging, aircraft movements, vehicle movements, waste incineration) will have lower impacts in the operations phase than in the construction phase. As no significant off-site impacts were identified for these activities during the construction phase, they have not been considered.

The results of the modeling undertaken in Part 2 of Volume 2 are presented in Tables 15.9 (HP/incineration) and 15.10 (MP/LP and acid gas injection). Results are presented for the three nearest sensitive human receptors identified near the CPF site and as predicted 'maximum off-site' concentrations. These maximum off-site concentrations have been extracted from the model output files based on the area proposed to be cleared as part of CPF construction (see facility boundary in Figure 15.1 and 15.2). They are therefore considered to be worst-case estimates of maximum off-site concentrations, as the boundary of an exclusion zone will be further away from the sources than assumed in the modeling.

Table 15.9 – Modeling Results – HP/Incineration

Pollutant	Averaging Period	Maximum Predicted Ground-level Concentrations* (μg/m³)					Ambient Air Quality Criteria (μg/m³)
		Poroi 1	Mapaio Fish Camp	Herd Base	Purari Airstrip House	Maximum Off-site	
NO_2	1-hour	44.7	13.6	27.3	22.8	109.6	**200**
	Annual	0.3	0.1	0.6	0.2	5.9	**40**
SO_2	10-minute	13.1	1.9	9.6	8.4	47.5	**500**
	1-hour	9.2	1.4	6.7	5.9	33.2	**200**
	24-hour	0.6	0.1	0.5	0.5	4.7	**20**
CO	1-hour	9.0	2.9	5.9	3.7	62.3	**30,000**
	8-hour	2.6	1.1	1.0	1.0	18.2	**10,000**
Benzene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**170**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**4.5**
Toluene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**4,500**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**1,200**
Xylene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**26,000**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**570**
Ethylbenzene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**2,200**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**180**

< = less than.
* Based on the following stack heights: 20 m for the power gas turbine and medium-pressure compressor stacks, 40 m for the heating boiler stacks and 50 m for the thermal oxidizer stack.

Table 15.10 – Modeling Results – MP/LP and Acid Gas Injection

Pollutant	Averaging Period	Maximum Predicted Ground-level Concentrations* ($\mu g/m^3$)					Ambient Air Quality Criteria ($\mu g/m^3$)
		Poroi 1	Mapaio Fish Camp	Herd Base	Purari Airstrip House	Maximum Off-site	
NO_2	1-hour	50.1	26.8	55.4	35.6	129.3	**200**
	Annual	0.6	0.1	1.0	0.3	15.5	**40**
SO_2	10-minute	4.7	1.5	3.4	2.7	33.8	**500**
	1-hour	3.3	1.0	2.4	1.9	23.6	**200**
	24-hour	0.4	0.1	0.2	0.2	3.4	**20**
CO	1-hour	11.9	6.9	16.2	8.7	123.7	**30,000**
	8-hour	3.7	2.9	3.2	2.5	57.9	**10,000**
Benzene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**170**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**4.5**
Toluene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**4,500**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**1,200**
Xylene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**26,000**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**570**
Ethylbenzene	1-hour	<0.1	<0.1	<0.1	<0.1	<0.1	**2,200**
	Annual	<0.1	<0.1	<0.1	<0.1	<0.1	**180**

< = less than.
* Based on the following stack heights: 20 m for the power gas turbine and medium-pressure compressor stacks, 40 m for the heating boiler stacks and 50 m for the thermal oxidizer stack.

Tables 15.8 and 15.9 show that for both operational scenarios assessed, the maximum ground-level NO_2, SO_2 and CO concentrations predicted at the sensitive receptors are well below the relevant ambient air quality criteria. Concentrations predicted at all off-site locations are also well below the relevant ambient air quality criteria. The maximum predicted ground-level VOC concentrations are negligible compared to the relative ambient air quality criteria. These results indicate the proposed CPF operations are expected to meet the applicable ambient air quality criteria under normal operating conditions.

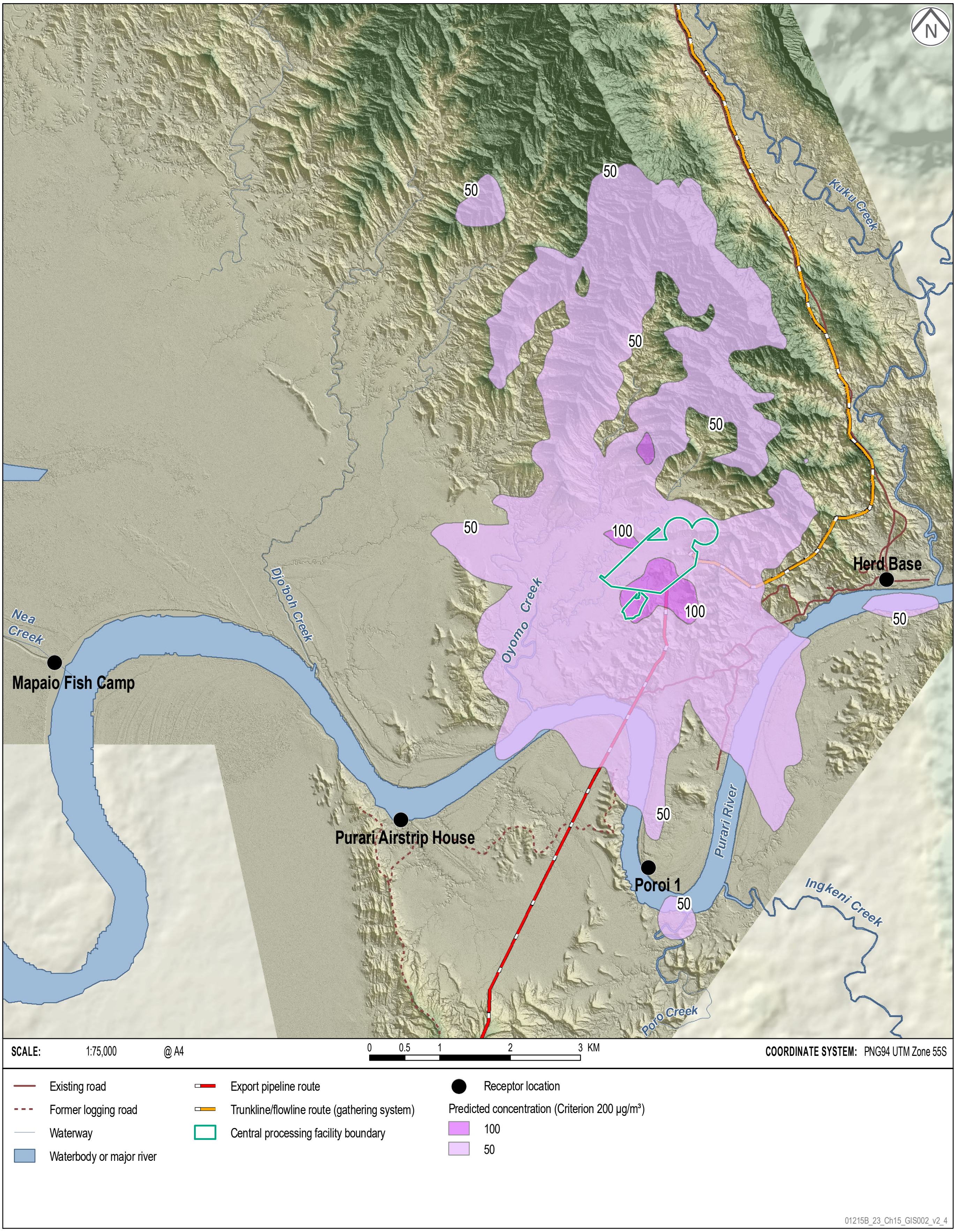
Contour plots showing the maximum ground level concentrations predicted across the modeling domain are presented in Part 2 of Volume 3. As shown in Figures 15.1 and 15.2, the maximum predicted short-term (1-hour average) SO_2 and NO_2 contours when acid gas is being recovered and discharged (after treatment to minimize SO_2 in the exhaust gases). The maximum concentrations are well below the air quality criteria.

As discussed in Section 15.1.2, the stack and emission data used in the modeling for the HP/incineration scenario were based on a pre-FEED design option that is being revised.

The SO_2 emission rate and stack conditions may increase ground level concentrations from those predicted by the modeling; however, the maximum ground level SO_2 concentrations predicted by the modeling at the sensitive receptor locations were very low, at less than 5% of the relevant ambient air quality criteria, while the maximum off-site ground level SO_2 concentrations predicted by the modeling were less than 25% of the relevant ambient air quality criteria. Given this, while the predicted ground level concentrations for the revised base case may increase due to the changed stack parameters for the thermal oxidizer, they may not approach or exceed the associated criteria at the receptor locations.

MAXIMUM PREDICTED 1-HOUR AVERAGE NO_2 CONCENTRATIONS - YEARS 1 TO 4 NORMAL OPERATIONS

FIGURE 15.1



MAXIMUM PREDICTED 1-HOUR AVERAGE SO_2 CONCENTRATIONS - YEARS 1 TO 4 NORMAL OPERATIONS

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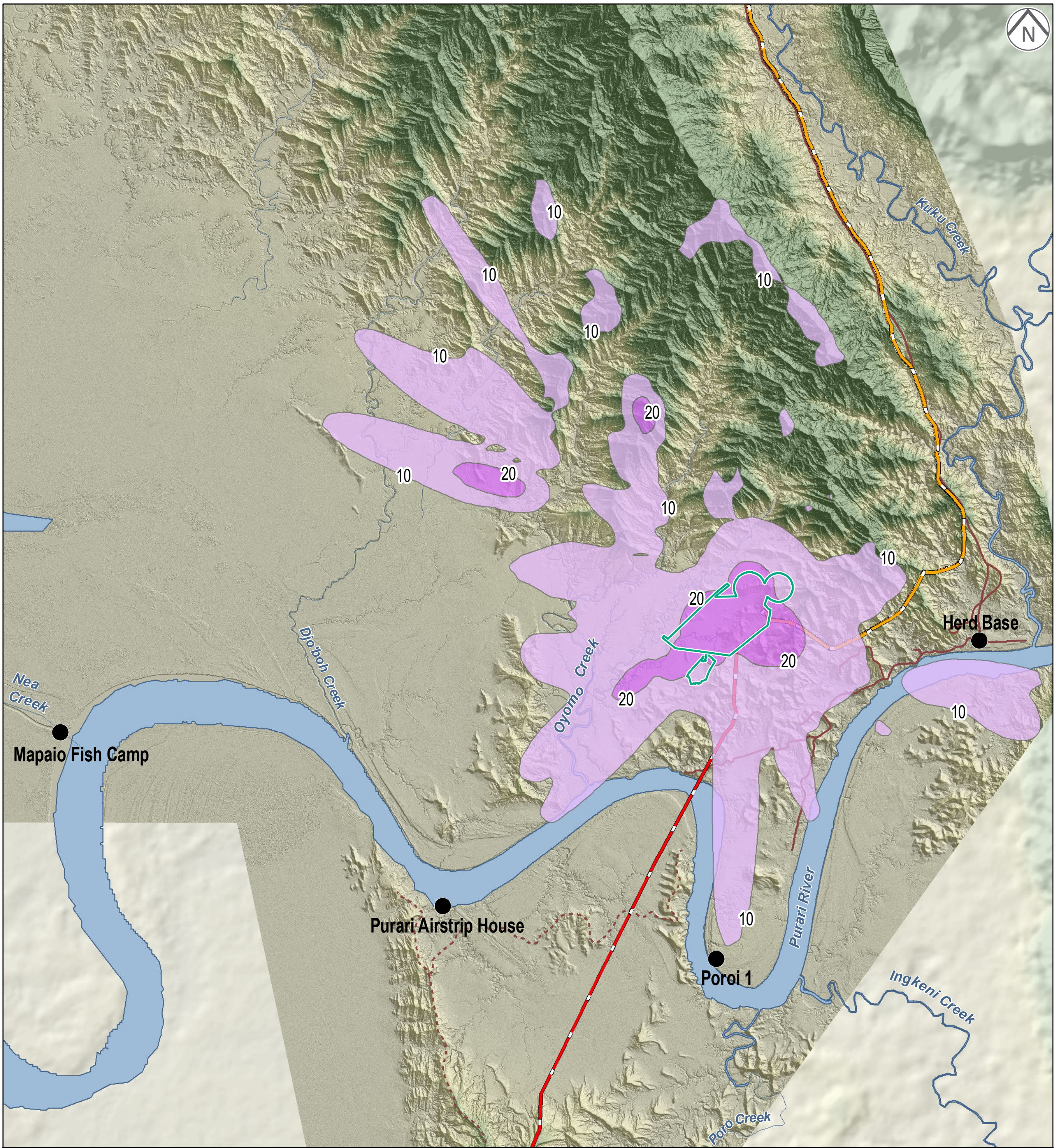
FIGURE 15.2



SCALE: 1:75,000 @ A4

0 0.5 1 2 3 KM

COORDINATE SYSTEM: PNG94 UTM Zone 55S

- Existing road
- Former logging road
- Waterway
- Waterbody or major river
- Export pipeline route
- Trunkline/flowline route (gathering system)
- Central processing facility boundary
- Receptor location

Predicted concentration (Criterion 200 μg/m³)

- 20
- 10

01215B_23_Ch15_GIS001_v2_4

A comparison of the in-stack pollutant concentrations used in the modeling study against the relevant emission limit values for each equipment type (see Section 15.1.2.3) shows:

- The proposed in-stack NO_X concentration of 50 ppm (dry gas basis, 15% O_2) for the power gas turbines:
  - Exceeds the IFC emission limit value of 25 ppm for turbines burning natural gas, 15 to 50 MW (IFC, 2007a).
  - Exceeds the GS EP ENV 001 emission limit value of 37 ppm for gas combustion used for power generation or mechanical drive purposes (TOTAL, 2011).
- The proposed in-stack NO_X concentration of 118 ppm (dry gas basis, 3% O_2) for the heating boilers complies with the IFC thermal power plants' emission limit value of 118 ppm for gas boilers >50 MWth (IFC, 2008).
- The proposed in-stack NO_X concentration of 50 ppm (dry gas basis, 15% O_2) for the medium-pressure compressors:
  - Exceeds the IFC emission limit value of 25 ppm for turbines burning natural gas, 15 to 50 MW (IFC, 2007a).
  - Exceeds the GS EP ENV 001 emission limit value of 37 ppm for gas combustion used for power generation or mechanical drive purposes (TOTAL, 2011).

While the NO_X emission concentrations proposed for the power gas turbines and the medium-pressure compressors exceed IFC and TOTAL emission limit values, the air dispersion modeling in Tables 15.8 and 15.9 shows that the stack heights used in the modeling for the CPF are sufficient to disperse these emissions to levels below the relevant ambient air quality criteria at all locations beyond the site boundary. No adverse off-site air quality impacts are therefore anticipated due to the emission concentrations.

In addition to human health impacts, air emissions from the CPF operations may adversely impact on the surrounding vegetation. The pollutant emitted from the CPF most likely to cause damage to vegetation is SO_2. At high concentrations, SO_2 can can produce acute injury in plants in the form of foliar necrosis even after relatively short duration exposure. Long-term exposure of plants to much lower concentrations of SO_2 can cause chronic injury, taking the form of reduced growth and yield, often with no clear visible symptoms or else with some degree of yellowing of the leaves. Different plant species and varieties, and even individuals of the same species may vary considerably in their sensitivity to SO_2.

The air dispersion modeling performed as part of this assessment predicted that maximum 24-hour average SO_2 concentrations beyond the site boundary would be less than 5 µg/m^3. It can be concluded that annual average off-site SO_2 concentrations will be far below the ICP (2017) guidelines for adverse impacts on vegetation and forest ecosystems of 20 µg/m^3. No adverse impacts on vegetation would therefore be anticipated due to SO_2 emissions from the CPF.

15.1.5.3 Summary of Predicted Impacts

A summary of the assessment of residual impacts related to air quality is provided in Table 15.11, including in which Project phase and location these impacts are expected to occur.

Table 15.11 – Summary of Compliance and Qualitative Assessment for Air Quality

Potential Impact	Location of Activity	Project Phase	Compliance Assessment
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction activities at the CPF.	PRL-15 (CPF)	Construction	The CPF is located more than 3.9 km from the nearest sensitive human receptor. Based on the assessment in Table 15.8, maximum ground-level suspended and deposited particulate levels would comply with relevant nuisance and health-based air quality criteria at this distance. Any impacts on vegetation from dust deposition will be limited to the immediate area and will be temporary in nature.
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction activities at the Logistics Base.	PRL-15 (Logistics Base)	Construction	The Logistics Base is located more than 2.6 km from the nearest sensitive human receptor. Based on the assessment in Table 15.8, maximum ground-level suspended and deposited particulate levels would comply with relevant nuisance and health-based air quality criteria at this distance. Any impacts on vegetation from dust deposition will be limited to the immediate area and will be temporary in nature.
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction of the export pipeline.	Onshore export pipeline	Construction	Aivai is the nearest sensitive human receptor to the pipeline construction activities (260 m away). Based on the number of receptors and the scale of the proposed activities, the risk of any adverse human health or nuisance impacts associated with fugitive dust emissions is concluded to be low even if no mitigation measures were implemented. Any impacts on vegetation from dust deposition will be limited to the immediate area and will be temporary in nature.
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction of the export pipeline shore crossing site at Orokolo Bay.	Export pipeline shore crossing Orokolo Bay	Construction	The nearest houses to the shore crossing construction activities are approximately 340 m away. Based on the number of receptors and the scale of the proposed activities, the risk of any adverse human health or nuisance impacts associated with fugitive dust emissions is concluded to be low even if no mitigation measures were implemented. Potential impacts on vegetation from dust deposition are concluded to be negligible.
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction of the access roads.	PRL-15 (access roads)	Construction	Access roads are located more than 2 km from the nearest sensitive human receptor. Based on the assessment in Table 15.8, maximum ground-level suspended and deposited particulate levels would comply with relevant nuisance and health-based air quality criteria at this distance. Any impacts on vegetation from dust deposition will be limited to the immediate area and will be temporary in nature.
Adverse human health, nuisance or vegetation effects due to fugitive dust emissions from construction of the Purari Airstrip extension.	Purari Airstrip	Construction	A single house is located approximately 85 m from the Purari Airstrip extension. Based on the number of receptors and the scale of the proposed activities, the risk of any adverse human health or nuisance impacts associated with fugitive dust emissions is concluded to be low. Any impacts on vegetation from dust deposition will be limited to the immediate area and will be temporary in nature.

Table 15.11 – Summary of Compliance and Qualitative Assessment for Air Quality (cont'd)

Potential Impact	Location of Activity	Project Phase	Compliance Assessment
Adverse human health and nuisance effects due to fuel combustion emissions from marine and river transport and during unloading.	Marine route and riverways	Construction, operations and decommissioning	The low frequency of barge movements means that there is no potential for air quality impacts at the villages on the banks of the rivers. The Logistics Base and Herd Base are located more than 2 km from the nearest sensitive human receptors, and air emissions from barges and cargo handling equipment are unlikely to adversely impact on air quality at these distances. Barging of aggregate from Herd Base to the airstrip construction site also would not potentially exceed air quality criteria at the Purari Airstrip House. There are no sensitive human receptors along the marine routes.
Adverse human health, nuisance or vegetation effects due to fuel combustion emissions or fugitive dust due to vehicles use on access roads.	PRL-15 and onshore export pipeline	Construction, operations and decommissioning	The nearest sensitive human receptor to Project access roads is located more than 2 km away in Poroi 1. At this distance vehicle movements would not adversely impact air quality. Any impacts on vegetation from wheel-generated dust will be limited to the immediate area adjacent to the road.
Adverse human health and nuisance effects due to fuel combustion emissions from air transport.	PRL-15 (Purari Airstrip)	Construction, operations and decommissioning	Emissions from the low frequency of flights (up to 5 per day) are unlikely to exceed ambient air quality criteria at the nearest sensitive human receptors (see assessment in Section 15.1.5).
Adverse human health and nuisance effects due to fuel combustion emissions and fugitive dust emissions from quarry operations.	PRL-15	Construction, operations and decommissioning	Project quarry sites are located more than 4 km from the nearest sensitive human receptors. Maximum ground-level suspended and deposited particulate levels will comply with relevant nuisance and health-based air quality criteria at this distance. Any impacts on vegetation from dust deposition will be limited to the immediate area.
Adverse human health effects from combustion emissions associated with waste incineration.	PRL-15	Construction, operations and decommissioning	The proposed incinerator at the general waste landfill site is located more than 3.5 km from the nearest sensitive human receptors. Based on the assessment in Section 15.1.5, maximum ground-level air pollutant concentrations associated with any waste incineration carried out at this site would comply with relevant air quality criteria at this distance.
Adverse human health and vegetation effects due to air emissions at the CPF.	PRL-15 (CPF)	Operations	Detailed air dispersion modeling studies for normal operations have demonstrated that maximum predicted off-site ground-level concentrations of NO_2, CO, SO_2, PM_{10} and $PM_{2.5}$, and VOCs (as BTEX) would comply with relevant health-based air quality criteria.
Adverse vegetation and fauna effects associated with SO_2 emissions from the CPF.	PRL-15 (CPF)	Operations	Annual average off-site SO_2 concentrations will be far below the ICP (2017) guideline for adverse impacts on vegetation and forest ecosystems of 20 µg/m^3. No adverse impacts on vegetation would therefore be anticipated due to SO_2 emissions from the CPF.

15.2 Greenhouse Gases and Climate Change

This section summarizes the findings of a greenhouse gas (GHG) assessment and climate change study undertaken for the Project, as detailed in Part 5 of Volume 3.

15.2.1 Context

The greenhouse effect is a naturally-occurring process that warms the Earth's surface and atmosphere. It is due to certain atmospheric gases, such as carbon dioxide (CO_2), water vapor and methane, influencing Earth’s energy balance by absorbing longwave radiation emitted from the surface. The GHG concentration in the Earth's atmosphere controls the amount of heat energy added to the atmosphere by the greenhouse effect.

GHG emissions can result from natural or anthropogenic sources; however, there is strong consensus in the climate science research community that GHG emissions from human activities have become the primary driver for an observed enhancement of the natural greenhouse effect, i.e., climate change, following the industrial revolution. Accurate quantification of GHG emissions will aid the ongoing assessment of climate impacts, and the development of targeted and effective policies and strategies to reduce the impact of global climate warming.

The PNG Government released Papua New Guinea’s First Biennial Update Report to the United Nations Framework on Climate Change (CCDA, 2018) in April 2019. This first Biennial Update Report (BUR1) presents an overview of PNG’s national circumstances relevant to climate change and presents an inventory of anthropogenic GHG emissions by sources and removals by sinks for years 2000 through to 2015. It also presents information on identified mitigation actions and associated constraints and gaps, including information on the results achieved by PNG from reducing emissions from deforestation, forest degradation and enhancement of forest carbon stocks.

A summary of the PNG GHG emission inventory data presented in the BUR1 report for 2000 to 2015 is presented in Figure 15.3. It shows that the ‘land use land-use change and forest’ sector is one of the biggest sectors in the PNG GHG emission inventory, and historically acted as a sink. This sector has become an increasingly smaller sink over time due to a decrease in forest lands, and in 2011, 2013, 2014 and 2015 the land use land-use change and forest sector was a net source of GHG emissions. Figure 15.3 also shows that the estimated GHG emissions from the energy sector increased notably in 2014 and 2015, and the BUR1 report attributes this to the PNG LNG project’s operations, and increased fugitive emissions associated with increasing natural gas production.

15.2.2 Discipline-specific Impact Assessment Method

The GHG assessment adopted a different approach to the impact assessment method described in Chapter 3.

The Project’s GHG emissions will not have a direct impact on the local or regional environment that can be quantified or assessed. Instead they will contribute to PNG’s national emissions and global anthropogenic GHG emissions, and will impact on the PNG government’s ability to comply with its National Climate Compatible Development Management Policy (CCDA, 2014) and to meet its international obligations under the 2016 Paris Climate Change Agreement. The GHG assessment therefore assesses the Project’s potential contribution to climate change by developing a GHG emissions inventory covering the life of the Project, including construction, operations and decommissioning. The significance of the Project’s estimated annual emissions has then been assessed in relation to PNG’s national GHG emission inventory.

Further information on the methods used in these studies is provided in the following sections.

ESTIMATED NATIONAL GHG EMISSIONS FOR PAPUA NEW GUINEA (2000 TO 2015)

Papua LNG Project | Environmental Impact Statement

FIGURE 15.3

CCDA, 2018.

ERIAS Group | 01215B_23_F15.3_v1

Details of the emission estimation method used to compile the Project's GHG emissions inventory are provided in Part 5 of Volume 3. Calculation of GHG emissions from the Project was undertaken in a five-stage process:

- Definition of the Project boundary (geographical and operational).
- Identification of emission sources within the Project boundary.
- Identification of emission calculation methods for each source.
- Identification of activity data for each emission source.
- Calculation of GHG emissions.

GHG emissions are defined as Scope 1 'direct', and Scope 2 or Scope 3 'indirect' emissions, as follows (Part 5 of Volume 3):

- Scope 1 – emissions are produced from sources within the boundary of an organization and are due to the organization's activities.
- Scope 2 – emissions from the generation of purchased electricity consumed in owned or controlled equipment or operations. As the Project will not be sourcing any appreciable quantities of electricity (e.g., only for offices in Port Moresby), Scope 2 emissions have not been considered further.
- Scope 3 – emissions generated in the wider economy due to an organization's activities but are physically produced by the activities of another organization.

Downstream processing of the gas and condensate produced by the Project will be undertaken at new LNG facilities to be co-located within the existing LNG plant at Caution Bay. Nuigini LNG Operating Company will permit, construct and operate the additional gas processing trains and marine facilities following a separate EIS and approvals process. For this assessment, GHG emissions associated with downstream gas processing have been included in this assessment as a Scope 3 emission source and not as a Scope 1 emission source, as the downstream processing is beyond the scope of this EIS.

GHG emission factors allow the quantity of GHG emitted by a source to be calculated from the units of activity. Relevant GHG emission factors were sourced to compile the Project's GHG emission inventory using the following hierarchy:

- Intergovernmental Panel on Climate Change (IPCC) for National Greenhouse Gas Inventories (IPCC,2016).
- Australian National Greenhouse Accounts (NGA) Factors Workbook (DEE, 2018).
- Published industry guidelines for GHG emission inventory development.

Other IPCC publications have been used to compile the emission estimates including Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003). Annual GHG emission estimates, calculated by the TOTAL design team for fuel gas combustion, flaring venting/diffuse emissions at the CPF, were used and the relevant activity data required for the calculations (e.g., land clearance areas, fuel consumption rates and barging activity data) were compiled based on the Project description and in consultation with TOTAL.

15.2.3 Identification of Potential Impacts

Estimated Scope 1 (direct) and Scope 3 (indirect) GHG emissions have been calculated for each year of the Project life and are presented in Figure 15.4 (Scope 1 emissions only) and Figure 15.5 (Scope 1 and Scope 3 emissions). The estimated annual and life of Project emissions are summarized in Table 15.12, with further details provided in Part 3 of Volume 3.

A review of the emission estimates shows the:

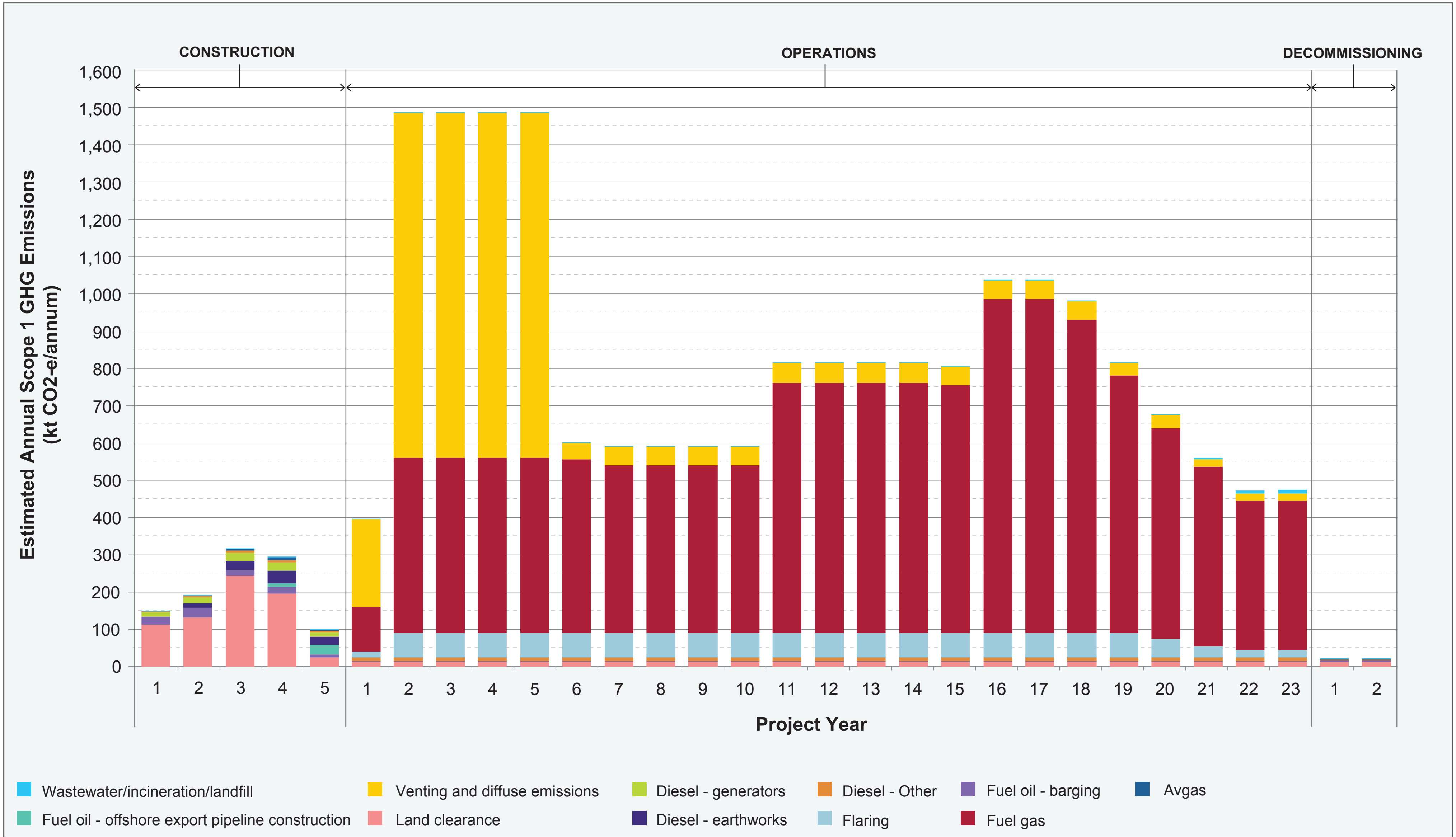
- Main contributor to the estimated Scope 1 emissions for the construction phase is the loss of carbon stocks due to land clearing (70% of the total Scope 1 emissions for the five-year construction period). Figure 15.4 shows the emission inventory also accounts for the ongoing annual carbon losses during the operations and decommissioning phases, due to cleared vegetation not being available to assimilate any further CO_2. These estimates do not include the areas cleared for the pipelines; however, as they will be allowed to revegetate, albeit to a limited extent (i.e., vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow).
- Estimated Scope 1 emissions are highest during Years 2 to 5 of operations at 1,489 kt CO_2-e/annum[1], which is related to the discharging of acid gas (containing CO_2) from the thermal oxidizer. This reduces significantly after Year 5, when acid gas injection is assumed to begin.
- Maximum calculated annual emissions of combined Scope 1 and 3 GHG emission estimates associated with Project operations are still predicted to occur during Years 2 to 5 of operations (Figure15.5), due to the Scope 1 emissions associated with discharging acid gas from the thermal oxidizer.
- Indicative Scope 1 emission estimates compiled for the decommissioning phase are 25 kt CO_2-e per annum emitted for the assumed two-year decommissioning period. These emissions represent a minor component of the Project in its entirety (0.2% of the life of Project Scope 1 emissions).
- Major Scope 1 emission source over the Project operational lifetime is predicted to be the combustion of fuel gas at the CPF to drive the compressors, run the heating boiler and to generate power (61.8%).
- Most significant contributors to the estimated total Scope 1 and Scope 3 emissions over the Project operational lifetime come from downstream gas processing (25.4%) and product gas combustion by the end user (64.8%).

1 kt CO_2-e = kilotonnes of CO_2 equivalent.

ESTIMATED ANNUAL SCOPE 1 GHG EMISSIONS FOR EACH YEAR OF PROJECT LIFE

Papua LNG Project | Environmental Impact Statement

FIGURE 15.4



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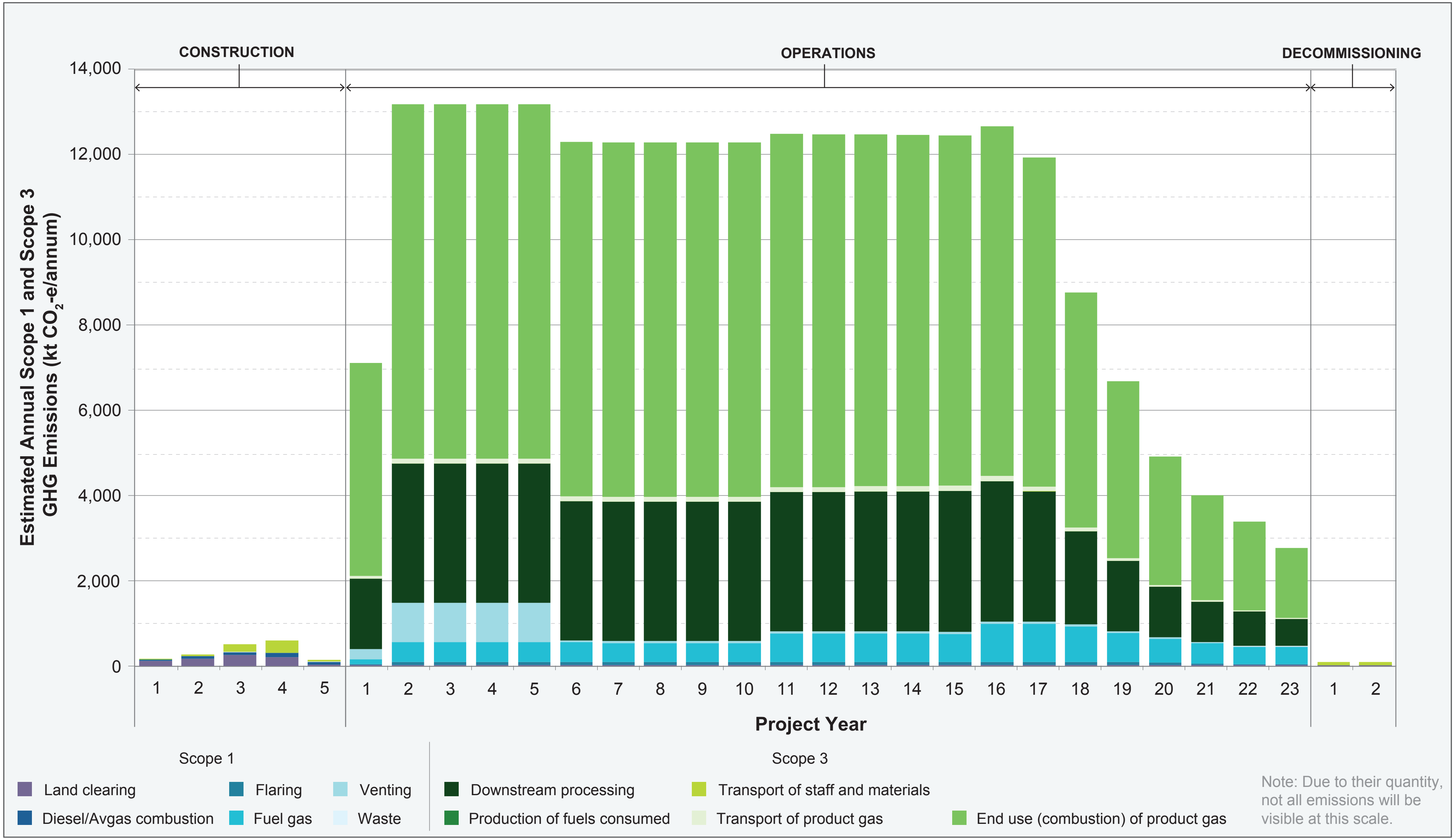
ESTIMATED ANNUAL SCOPE 1 AND SCOPE 3 GHG EMISSIONS FOR EACH YEAR OF PROJECT LIFE

Papua LNG Project | Environmental Impact Statement

FIGURE 15.5



ERIAS Group | 01215B_23_F15.5_v2

Table 15.12 – Summary of Estimated Project GHG Emissions

Project Year	Estimated Annual GHG Emissions (kt CO_2-e)		
	Scope 1	**Scope 3**	**Total**
Construction Year 1	152	22	173
Construction Year 2	233	41	274
Construction Year 3	330	184	514
Construction Year 4	309	287	596
Construction Year 5	103	46	149
Operations Year 1 – high pressure phase, acid gas discharge from the thermal oxidizer (start-up year)	399	6,726	7,124
Operations Years 2 to 5 – high-pressure phase, acid gas discharge from the thermal oxidizer (average)	1,489	11,710	13,199
Operations Years 6 to 10 – high-pressure phase, acid gas injection (average)	597	11,710	12,306
Operations Years 11 to 15 – medium-pressure phase, acid gas injection (average)	818	11,667	12,485
Operations Years 16 to 23 – low-pressure phase, acid gas injection (average)	760	6,140	6,900
Decommissioning Year 1	25	68	93
Decommissioning Year 2	25	68	93
Total Life of Project GHG Emissions	**20,682**	**220,286**	**240,968**

Note: Rows may not add up exactly due to rounding. The emissions for the years of operation represent an average over the relevant period, hence the column totals do not add exactly to the total life of project emissions.

In summary, vegetation clearing; gas production, processing and transportation; and the operation of fixed and mobile equipment will generate GHG emissions (as estimated in Table 15.12) that have the potential to increase the greenhouse effect and climate change.

A number of embedded design controls address GHG emissions:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- The flares will be used only for safety flaring in alignment with the TOTAL no routine flaring policy [ED023].
- Once the Elk reservoir has been depleted, acid gas removed from the raw gas using the AGRU will be disposed of by injecting it into the reservoir [ED025].
- The Project will generate its own electricity during the operation phase, which will minimize the use of diesel and related emissions [ED027].
- Waste-heat recovery units will be installed on the power gas turbines [ED028].
- Buildings will be insulated, where practicable [ED029].

15.2.4 Proposed Mitigation and Management Measures

Table 15.13 describes proposed mitigation to be implemented to further reduce impacts to GHG emissions for the Project. TEP PNG will monitor emerging issues and technology developments throughout the life of the Project and will consider adopting feasible technological solutions.

Table 15.13 – GHG Mitigation Strategies and Management Plans

Potential Impact	Mitigation Strategy	Relevant Management Plan(s)
Generation of GHG emissions contributing to an increase in the greenhouse effect and climate change.	♦ Implement standard practices to minimise fuel consumption, e.g., reduce speeds and idling times, maintain good road conditions, reduce site gradients, optimize vehicle tire pressure and maintain vehicles [EM044]. ♦ Implement fugitive emissions measurement controls [EM045].	Air Emissions and GHG Management Plan; Biodiversity Action Plan; Soil Management Plan

15.2.5 Residual Impact Assessment

The following section presents a comparison of the GHG emissions predicted for the Project to the PNG National emissions inventory and the GHG emissions intensity calculated for the Project to that reported internationally for similar projects.

The assessment is subject to the embedded design controls in Section 15.2.3 and the successful implementation of the mitigation and management measures in Section 15.2.4.

Project Contribution to PNG's National GHG Emissions Inventory

Emissions from the Project will be included in PNG's national GHG emissions inventory as part of the energy sector emissions.

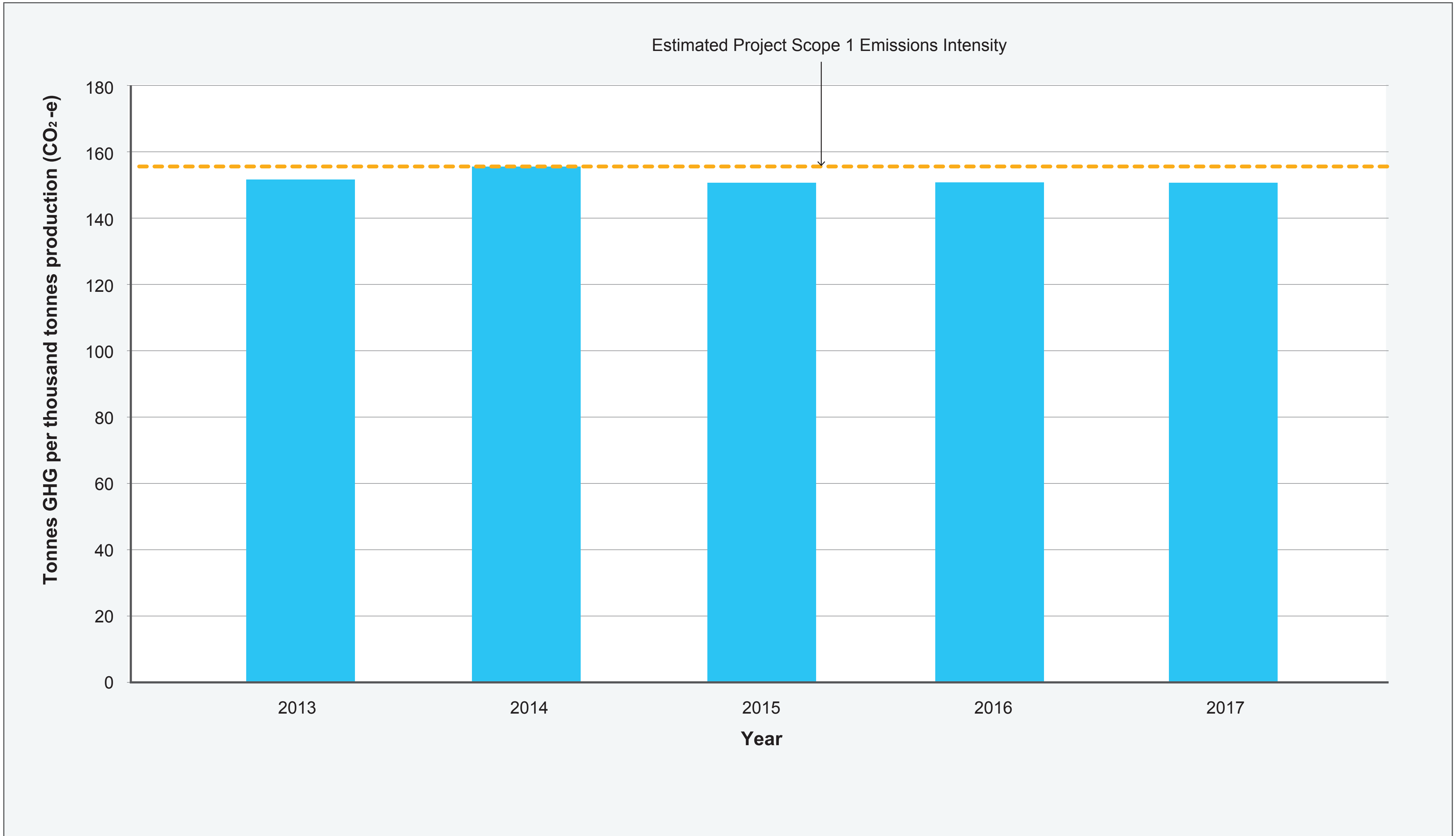
The Project's estimated maximum annual Scope 1 GHG (i.e., during the acid gas discharge phase in operations years 2 to 5) are 1,487 kt CO_2-e. This represents an additional 9.8% increase in the total reported national PNG GHG emissions (including land use land-use change and forest) for 2015 of 15,193 kt CO_2-e. The contribution during other years of the Project life will be less, e.g., 3.9% during years 7 to 10.

Benchmarking Against Similar Projects

The international Association of Oil and Gas Producers (IOGP) has collected environmental data from its member companies annually since 1999. The objective is to allow member companies to compare their performance with other companies in the sector to facilitate improved and more efficient performance. The latest Environmental Performance Indicators – 2017 Data Report (IOGP, 2018) summarizes the GHG emissions (as CO_2-e) per thousand tonnes of hydrocarbon production from 2013 to 2017 (Figure 15.6). The Project's GHG emissions intensity (in tonnes GHG per thousand tonnes of hydrocarbon production) has been calculated based on the estimated total life of Project GHG emissions and the projected production volumes over the life of the Project. These calculations give a Scope 1 GHG emissions intensity (i.e., excluding downstream processing) of 155.4 tonnes GHG per thousand tonnes of hydrocarbon production. This emissions intensity value is 3% above the average value of 151 tonnes GHG per thousand tonnes of hydrocarbon production reported by the IOGP for 2017.

REPORTED GHG EMISSIONS INTENSITIES FOR IOGP MEMBER COMPANIES

FIGURE 15.6



IOGP, 2018.

15.3 Noise

15.3.1 Context

15.3.1.1 Existing Noise Environment

As identified in the Upstream Noise Baseline Report (Part 20 of Volume 2) and summarized in Section 10.3 of this report, the PAOI is remote from any existing industrial noise sources.

To quantify the existing ambient background noise, unattended noise monitoring was conducted at representative locations along the Project alignment including:

- The upstream wellpads.
- The closest villages (sensitive human receptors) near the CPF.
- Along the onshore export pipeline route.
- An existing village near the pipe shore crossing in the Orokolo Bay coastal area.

The monitoring was undertaken in November 2016 in general accordance with IFC monitoring requirements (see Part 20 of Volume 2).

Results indicate that existing noise levels in uninhabited forest areas can be very high during the night due to local insect noise. In these areas, the daytime background noise levels were typically between 42 and 46 dBA, L_{90}, increasing to a relatively continuous 56 dBA, L_{90} at night.

The measured background noise levels were significantly lower relative to uninhabited regions surrounded by thick forest due to land clearing around established villages. Nonetheless, insect noise still affected most village locations, but to a lower extent than forested areas, with the measured background noise levels typically between 35 and 44 dBA, L_{90} during the day and 38 dBA, L_{90} (at Hururu on the Orokolo Bay coast) and 41 dBA, L_{90} (at Mapaio Fish Camp) during the night.

Noise in villages was also influenced by intermittent noise associated with human habitation, such as voice/conversation noise, roosters crowing, dogs barking, intermittent use of line trimmers, diesel generators, motorboats (for locations along the river). These generally short-term activities had minimal effect on the resultant background L_{90} noise levels.

The area surrounding the house near the Purari Airstrip and the Purari River included noticeably more gardens and understory growth relative to the larger settlements and villages. The resulting background noise levels at this location were somewhat higher; i.e., an average noise level of 44 dBA, L_{90} during the day and 47 dBA, L_{90} at night.

The findings of the baseline noise monitoring are consistent with those SLR found during other surveys in similar regions of Papua New Guinea (SLR, 2009, 2010, 2012).

15.3.1.2 Sensitive Receptors

Sensitive human receptors are described in Section 15.1.1.2.1.

Sensitive ecological receptors are limited to terrestrial fauna as described in Chapter 7.

15.3.2 Discipline-specific Impact Assessment Method

The noise impact assessment has been performed using a combination of quantitative and semi-qualitative assessment techniques, as detailed in Part 3 of Volume 3 and summarized in the following sections.

Project noise emissions with a higher potential to adversely impact surrounding sensitive land uses were assessed quantitatively using a detailed three dimensional (3D) computer noise model. Components assessed quantitatively include the construction and continuous operation of the CPF, and where the onshore export pipeline construction is near existing villages on the Orokolo Bay coastline, particularly the shore crossing area.

Noise emissions from construction activities and CPF operations were predicted based on design information and specifications provided by TOTAL. SLR made conservative assumptions based on similar works previously undertaken where detailed information was unavailable. The 3D noise model incorporates the local topography and meteorological conditions to predict noise levels at nearby sensitive receptors. The method used in the noise modeling study is outlined in Section 15.3.2.1 while the noise criteria used to assess compliance are summarized in Section 5.3.2.3.

Noise emissions have been assessed by predicting buffer distances required to meet noise criteria for areas where noise impacts are likely to be short-term and/or are located a significant distance from any sensitive receptors. The prediction method used is described in Section 15.3.2.2.

15.3.2.1 Noise Modeling Method

Details of the meteorological environment and the modeling method used to assess potential noise impacts are provided in Part 3 of Volume 3. The noise modeling was undertaken using the CONservation of Clean Air and Water in Europe (CONCAWE) noise propagation algorithm as implemented in the SoundPLAN (V8.1) noise modeling package. CONCAWE (1981) provides a detailed description of a noise prediction model specially designed for large petrochemical complexes. The method incorporates the influence of wind effects and temperature inversions on noise propagation over large distances.

The scenarios selected for modeling were chosen to represent different stages in the life of the Project as identified in Table 15.14.

Table 15.14 – Summary of Scenarios Being Assessed by 3D Modeling

Project Component	Project Phase	Activities	Scenario/s Assessed
CPF	Construction	Vegetation clearance, earthworks and site preparation, pad preparation, civil works/building erection	Site preparation and civil works
	Operation	Gas turbines, compressors, pipework, pumps, flare	See note
Onshore export pipeline shore crossing	Construction	Earthworks (as per right of way)	Trenching

Note: Two conservative scenarios have been considered for the operational CPF:
1. All plant is operating 10 years after first gas (i.e., when the additional 5 x medium-pressure gas turbine compressors come online to achieve deeper depletion of the Antelope reservoir).
2. As above with emergency flaring at the 104-m high tower located approximately 400 m northeast of the main plant.

Noise levels have been calculated for both neutral (calm) and enhanced propagation (i.e., worst-case weather) conditions. The parameters used to assess the effects of enhanced meteorological conditions, such as temperature inversions and slight winds (from the source to receiver), are discussed in Part 3 of Volume 3. Topographical shielding, ground hardness and dense vegetation are other factors (in addition to meteorological factors) that were considered when assessing noise propagation.

A detailed noise inventory was prepared of all major noise generating plant associated with the Project. The most significant noise producing equipment at the CPF will be:

- Gas turbine compressors (3 x 22.27 MW).
- Acid gas (AG) compressor (1 x 14.1 MW).
- C3 propane gas compressors (2 x 2.4 MW).
- Medium-pressure gas compressors (assume Solar Titan 250 gas turbine compressor set; 5 x 22.27 MW).
- Elevated low-pressure/high-pressure flare (one for startup/maintenance/emergency and upset conditions at 60 MMSCFD, except purge and pilot gases).

Other noise sources include fin fans, mono-ethylene glycol (MEG) injection pump/regeneration plant, pilot flare (for normal conditions), propane loop condenser and chiller, liquid and water transfer pumps, pipeline and booster compressor inter-stage and aftercoolers and inlet coolers.

15.3.2.2 Predicted Buffer Distance Assessment

Project activities with a lower potential for noise impact have been assessed using a semi-qualitative approach, as detailed in Part 3 of Volume 3. This was undertaken using the same CONCAWE prediction algorithm discussed in Section 15.3.2.1 to conservatively estimate noise emissions at a range of distances to determine the typical buffer distance required to meet the Project noise criteria.

The scenarios selected for the predicted buffer distance assessment are identified in Table 15.15 with a summary of the relevant Project components and key activities for each stage of the Project.

Table 15.15 – Summary of Scenarios Being Assessed Using Buffer Distance Method

Project Component	Project Phase	Activities	Assessed Scenario
Logistics Base	Construction and operation	Clear and grade activities, earthworks, general base operation (during the Project construction phase)	Clear and grade
Roads	Construction	Clear and grade activities, earthworks	Clear and grade
Export pipeline route	Construction	ROW clearing, stringing and bending, mainline welding, earthworks (trenching, lowering and backfilling)	Trenching
Accommodation camps (along the onshore export pipeline route)	Construction	Clear and grade, general operation of the camp (during the Project construction)	Clear and grade, and continuous operation of the facility
Purari Airstrip extension	Construction	Clear and grade activities, earthworks	Clear and grade
Purari Airstrip operations	Construction	Aircraft movements	Aircraft flyovers

The Australian Standard (AS 2021:2015) Acoustics–Aircraft Noise Intrusion–Building Siting and Construction was used to estimate the maximum noise from typical aircraft operations at the Purari Airstrip. Aircraft operations will continue at the runway after the CPF is completed;

however, during peak construction more aircraft will transport personnel and equipment to and from site.

15.3.2.3 Ambient Noise Guidelines

The CEPA Technical Guideline (Additional Information) for Noise Discharges (DEC, 2004) sets out the information that should be provided as part of an application for an environment permit to discharge waste. This includes:

- An outline of the proposal describing the nature and extent of activities.
- Site plans that also indicate the location of all external plant and equipment.
- Maps of the surrounding area to indicate the position of nearby receptors.
- Floor plans of internal plant of all major noise producing plant and details of existing or proposed mitigation measures (e.g., as enclosures, silencers or barriers).
- Sound power data for all significant plant and equipment.
- Plant operating hours, noting that background noise measurements should be taken over the proposed operating period with the results presented as hourly A-weighted L_{90} noise levels.

The above requirements provide a basis from which environmental noise from a facility can be predicted at the surrounding noise sensitive receptors and assessed. Part 3 of Volume 3 presents the above information for the Project's construction and operations phases, as relevant. Information on proposed methods to mitigate noise emissions are discussed in Section 15.3.4.

Papua New Guinea does not currently have any statutory ambient noise standards. A review of relevant noise criteria and guidelines set by other agencies was therefore undertaken as part of the Upstream Noise Baseline Report (Part 20 of Volume 2), including (in order of priority):

- Guidelines for Community Noise (WHO, 1999).
- General Environmental, Health and Safety (EHS) Guidelines (IFC, 2007b).
- TOTAL General Specification, Environmental requirements for project design and E&P activities, Section 5.9 Noise level (GS EP ENV 001).
- TOTAL General Specification, Safety rules for buildings. (GS EP SAF 221).
- Interim Construction Noise Guidelines (DECC, 2009), as construction noise is generally addressed separately from operational noise.

Noise from human activities associated with developments such as new infrastructure or industrial developments can affect fauna. The following literature was reviewed to determine appropriate noise criteria for fauna:

- Mackenzie Gas Project Effects of Noise on Wildlife (AMEC, 2005).
- Noise Disturbance along Highways: Kuranda Range Road Upgrade Project (Dawe and Goosem, 2008).
- Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis (Manci et al, 1998).
- Synthesis of Noise Effects on Wildlife Populations (US FHWA, 2004).

Table 15.16 summarizes the ambient noise criteria adopted for the impact assessment for the Project based on this review.

Table 15.16 – Project Noise Criteria

Activity/ Receptor	Noise Level Guidelines[1] One hour L_{Aeq} (dBA)		Comment
	Day/Evening 7.00 am - 10.00 pm	Night 10.00 pm - 7.00 am	
Construction noise[2, 3]/human	55 dBA Leq[2] (long-term target, i.e., impacting a receptor for longer than 1 month) 75 dBA Leq[4] (short-term target for all daytime works)	45 dBA L_{eq}	As an overall long-term target, noise management levels equivalent to the general operational noise limits have been nominated. A higher limit of 75 dBA, Leq has also been nominated for short-term daytime construction works. Where noise exceeds this upper threshold the receiver is considered 'highly noise affected', and all feasible and reasonable noise management and mitigation measures should be considered to help reduce the impacts.
General operational noise[2]/human	55 dBA Leq[2]	44 dBA, L_{eq}	The criteria is the lower of: Average night background level (L_{90}) + 3 dBA[3]. OR 45 dBA L_{eq}[2]. Background noise monitoring results at the closest villages/settlements to the CPF during the critical night period were typically between 41 and 47 dBA, L_{90}. The lower night-time noise criteria is 44 dBA, $L_{eq(1h)}$ based on the quietest noise level of 41 dBA.
Construction & general operational noise/fauna	65 dBA, L_{eq}		Adverse impacts on fauna are highly unlikely at noise levels below 50 dBA, L_{eq} and unlikely at noise levels below 65 dBA, L_{eq}. Long-term adverse impacts on fauna are unlikely to arise from short duration, high noise events up to 90 dBA (Manci et al., 1998). These events may; however, cause a short-term startle response. Very high maximum noise levels up to 100 dBA (WHO, 2015) may cause hearing loss, or other long-term physiological effects. The hearing damage threshold is species and frequency dependent, and, as with humans, damage may be cumulative over time.

Note 1: Guidelines values are for noise levels measured out of doors.
Note 2: WHO, 1999 guideline noise level recommended during the day period to 'protect the majority of people from being seriously annoyed'.
Note 3: IFC, 2007b requirement to not 'result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site'.
Note 4: DECC, 2009 represents the 'point above which there may be a strong community reaction to noise'.

Total (2011) requires the evaluation of 'noise emissions at the facilities boundary limit'. As information on the proposed boundary of an exclusion zone for the CPF is currently unavailable, these emissions have been extracted from the model output files based on the area proposed to be cleared as part of the CPF construction. This approach will result in worst case estimates of maximum off-site emissions, given that the boundary will likely be further away from the sources than assumed in the modeling. Day/evening and night targets used for the assessment of off-site emissions are 55 dBA Leq and 45 dBA, Leq, respectively.

15.3.3 Identification of Potential Impacts

The Project activities with the greatest potential for adverse off-site noise impacts, i.e., human health, amenity and/or fauna effects have been assessed as part of this study. Potential human health, amenity or terrestrial fauna impacts include:

- Human health and amenity impacts: Perception of sound in day-to-day life is of importance for human wellbeing and amenity. Communication through speech, sounds from playing children, music, and natural ambient sounds in vegetation (e.g., birdsong, local wildlife, rustling water, wind in trees) are all examples of sounds considered essential for satisfaction in everyday human life. Excessive noise has the potential to impact health and wellbeing causing nuisance, interfering with normal speech communication, causing changes in behavior/upset daily work patterns, sleep disturbance/deprivation, and anxiety over sudden or unknown loud noises. These impacts can lead to stress and increased blood pressure, and other physical, physiological and psychological effects.
- Terrestrial fauna impacts: Impacts include physical damage to hearing organs, increased energy expenditure or physical injury while responding to noise, interference with normal activities, and impaired communication. Responses to noise disturbance cannot be generalized across species and depend on a variety of factors, e.g., noise level, frequency distribution, duration, number of events and variation over time. Individual responses to noise events will vary from a mild alert response (to relatively low noise events) to avoidance or the abandonment of otherwise suitable habitat. Generally, continuous noise (i.e., noise produced by generators is more readily tolerated by terrestrial fauna (particularly birds) than episodic noise disturbances, such as, haul trucks moving about the site, or low altitude helicopter flyovers).

Construction Phase

- Construction of the CPF: Clearing, earthworks and construction activities that have potential to emit noise from operation of vehicles, equipment and machinery for civil works, and erection of plant. This will initially involve site preparation and significant bulk earthworks to grade the site before the CPF modules are assembled. Noise emissions associated with these works have been assessed for their potential to impact the amenity of existing villages near the CPF and terrestrial fauna that inhabit surrounding vegetation.
- Construction of the Logistics Base, accommodation camps, and the Purari Airstrip extension: Clearing, earthworks and construction activities that have the potential to emit noise from operation of vehicles, equipment and machinery for civil works will occur at these sites for an extended period. These emissions have been assessed for their potential to cause amenity and fauna impacts.
- Accommodation camps: Noise emissions from 24 hr operation of equipment (i.e., air-conditioning units, refrigerated shipping containers, diesel power plant, water treatment plant) to run the camps during the construction phase have been assessed to determine potential amenity and fauna impacts.
- Construction of the onshore export pipeline and access roads, including the pipeline shore crossing at Orokolo Bay, which is near coastal settlements: Clearing, earthworks and construction activities have the potential to emit noise from operation of vehicles, machinery and equipment movement, as activity progresses along the pipeline route — for the excavating trench, stringing, bending, welding, lowering and backfilling sequence — and road alignments. These emissions have been assessed for their potential to cause amenity and fauna impacts.

- Air transport: Potential noise (amenity and fauna) impacts associated with aircraft take-off and landing movements at the Purari Airstrip, with the construction phase as a worst case, given that the frequency of flights will be lower during the operations phase.

Operations Phase

- CPF operations: Noise emissions from the 24 hr operation of gas processing equipment (e.g., gas turbines, compressors, pipework, pumps, and flaring when required) at the CPF have been assessed to determine the potential amenity and fauna noise impacts.

Decommissioning Phase

Noise emissions associated with the Project's decommissioning phase will depend on the type and scale of activities that are undertaken. The noise emissions will mostly be limited to demolition activities, and infrastructure removal and rehabilitation works. Generally, noise impacts associated with decommissioning works are likely to be less than those associated with the initial construction works (e.g., vegetation clearing, earthworks or pile driving).

A number of embedded design controls address impact to noise:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- Minimise noise from machinery, plant and equipment, as far as practicable [ED031].
- The Project will design its plant and undertake activities to comply with the applicable noise criteria [ED032].
- All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired [ED019].
- Fixed or mobile equipment will be used and/or located in consideration of people and other sensitive receptors [ED030].
- The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

The following identified potential noise emissions are inherently addressed by the above embedded design controls or have been concluded to be negligible, with no significant potential for off-site noise impacts, and therefore have not been considered further in the assessment:

- Noise emissions from wellpad and trunklines/flowline construction:
  - Noise from wellpad construction: ANT-10 is a new wellpad, but the ELK10 and ANT-11 wellpads will be established on the existing Elk-1 and ANT-1 wellpads that were developed during the exploration and appraisal phases. Consequently, site preparation works will be of a smaller scale than if three new wellpads were required to be developed, reducing the land disturbance and hence earthworks required in a remote location.
  - Noise emissions from trunklines/flowline construction: Clearing, earthworks and construction activities have the potential to emit noise from operation of vehicles, machinery and equipment movement along the pipeline routes; however, approximately

77%, 35% and 68% of the Antelope trunklines, Elk flowlines and water injection flowline follow existing tracks, respectively, reducing the land disturbance and hence earthworks required.

- On this basis, and given that the wellpads, trunklines and flowlines will be located more than 14 km from the nearest sensitive receptors, it is concluded that construction noise for the wellpads and trunklines/flowlines will not impact the nearest sensitive human receptors. It is likely that fauna near the construction works could temporarily retreat further into the bush. As discussed widely in the literature (Dawe, G. and M. Goosem, 2008), many bird species become habituated to noise disturbances, particularly noise such as that associated with the operation of plant and equipment.

- Noise emissions from wellpad operations: Continuous noise from drilling operations will occur at each wellpad during the drilling campaign. The total drilling duration across the three wellpads (including mobilization and demobilization) is estimated to be 30 to 37 months, with an average of 70 days for the drilling of each well. Given the rugged and remote location of each wellpad, it is highly unlikely that there will be any in-migration to this area during this period. As the wellpads will be located more than 14 km from the nearest sensitive human receptors, it is concluded that activities at the wellpads will not impact the nearest sensitive human receptors. It is likely that fauna near the work area could temporarily retreat further into the bush during the drilling program. As discussed widely in the literature (Dawe, G. and M. Goosem, 2008), many bird species become habituated to noise disturbances, particularly continuous noise such as that associated with the operation of generators and drilling mud pumps, which are dominant throughout most of a drilling program.
- Noise emissions from construction of the offshore export pipeline and pipeline shore crossing at Caution Bay: Noise from construction vessels used for the offshore export pipeline will occur over relatively large areas and will rapidly disperse. Noise emissions from construction of the offshore export pipeline and pipeline shore crossing at Caution Bay are not considered by this assessment as the EIS is limited to works up to the PNG LNG project lease boundary
- Noise emissions from road and river transport activities during construction and operations: Potential noise impacts associated with trucks travelling along the Project roads will be limited to short-term pass-by events with noise levels reaching a maximum of around 80 dBA at a distance of 15 m from the source for a few seconds. While noise from barge diesel engines has the potential to be audible at some of the villages located along the river, e.g., Aumu, Evara, Kaevara, Poroi 1, any potential noise impacts will be limited to the time it takes for the barge to travel along the exposed section of river. Given the distance from Project roads (more than 2.5 km) and barge routes to any sensitive human receptors, any potential human health and amenity noise impacts associated with these sources will be minimal.
- Four condensate valve and two gas valve stations will be located along the onshore export pipeline. These stations include no major noise generating plant, with the electric actuator installed inside a building typically more than 350 m from any sensitive human receptor. As such, there will be minimal noise impacts associated with the valve stations.

- The proposed Herd Base Quarry C is approximately 2.5 km north northeast of the closest human sensitive receptor, which is in Poroi 1. While some blasting may be associated with removing material at the quarry, any potential noise and vibration impacts at existing sensitive human receptors would be well within acceptable limits given the distance to the closest sensitive receptor.[2] While infrequent blasting noise may cause fauna startle response, the noise and disturbance is momentary and as the disturbance is temporary the fauna are likely to resume normal behaviors within a short timeframe.
- Given the nature and typical offset distance from Project construction works to existing sensitive buildings, any transmitted ground vibration (e.g., due to rock breaking, piling works) would be well below typical damage-based vibration criteria. The levels are likely to also be below the threshold of human perception. Consequently, ground-borne vibration from Project construction or quarry activities has not been assessed any further.

15.3.4 Proposed Mitigation and Management Measures

Table 15.17 describes proposed mitigation and management measures to further reduce potential noise impacts.

Table 15.17 – Noise Mitigation and Management Measures

Potential Impact	Mitigation and Management Measures	Relevant Management Plans
Nuisance and disturbance, reduced amenity and fauna impacts, due to noise emissions from construction activities.	♦ Limit construction work, where practicable, to daytime hours [EM046]. ♦ The Project will prepare an updated stakeholder engagement plan for the Project's construction, operations and decommissioning phases, according to TOTAL's General Specifications and IFC PS1 and PS7. The updated stakeholder engagement plan will include the following key requirements: – Regular engagement with project affected communities on Project impacts, action plans and grievance mechanism. – Notification as early as possible to affected communities in advance of Project works, which describes the activities and how long they are expected to take. Particular focus is to be given to communities affected by project-induced in-migration. – A mechanism for enquiries and feedback. – Ongoing grievance and issues management [SEM002].	Noise and Vibration Management Plan
Nuisance and disturbance, reduced amenity and fauna impacts, due to noise emissions from drilling.	No additional mitigation measures proposed.	NA

2 Calculations were made using AS 2187.2-2006 and conservatively assumed a maximum instantaneous charge of 500 kg to determine potential air blast noise and vibration impacts at sensitive receptor locations. The predicted noise level of 60 dBLin is well within the target of 115 dBLin for 95% of all blasts. Similarly, vibration which was predicted at approximately 0.6 mm/s is well below the minimum 5 mm/s target for 95% of all blasts.500 kg to determine potential air blast noise and vibration impacts at sensitive receptor locations. The predicted noise level of 60 dBLin is well within the target of 115 dBLin for 95% of all blasts. Similarly, vibration which was predicted at approximately 0.6 mm/s is well below the minimum 5 mm/s target for 95% of all blasts.

Table 15.17 – Noise Mitigation and Management Measures (cont'd)

Potential Impact	Mitigation and Management Measures	Relevant Management Plans
Nuisance and disturbance, reduced amenity and fauna impacts, due to noise emissions from aircraft.	♦ The Project will prepare an updated stakeholder engagement plan for the Project's construction, operations and decommissioning phases, according to TOTAL's General Specifications and IFC PS1 and PS7. The updated stakeholder engagement plan will include the following key requirements: – Regular engagement with project affected communities on Project impacts, action plans and grievance mechanism. – Notification as early as possible to affected communities in advance of Project works, which describes the activities and how long they are expected to take. Particular focus is to be given to communities affected by project-induced in-migration. – A mechanism for enquiries and feedback. – Ongoing grievance and issues management [SEM002].	Noise and Vibration Management Plan

Note: NA = Not applicable.

15.3.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to noise subject to the embedded design controls in Section 15.3.3 and the successful implementation of the mitigation and management measures in Section 15.3.4.

15.3.5.1 Construction Phase

As outlined in Section 15.3.3, the construction phase activities identified as requiring assessment are:

- Construction of the CPF.
- Construction of the Logistics Base, Accommodation Camps and Purari Airstrip.
- Construction of the onshore pipeline including the pipeline shore crossing at Orokolo Bay and access roads.
- Noise associated with using the Purari Airstrip.

The potential noise impacts associated with each of these activities are discussed in the following sections.

Construction of the CPF

The results of the predicted noise associated with construction of the CPF has been extracted from the noise model outputs provided in Part 3 of Volume 3.

The predicted noise levels during daytime construction works will range from 21 to 30 dBA, L_{eq} at the closest villages/settlements under enhanced propagation conditions. Given the significant margin of compliance with the long-term noise target of 55 dBA, L_{eq}, it is unlikely that there will be any adverse noise impacts while constructing the CPF.

Logistics Base, Accommodation Camps and the Purari Airstrip

Construction and Operation of the Logistics Base and Accommodation Camps

Site clearing, earthworks, construction/civil activities will create variable noise levels during the scheduled 'day' works required to build the Logistics Base on the north bank of the Purari River and the accommodation camps.

The closest accommodation camp with the potential to impact a sensitive human receptor is pipeline construction camp 2 approximately halfway along the export pipe route (near pipe yard 4) approximately 730 m east of Aivai village (see Figure 4.6). Noise will be associated with the construction and operation of this camp.

Table 1518 shows the predicted construction noise at a range of offset distances from the Logistics Base and accommodation camps, including at the closest sensitive human receptors, Aivai village and the Purari Airstrip House for the pipeline construction camp and the Logistics Base, respectively.

Table 15.18 – Predicted Construction Noise with Distance from the Logistics Base and Accommodation Camps

Weather Conditions	Predicted Noise Level with Distance (dBA, Leq)						
	50 m	100 m	250 m	500 m	730 m Aivai Village	2.7 km Purari Airstrip	4 km
Neutral	77	71	60	51	46	27	25
Enhanced	77	72	63	55	50	32	29

Note: The result is highlighted PINK where the predicted construction noise exceeds the short-term target of 75 dBA, Leq(1h). The result is highlighted ORANGE where the predicted noise level exceeds the long-term operational daytime noise target of 55 dBA, Leq(1h).

The predicted construction noise levels at Aivai village range from 46 dBA to 50 dBA, Leq(1h) which is below the nominated noise targets.

At the Purari Airstrip House approximately 2.7 km west southwest of the Logistics Base, the predicted noise level during the daytime construction works was between 27 and 32 dBA, Leq, which is well below the nominated 55 dBA, Leq(1h) long-term noise target. Noise levels of this magnitude are likely to be inaudible at this receptor (Part 20 of Volume 2).

Once the Logistics Base and accommodation camps are operational, there will be noise emissions associated with normal camp operation (i.e., from air-conditioning units, refrigerated shipping containers, the diesel power plant and the water treatment plant) 24 hours/day, 7 days/week. The resulting noise emissions from the accommodation camps once operational have also been predicted and assessed against the long-term night time operational noise target of 45 dBA, Leq(1h) with the results shown in Table 15.19.

Table 15.19 – Predicted Operational Noise from Logistics Base and Accommodation Camps

Weather Conditions	Predicted Noise Level with Distance (dBA, Leq)						
	50 m	100 m	250 m	500 m	730 m Aivai Village	2.7 km Purari Village	4 km
Neutral	67	63	51	43	38	20	15
Enhanced	67	63	54	46	42	24	19

Note: The result is highlighted PINK where the predicted noise level exceeds the long-term operational daytime noise target of 55 dBA, Leq(1h). Potential night time noise levels in excess of 45 dBA, Leq(1h) have also been highlighted ORANGE, as the accommodation camps will operate 24 hours/day, 7 days/week.

The predicted continuous noise from normal operation of the Logistics Base and pipeline construction camp (near Aivai Village) are below the nominated operational criteria.

Purari Airstrip Construction

The Purari Airstrip House on the south bank of the Purari River is situated 190 m from the northwestern end of the existing Purari Airstrip, which extends to approximately 1.3 km to the southeast. The runway will be extended to accommodate larger aircraft for the Project which will also necessitate an upgrade to the airstrip facilities. Most of the construction works will extend the southeastern end of the runway; however, additional sealing/surfacing and terminal building works will be undertaken as part of the upgrade, the closest aspect of this being approximately 200 m from the Purari Airstrip House.

Table 15.20 provides predicted noise from the Purari Airstrip extension works for a range of different offset distances.

Table 15.20 – Predicted Construction Noise with Distance from the Purari Airstrip Extension

Weather Conditions.	Predicted Noise Level with Distance (dBA, Leq)						
	50 m	100 m	200 m Northwestern end of the Runway	400 m Existing Terminal Building	1 km	2 km	4 km
Neutral	74	68	59	50	37	26	14
Enhanced	74	70	63	55	42	32	20

Note: The result is highlighted ORANGE where the predicted noise level exceeds the long-term operational daytime noise target of 55 dBA, $L_{eq(1h)}$.

For works conducted at the northwestern end of the runway (i.e., within approximately 200 m of the house) the predicted noise levels were between 59 and 63 dBA, L_{eq}. While this is higher than the long-term daytime noise target of 55 dBA, L_{eq}, it is unlikely that the surfacing works in this area would last for more than a few days. Given the nature of the works program, and typical distance from the works, noise emissions at this dwelling are also likely to comply with the upper 75 dBA, L_{eq} short-term noise target. The new terminal buildings will be located no closer than the existing transit building/warehouse, which is located approximately 400 m southeast of the dwelling, therefore it is unlikely that the works would exceed the long-term noise target. Furthermore, the area of the runway extension will be sufficiently far away from the dwelling where noise emissions are predicted to meet noise targets.

Construction of the Onshore Export Pipeline Including the Pipeline Shore Crossing at Orokolo Bay and Access Roads

Access Road Construction

Earthworks associated with constructing the access roads will only occur for a limited duration in any given area, as they progress along the road alignment. Road works are limited to daytime hours, where practicable. The Project criteria for works taking more than one month is 55 dBA, $L_{eq(1h)}$.

Table 15.21 provides the predicted noise levels at a range of offset distances, including the three closest villages to the onshore export pipeline alignment along which the access roads will be built.

Table 15.21 – Predicted Construction Noise with Distance from Road Works

Weather Conditions	Predicted Noise Level with Distance (dBA, Leq)						
	50 m	100 m	250 m	500 m	1 km Hepere & Paevara Villages	2 km Kilavi Village	4 km
Neutral	72	66	54	45	35	25	13
Enhanced	72	67	58	50	41	31	19

Note: The result is highlighted ORANGE where the predicted noise level exceeds the long-term operational daytime noise target of 55 dBA, Leq(1h)..

The access roads are typically more than 1 km from any existing village except where the onshore export pipeline will cross the shore (see Table 15.23). The predicted noise from the associated daytime road construction works was from 35 dBA to 41 dBA, Leq depending on propagation conditions at Hepere and Paevara villages, which are both approximately 1 km from the onshore export pipeline right of way. Consequently, it is highly unlikely that these works will cause any adverse noise impacts.

Onshore Pipeline Construction

Similar to road construction, construction of the onshore export pipeline will only occur for a limited duration in any location, as the pipeline construction spread moves along the alignment. The predicted noise levels at a range of offset distances, including the closest three villages are shown in Table 15.22. The predicted noise levels shown at the offset distances provided in Table 15.22 are conservative in that that they assume all the plant and equipment is located at the closest point; whereas, the plant and equipment would be distributed across the pipeline spread.

Table 15.22 – Predicted Construction Noise with Distance from the Onshore Export Pipeline Construction

Weather Conditions	Predicted Noise Level with Distance (dBA, Leq)						
	50 m	100 m	250 m	500 m	1 km Hepere & Paevara Villages	2 km Kilavi Village	4 km
Neutral	78	71	59	51	41	30	18
Enhanced	78	73	64	55	46	36	23

Note: The result is highlighted PINK where the predicted construction noise exceeds the short-term target of 75 dBA, Leq(1h).. The result is highlighted ORANGE where the predicted noise level exceeds the long-term operational daytime noise target of 55 dBA, Leq(1h).

The maximum noise emissions from the daytime pipeline construction works were predicted to be 46 dBA, Leq at Hepere and Paevara villages, i.e., the closest villages. It is highly unlikely that noise from these works will cause any adverse noise impacts, as this is well below the nominated long-term construction noise target..

Noise from the onshore export pipeline construction works to villages along the coastline near the Orokolo Bay shore crossing was predicted using a detailed 3D noise model. The model assumed that as a conservative scenario, approximately 60 heavy vehicles would be operating across a 2-km work front (i.e., approximately one heavy vehicle every 30 m). Details regarding the assessed scenarios are provided in Part 3 of Volume 3.

Table 15.23 shows the predicted noise impacts to the closest villages along the coastline.

Table 15.23 – Predicted Noise from the Onshore Export Pipeline Construction Works at the Shore Crossing

Receptor	Predicted Noise at Village, dBA, Leq	
	Neutral Propagation	Enhanced Propagation
Iuku	44	48
Iuku East	47	50
Mareke	43	48
Mareke West	53	57

Note: The result is highlighted ORANGE. where the predicted noise level exceeds the long-term operational noise target of 55 dBA, $L_{eq(1h)}$.

The predicted construction noise levels at sensitive human receptors surrounding the onshore export pipeline route were predominantly below the long-term noise target of 55 dBA, $L_{eq(1h)}$, under both neutral and enhanced conditions. At Mareke West to the east of the onshore export pipeline right of way, there are three isolated properties where noise levels are predicted to exceed the long-term noise target by up to 2 dBA (i.e., 57 dBA, $L_{eq(1h)}$) under enhanced (i.e., worst case) propagation conditions. Under normal propagation conditions the predicted noise levels comply at all receptor locations. The predicted noise levels are well below that sufficient to cause a significant adverse reaction to construction noise, i.e., the short-term target of 75 dBA, $L_{eq(1h)}$, for which specific noise management/mitigation measures should be considered.

The maximum noise level predicted at Mareke West was 62 dBA associated with short-term tree felling/chainsaw works (with a sound power level of 121 dBA) at the closest point, approximately 250 m from the property. This would also comply with the short-term 75 dBA noise target. Similarly, the predicted noise levels were found to be 53 dBA to 56 dBA when a single grader is operating in this area.

Purari Airstrip

Up to approximately 5 to 7 flights per day are estimated to occur (using ATR42 or Twin Otter type aircraft) once the extension works are completed.

Australian Standard (AS 2021:2015) was used to predict maximum noise levels associated with aircraft using the runway based on the aircraft classification and the relative location of the receptor dwelling.

The maximum predicted external noise levels at the Purari Airstrip House were 73 dBA to 93 dBA, L_{max} during take-off and landing movements. Given the low frequency and typically short-term duration associated with each movement (e.g., typically less than a minute), it is unlikely that using the runway will cause any adverse noise impacts; however, open communications will be maintained with the family to identify any noise and amenity related concerns.

Fauna Impacts

Tables 15.18, 15.19, 15.20, 15.21 and 15.22 indicate that the zone of influence where adverse effects are possible (see Table 15.16) is limited to within approximately 100 to 200 m from the construction works.

During the initial site clearance and earthworks construction stages, when new noise sources are introduced, changes could be expected in the behavior of some fauna, particularly those individuals closest to the new noises.

Following the initial stages of construction, equilibrium is likely to be reached, involving:

- Likely changes in species composition near the Project, with less noise-tolerant species moving further away.
- Selection of more noise-tolerant individuals within the species' populations close to the Project.
- Habituation of some species and individuals to the noise impacts, as currently displayed by some species near existing operations.

Noise can have adverse effects on terrestrial fauna, with different species being sensitive to noise. Extremely high noise levels can cause hearing damage or other physiological effects, although fauna generally avoid exposure to such impacts wherever possible. At lower noise levels, terrestrial fauna will generally avoid anthropogenic noise sources and prefer to occupy areas more distant from noise sources.

Generally, terrestrial fauna will avoid areas where very high noise levels sufficient to cause injury or damage occur. Noise levels in excess of 100 dBA over extensive periods would be required to cause physical damage or injury (WHO, 2015). It is unlikely that any terrestrial fauna would remain in any area affected by these noise levels.

15.3.5.2 Operations Phase

CPF Impacts on Human Receptors

As outlined in Section 15.3.3, the only operations phase activity identified as requiring assessment is the CPF operations (gas processing) which includes significant noise generating plant.

Other noise sources associated with the Project's operational phase will either have minimal noise impacts compared with the constructions phase (such as the valve/condensate stations), or are sufficiently distant from any existing sensitive receptors.

The results of the modeling (refer to Part 3 of Volume 3) undertaken for years 10+ with additional compression are presented in Table 15.24. Both normal, and upset conditions when flaring occurs, have been modeled under neutral and enhanced propagation, and the results presented for the three closest sensitive receptors. Figure 15.7 shows contours for noise emissions from normal operations at the CPF under enhanced propagation conditions.

Table 15.24 – Predicted Operations Noise from the CPF (Years 10+), dBA, L_{eq}

Receptor	Normal Operations		Upset Conditions/Emergency Flaring	
	Neutral Propagation	Enhanced Propagation	Neutral Propagation	Enhanced Propagation
Poroi 1	27	32	38	40
Mapaio Fish Camp	22	26	29	33
Purari Airstrip House	29	34	38	41

Note: The operational daytime noise target is 55 dBA, $L_{eq(1h)}$. The night-time noise target is 44 dBA, $L_{eq(1h)}$.

Operational Project noise targets will be met at all existing villages and the settlement near the CPF site. Emergency flaring may be required at times and, when required, an increase in the level of received noise is expected (i.e., 7 to 11 dBA); however, the predicted noise levels still comply with the most stringent 44 dBA, L_{eq} night-time noise target by a 3 dB margin.

Predicted maximum off-site noise levels at the southeast facility boundary near the medium-pressure compressors are up to 81 dBA, L_{eq} and the results on the western and southwestern facility boundary are approximately 60 to 69 dBA, L_{eq}. Consequently, the resultant noise

PREDICTED NOISE FROM THE CPF, NORMAL OPERATIONS AFTER 10 YEARS, UNDER ENHANCED PROPAGATION

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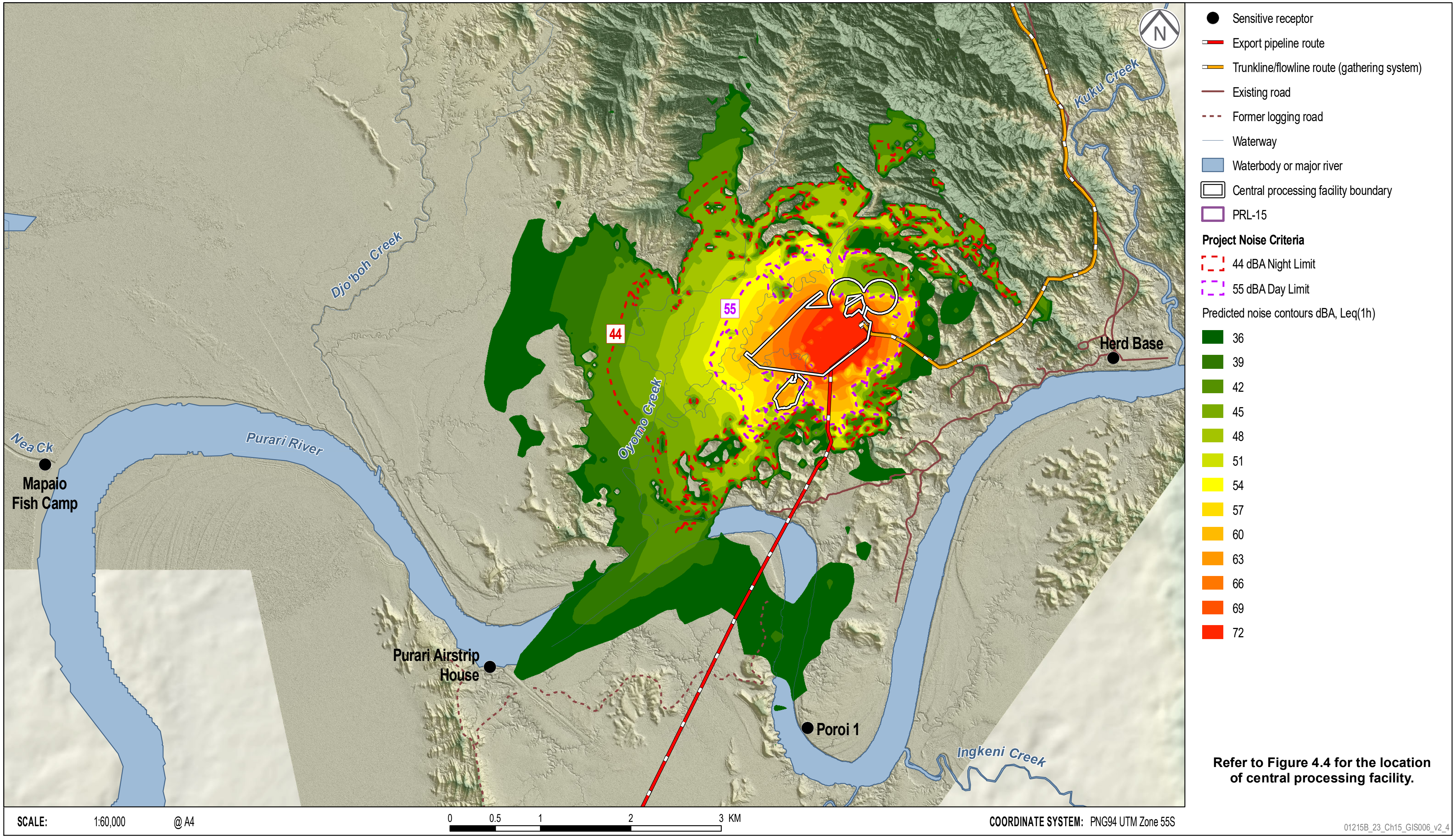
FIGURE 15.7



ERIAS Group | 01215B_23_15.7_v2

emissions would exceed the nominated night time noise target by approximately 15 to 37 dBA if the vegetation clearance area was adopted as the CPF boundary.

An exclusion zone boundary would need to extend approximately 400 m and 1.4 km to the east/southeast and west/southwest, respectively, beyond this zone to meet the nominated night time noise target without further noise mitigation.

CPF, Impacts on Fauna Receptors

Under normal operating conditions the predicted noise levels at the PRL-15 oxbow wetlands were typically less than 30 dBA, Leq, which is well below the existing ambient background noise environment and the nominated guideline noise target of 65 dBA, Leq where fauna are unlikely to experience adverse impacts. Normal CPF operation will; therefore, not cause any adverse noise impacts to wildlife in the PRL-15 oxbow wetlands.

The predicted noise levels to forest immediately surrounding the CPF are predominantly below the nominated 65 dBA, Leq noise target. The only area where noise from the plant could potentially impact local fauna extends approximately 250 to 350 m southeast of the medium-pressure compressors. This could cause some wildlife to relocate further away from the plant; however, as noted in Section 15.3.3, noise from continuous sources such as compressors is more readily tolerated by terrestrial fauna (particularly birds) than episodic noise disturbances, such as low altitude helicopter flyovers.

15.4 Landscape and Visual Amenity

15.4.1 Context

This assessment is based on the information gathered from the landscape and visual amenity baseline study, which involved a desktop study mapping and describing broad landscape character types (Part 21 of Volume 2). It focuses on PRL-15 and the Project components that are likely to cause the most significant landscape and visual impacts, which are the proposed CPF, Logistics Base and associated infrastructure, and Project components that are likely to be visible to more people, such as the export pipeline shore crossing at Orokolo Bay. Other Project components, including wellpads, flowlines and quarries are remote and accessible and visible only to Project personnel, and are therefore excluded from this assessment.

Steeply sloped mountainous terrain dominates the northern two thirds of PRL-15 (within which the wellpads are located). The southwestern portion of PRL-15 contains alluvial plains of the Purari River basin that are subject to frequent inundation from overbank river flows.

The proposed CPF, Logistics Base, river offloading facilities, camps, roads and bridges are in a hilly area adjacent to the Purari River alluvial plain, which is bounded to the south by the Purari River main channel. The Purari Airstrip is to the south of this channel.

After crossing the Purari River, the onshore export pipeline route traverses a varied landscape over 60 km, including a 3-km hilly area, then alluvial plains for 38 km, followed by steeper hills for 10 km, before a flat coastal area consisting of sand dunes and beach ridges. The topography is very low lying where the onshore export pipeline route intersects the coastal zone at Orokolo Bay. Beaches in this area are regularly interrupted by rivers, coastal lagoons and inlets.

The dominant anthropogenic activities in the Project area can be attributed to gas exploration and logging activities. As shown in Figures 7.19 and 7.20, logging roads are an existing feature of much of the Project area, particularly south of the Purari River, where riverside clearance also occurs to facilitate log landings and movement of machinery.

PRL-15 is predominantly unsettled, except for a small, subsistence-based village and a settlement along the Purari River to the west of Herd Base, i.e., Poroi 1 and Mapaio Fish Camp respectively. There is a single house near the Purari Airstrip on the Purari River bank. The export pipeline route is unsettled; however, settlements do occur near the route in the coastal area. Villages also occur intermittently along the river transport corridors.

Further characterization of the regional and PAOI landscape is provided in the baseline study (Part 21 of Volume 2).

15.4.2 Discipline-specific Impact Assessment Method

This assessment evaluates potential changes to visual amenity experienced by viewers at specific viewpoints, and to the broader landscape character, due to the Project. The assessment is founded upon:

- The Landscape Institute and Institute of Environmental Management and Assessment's Guidelines for Landscape and Visual Impact Assessment (LI and IEMA, 2013).
- TOTAL General Specification: Environmental Impact Assessment of E&P Activities (GS EP ENV 120).
- TOTAL General Specification, Sustainable Development: Social Impact Assessment (GS EP SDV 102).

The following sections describe the assessment method that has been adopted for this assessment.

15.4.2.1 Visual Impact Assessment

Approach

The baseline characterization study and this assessment have been informed by aerial photography, topographic surveys and GIS data, satellite imagery and LIDAR data, the Forest Inventory Mapping System (Hammermaster and Saunders, 1995), and photographs and physical observations collected by specialist teams during visits to the Project area.

A three-dimensional computer model, or viewshed analysis, was undertaken using elevation data from airborne LIDAR technology to derive an accurate digital elevation model of the topography surrounding the CPF, Logistics Base and Purari Airstrip extension. These models typically use only ground data points, removing existing non-Project structures and vegetation; however, as vegetation in the onshore Project area will have a considerable effect on reducing the visibility of the Project components and activities, this model incorporated an assumed average vegetation height to all non-cleared areas to account for existing vegetation.

The location, extent and height of key Project components were incorporated into the model for the CPF, Logistics Base and associated infrastructure in PRL-15. Assumptions incorporated into the model, which represents a conservative scenario in terms of its prediction of overall visibility, are listed below:

- Heights of the CPF low-pressure vent and high-pressure flare are 50 m and 104 m, respectively. These heights are measured from ground level and include the platform for each piece of infrastructure.
- Buildings at the Purari Airstrip are 4 m high.
- Buildings at the Logistics Base are 8 m high.
- Buildings at the CPF are 8 m high.

- Canopy cover in the onshore Project area is 60 to 80%, and canopy height varies considerably. The vegetation canopy height included in the viewshed analysis is 20 m, as a conservative value based on advice of the Project biodiversity specialists.
- Modeling from viewpoints has applied a viewer eye level of 1.5 m above the ground surface, within a 100 m buffer around Poroi 1, Mapaio Fish Camp, the Purari Airstrip House, and the PRL-15 oxbow wetlands.

The significance assessment method described in Chapter 3 was adopted to qualitatively assess the potential impact on visual amenity. This method considers the magnitude of impact on a receptor and the sensitivity of that receptor. Impact assessment criteria have been developed specifically for this assessment.

Visual sensitivity is a measure of how changes to the landscape or viewshed are viewed by receptors (or viewers – in this case primarily village residents) from representative viewpoints surrounding a development. While individuals will perceive change to their environment differently, visual sensitivity does not consider viewer opinion (i.e., whether the view is considered good or bad), but incorporates the viewer’s likely expectations and experience (i.e., whether the view is what is expected considering the surrounding landscape and the activities being undertaken), the number of viewers to experience the view and the duration of the view.

Table 15.25 outlines ratings for sensitivity in relation to visual amenity.

Table 15.25 – Visual Amenity Sensitivity Criteria

Sensitivity	Description
Very High	♦ The viewpoint is a location where people’s attention is focused on the landscape (e.g., a national park viewing platform). ♦ The viewpoint is visited daily and/or by more than 2,000 people per day from local, regional or international communities/visitors. ♦ Views are experienced for more than a day by local, regional or international communities/visitors. ♦ Very high-use subsistence and recreational areas, specific cultural sites and viewpoints of national significance.
High	♦ The viewpoint is a location where people’s attention is often focused on the landscape. ♦ The viewpoint is visited weekly and/or by 1,000 - 2,000 people per day from local or regional communities. ♦ Views are experienced over several hours by local or regional communities. ♦ High-use subsistence and recreational areas, specific cultural sites and viewpoints of local significance.
Medium	♦ The viewpoint is a location where people’s attention is occasionally focused on the landscape. ♦ The viewpoint is visited fortnightly and/or by 500 – 1,000 people per day from local communities. ♦ Views are experienced for 1 – 2 hours by local communities. ♦ Moderate-use subsistence and recreational areas that are used weekly by the local community for subsistence or travel.
Low	♦ The viewpoint is not a location where people’s attention is focused on the landscape. ♦ The viewpoint is visited monthly and/or by less than 500 people per day from local communities. ♦ Views are experienced for less than 1 hour by local communities. ♦ Moderate-use subsistence or recreational areas that are used monthly by people from local communities for subsistence or travel.
Minimal	♦ Physically and/or visually inaccessible areas, or rarely accessed by local people. ♦ Areas with no permanent settlements.

The extent of modifications being made to the existing landscape, the distance of viewpoints from Project infrastructure and angle of view, the extent of screening and the permanency of change, are key factors in assessing the magnitude of a visual impact. The magnitude of visual impact of the Project was determined using the descriptors in Table 15.26

Table 15.26 – Visual Amenity Magnitude of Impacts Criteria

Magnitude	Description
Very High	♦ Landscape modification that is visually dominant in the immediate foreground of view (i.e., up to 0.5 km from the viewpoint) and/or occupies more than 45° of the field of vision. ♦ A permanent change to the visual landscape that takes place in weeks or months. ♦ Visual modification or intrusion, including buildings and facilities, that presents as an alien form to visual amenity, representing a fundamental change to the landscape character.
High	♦ Landscape modification that is clearly visible in the fore- to mid-ground of view (i.e., 0.5 to 1 km from the viewpoint), and/or occupies 30 to 45° of the field of vision. ♦ A permanent change to the visual landscape that takes place over 1 to 2 years. ♦ Visual modification or intrusion that presents as an alien form to visual amenity and is apparent due to dissimilarity to the existing landscape character.
Medium	♦ Landscape modification that is visible in the middle ground of view (i.e., 1 to 5 km from the viewpoint) and/or occupies 15 to 30° of the field of vision. ♦ A permanent change to the visual landscape that takes place in the long term over 3 or more years. ♦ Visual modification that leads to moderate change to visual amenity; it causes an apparent but not substantial change to the landscape character.
Low	♦ Landscape modification that is visible in the background of view (i.e., more than 5 km and less than 15 km from the viewpoint) and/or occupies 2.5 to 15° of the field of vision. ♦ A temporary change to the visual landscape that occurs over months to 2 years. ♦ Visual modification that leads to a minor change to visual amenity; it may be apparent but blends in with the existing view and will not cause a fundamental change to the landscape character, or other alien forms exist in the landscape.
Minimal	♦ Landscape modification that is barely perceptible in the distant background of view (i.e.,15 to 30 km from the viewpoint) and/or occupies up to 2.5° of the field of vision, ♦ A temporary change to the visual landscape that occurs over weeks to months. ♦ Change is imperceptible or barely detectable with respect to the existing landscape character (e.g., a road/clearing in an area containing other roads/clearings), and/or almost completely screened by intervening features.

The potential visual impact of the Project components was assessed by considering the visual sensitivity of a receptor from a specific viewpoint, and the magnitude of visual effect of the Project from each viewpoint using the matrix shown in Table 15.27.

Table 15.27 – Visual Amenity Significance of Assessment Matrix

Magnitude of Impact	Sensitivity				
	Very High	High	Medium	Low	Minimal
Very High	Extreme	Major	Major	Moderate	Moderate
High	Major	Major	Moderate	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor	Minor
Low	Moderate	Moderate	Minor	Minor	Negligible
Minimal	Minor	Minor	Negligible	Negligible	Negligible

Viewpoints

There are limited viewpoints in the Project area that are likely to have significant visual divergence from the surrounding visual landscape due to the dense vegetative cover, remoteness, and topographical features. Viewpoints were selected to represent the range of views and receptors likely to be affected by the Project, and considered:

- Places of habitation and other areas of land use or transit from which Project components may be seen.
- The distance of viewpoints from Project areas and the angle of view.
- Whether viewpoints are permanent (e.g., villages) or transient (e.g., river traffic).

On this basis, viewpoints have been identified and a sensitivity assigned in Table 15.28.

Table 15.28 – Project Viewpoints Assessed

Location	Description
Places of habitation near the CPF, Logistics Base and Purari Airstrip.	♦ Poroi 1 and Mapaio Fish Camp are approximately 2.5 km to the southeast and 6.9 km to the west (respectively) of the Logistics Base on the Purari River (see Figure 4.4). ♦ The house near the Purari Airstrip is approximately 2.9 km southwest of the Logistics Base. ♦ **Low sensitivity** (less than 500 people per day; only used by people from local communities; views are temporary; high use for primary subsistence activities).
PRL-15 oxbow wetlands.	♦ The PRL-15 oxbow wetlands are approximately 8.5 km west of the CPF and 2.5 km north of Mapaio Fish Camp (see Figure 7.28). ♦ The wetlands are accessed by local communities year-round for subsistence collection of natural resources and for cultural reasons. ♦ **Minimal sensitivity** (area with no permanent settlement accessed rarely by people from local communities).
River transport corridors and river villages.	♦ Villages in the river transport corridors include Kaevaria, Evara, Aivai, Aumu and Apiope on the Purari River, and Mapaio, Kairu'u and Akoma on the Urika-Ivo River (see Figure 13.1). ♦ The village of Aivai on the west bank of the Purari River is approximately 1.8 km west of the onshore export pipeline route. A pipe yard and pipeline construction camp are proposed between the east bank of the river and the onshore export pipeline route (see Figure 4.6). ♦ The river transport corridors are used daily by both the community and commercial operators (see Sections 9.10 and 10.5). ♦ **Low sensitivity** (riverways have daily but often transient use mostly less than 500 people per day, predominantly from local communities; daily use for primary subsistence activities).
Coastal villages and land use areas near the export pipeline route.	♦ The closest villages to the onshore export pipeline route near the coast are Mareke and Iuku, the closest residences of which are 350 m from the proposed route (see Figure 13.1). ♦ In addition to residences, local inhabitants use the beach, walking tracks and vegetated areas near the pipeline route on a daily basis. ♦ **Medium sensitivity** (between 500 and 1,000 local people use the coastal area daily for primary subsistence activities, cultural activities, access, travel and recreation; views are typically experienced for 1 to 2 hours).

Lighting Impacts

The assessment also considered potential visual impacts at night. Direct lighting impacts were the key consideration and included all lights that have a line of sight exposure to locations beyond a Project site boundary that are not screened by topography or vegetation. Indirect light, which is defined as the contribution that Project lighting has to the 'glow' effect visible in a dark night sky, was not considered in this assessment due to substantial topographic features, and dense vegetation coverage which restrict views from places of habitation.

15.4.2.2 Landscape Character Assessment

Landscape character refers to the distinct, recognizable and consistent pattern of elements in the landscape that makes one landscape different from another. Part 21 of Volume 2 provides a detailed description of landscape character for the Project area.

The landscape character assessment considers the relative capacity of the landscape to accommodate changes of the type and scale due to the Project, through both the introduction of new features and the loss or modification of existing features. It sought to assess how Project-related changes may affect landscape character and its contribution to a 'sense of place' and was undertaken in the context of how Project infrastructure would impact on the broader regional setting, as seen from the air.

The sensitivity of a landscape considers the extent to which it can accept change of a particular nature and scale without adverse effects on its character. In this assessment it considers whether:

- It is protected by national designation and/or widely acknowledged for its quality and value.
- It has a distinctive character and low capacity to accommodate the nature and scale of change proposed.

Changes to landscape character were assessed in consideration of these factors and the Project description in Chapter 4.

15.4.3 Identification of Potential Impacts

15.4.3.1 Change to Visual Amenity

The construction and operations of Project facilities and infrastructure, some of which may be temporary in nature, may change, reduce or lose existing visual amenity or landscape character for viewers from representative viewpoints (i.e., Project receptors). Temporary construction areas include laydown areas associated with pipeline construction, camps, pipeline and material storage yards, workshops and material extraction sites. Operations phase footprints, which have a longer duration, include wellpads, the CPF, Logistics Base, pipeline right of ways, access roads, the upgraded Purari Airstrip, and ancillary and communication facilities.

During the Project's construction phase, the extent of changes to visual amenity will progressively increase as the Project footprint increases. As key elements in PRL-15, such as the CPF, most notably the vent and flare, Logistics Base and the Purari Airstrip extension, are progressively constructed, viewpoints from which Project components and activities may be seen by Project receptors will increase depending on the viewpoint (whether along the river, PRL-15 oxbow wetlands, the Purari Airstrip House, or as people move through the Project area). Project construction will change the landform and introduce new industrial elements into a remote and largely natural landscape. To some extent screening by elevated topography and dense, tall vegetation will ameliorate these landscape and visual amenity impacts.

While vegetation clearing and earthworks associated with the construction of the onshore export pipeline will change the landscape and visual amenity, few villages or transport routes are close enough to the corridor to be exposed to these impacts. The exception are communities close to the onshore export pipeline at Orokolo Bay who will experience reduced visual amenity during the approximately 6-month export pipeline construction period on the approach to and at the shore crossing. Vegetation in the pipeline right of way will be allowed to partially regenerate following rehabilitation works, which will reduce visual amenity impacts. Nonetheless, vegetation height will be permanently reduced along the pipeline route for ongoing pipeline integrity and to enable maintenance, which represents a longer-term change to landscape character.

During the 25-year Project operations phase, the extent of landscape change and visual impact will vary as construction progresses and screening provided by existing vegetation and vegetation regrowth. The most prominent change to landscape character and visual amenity will result from the most visible key Project components, such as the vent and flare at the CPF, and the Logistics Base adjacent to the Purari River.

The following embedded design controls address impacts to visual amenity and landscape:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- Waste will be managed to reduce, reuse and recycle/recover the waste where practicable. Waste management requirements (e.g., waste inventory, segregation, storage, disposal, tracking, recording) will be detailed during FEED [ED039].

15.4.3.2 Viewshed Analysis

A viewshed analysis was completed to identify the extent of potential visual impacts to sensitive receptors in the onshore Project area (see Section 15.4.5). The viewshed analysis outlines areas that are potentially visible from identified viewpoints described in Table 15.28.

CPF, Logistics Base and Purari Airstrip

Project components in PRL-15 that have the potential to be seen from the four identified viewpoints in Table 15.29 include the CPF flare, vent, and buildings, the buildings of the Logistics Base, and the buildings of the Purari Airstrip extension. Table 15.30 provides approximate distances between the viewpoints and these features, and Figure 15.8 shows the viewshed analysis undertaken for this area.

Table 15.29 – Distance of Viewpoints from Project Features

Viewpoint	Approximate Distance from Project Feature (km)		
	CPF	Logistics Base	Purari Airstrip*
Poroi 1	3.8	2.5	1.8
Mapaio Fish Camp	7.9	6.9	5.4
Purari Airstrip House	4.8	2.5	0.1**
PRL-15 oxbow wetlands	8.5	8.3	7.9

Note: * Measured to the closest boundary of the proposed upgrade. ** 85 m to the proposed perimeter road at the northern end of the airstrip.

The viewshed analysis indicates that the shorter of these Project components will theoretically be visible for 5 km or more, while the flare and vent (104 m and 50 m tall, respectively) could potentially be visible above the tree line for 10 km or more. In both cases, little of this area is inhabited, and the screening effects of existing tall, dense vegetation and topography will limit the visibility of these features considerably.

As shown in Figure 15.8 and summarized in Table 15.30, given their river valley locations and the screening effects of the local environment, viewers at Poroi 1 and Mapaio Fish Camp will not be able to see any Project features. The family house at the Purari Airstrip, day users at the PRL-15 oxbow wetlands or those on the Purari River transiting near the Logistics Base may be able to see some of the Project components in PRL-15.

CPF, LOGISTICS BASE AND PURARI AIRSTRIP VIEWSHED ANALYSIS

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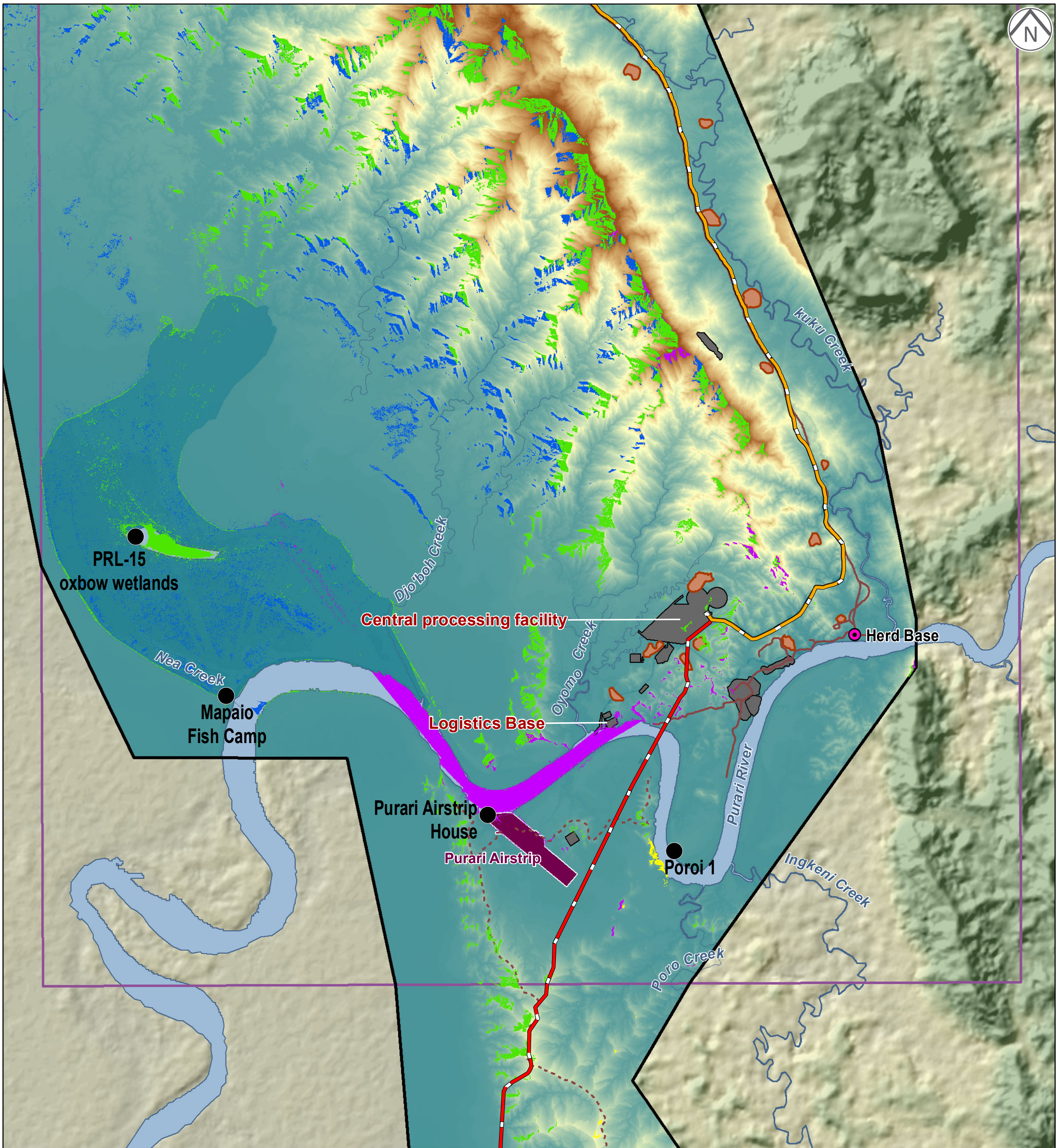
FIGURE 15.8



SCALE: 1:110,000 @ A4 | 0 1.25 2.5 5 KM | COORDINATE SYSTEM: PNG94 UTM Zone 55S

- Existing road
- Former logging road
- Waterway
- Waterbody or major river
- PRL-15
- Base camp
- Export pipeline route
- Trunkline/flowline route (gathering system)
- Proposed Project arrangement (See Figure 4.4 for detail)
- Spoil disposal site
- Sensitive receptor
- Assessed area
- Visibility from Poroi 1
- Visibility from Purari Airstrip House
- Visibility from PRL-15 oxbow wetlands
- Visibility from Mapaio Fish Camp

Elevation (m)
High : 454
Low : 0

Inhabitants of:
- Poroi 1 cannot see the CPF vent, flare or any associated building infrastructure.
- Purari Airstrip House can see the Purari Airstrip, Logistics Base and the CPF flare.
- Mapaio Fish Camp cannot see the CPF vent, flare or any associated building infrastructure.
Users of the PRL-15 oxbow wetlands can see the CPF vent, flare and CPF building infrastructure.

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Table 15.30 – Visibility of Project Features from Viewpoints

Viewpoint	Ability to View Project Features				
	CPF Buildings	CPF Flare	CPF Vent	Logistics Base Buildings	Purari Airstrip Buildings
Poroi 1	No	No	No	No	No
Mapaio Fish Camp	No	No	No	No	No
Purari Airstrip House	No	Yes	No	Yes	Yes
PRL-15 oxbow wetlands	Yes	Yes	Yes	No	No

Note: Visibility from the viewpoints modeled consider an average 20 m vegetation height.

River Transport Corridors

The primary visual impact of the river transport corridors will relate to increased river traffic, rather than construction or operation of infrastructure, although users of the Purari River near the Logistic Base and the Purari Airstrip may notice Project construction and increased activity, and may catch distant views of the CPF flare. As noted in Table 15.28 viewpoints in the river transport corridors include villages on the banks of the Purari and Urika-Ivo rivers. Residents of these villages will view increased river traffic, primarily during the construction phase, both from their villages and while using the river and banks for travel and subsistence activities.

Onshore Export Pipeline Route

Changes to visual amenity during construction along the onshore export pipeline route will be due to temporary construction activities such as vegetation clearing, earthworks and the presence of machinery. Operations phase landscape changes will be a permanent, cleared corridor with short vegetation through logged forest, signage and valve stations.

The Aivai village residents may experience a temporary decline in visual amenity (in addition to river transport impacts) during the Project construction phase due to the proposed pipe yard and pipeline construction camp on the opposite side of the river to the village.

Most of the export pipeline route passes through uninhabited areas, with minimal potential for visual impacts associated with the pipeline right of way, until it reaches the more densely populated coastal area in Orokolo, where the pipeline route passes closer to communities. Here communities are likely to see a temporary decline in visual amenity associated with clearing of the right of way and access track, and the presence of construction vessels offshore.

15.4.3.3 Project Lighting Impacts

General Lighting

Permanent lighting is planned for facilities that are constantly crewed, such as the CPF. Throughout the Project construction and operations phases, night lighting will be required to illuminate work areas and associated infrastructure for safe operations. Night lighting will be located, as required, for safety and security.

Lighting requirements for the Project components are yet to be finalized. Night operations are not currently planned for the Purari Airstrip, and as such, any lighting will be restricted to security or safety lighting.

As the CPF buildings will not be seen from any villages, night lighting from the CPF is not expected to adversely affect any local inhabitants. The Logistics Base and Purari Airstrip may be visible from the Purari Airstrip House during both the night and the day, depending upon the final lighting design for these two facilities; however, as the airstrip will not be used for night flights and the Logistics Base is primarily a day use operational area, substantial night-lighting is not anticipated to be required and is not expected to adversely affect local inhabitants.

Gas Flare

Gas flaring from the CPF will be required occasionally during start-up, maintenance and upset conditions. The 104 m tall, high-pressure flare stack may be seen from the Purari Airstrip House. If flaring is required at night, the flare may reduce visual amenity at this location due to the brightness and apparent movement of the flame; however, upset condition flaring is rare and would not adversely affect residents of the Purari Airstrip House; therefore, flaring is not assessed further.

In addition to flaring, aircraft warning lights on the flare stack will be visible, though more so at night. Given the nature of these lights (i.e., height, directionality, purpose), these are not expected to adversely affect residents of the Purari Airstrip House and they are not assessed further.

15.4.3.4 Landscape Character

Changes to landscape character comprise the introduction of industrial elements into landscapes that contain few built structures of a similar nature, and that are generally characterized by dense vegetation and restricted access, based upon river transportation and a very limited network of existing roads and trails. In places, modifications to landform due to earthworks to develop these facilities (e.g., CPF, quarries) will also change landscape character.

15.4.3.5 Summary of Potential Impacts

The Project has the potential to cause the following potential impacts to landscape and visual amenity:

- Decline, loss of or change to existing visual amenity or landscape character, including illumination from night lighting for the Purari Airstrip House.
- Decline or change to existing visual amenity, landscape character or connectivity for people using the PRL-15 oxbow wetlands for fishing, hunting or cultural activities.
- Temporary decline or change to existing visual amenity along the river transport corridor due to increased barge traffic.
- Decline or change to existing visual amenity for river users near the Logistics Base and the Purari Airstrip.
- Temporary decline or change to existing visual amenity for people in Aivai, particularly during pipeline construction.
- Change in landscape connectivity and a temporary decline in visual amenity for some communities in Orokolo Bay.
- The introduction of new industrial elements into a predominantly natural landscape.

15.4.4 Proposed Mitigation and Management Measures

Table 15.31 describes proposed mitigation and management measures to further reduce adverse effects on landscape and visual amenity .

Table 15.31 – Landscape and Visual Amenity Mitigation Strategies and Management Plans

<table>
<tr><th>Potential Impact</th><th>Mitigation Strategy</th><th>Relevant Management Plan</th></tr>
<tr><td>Decline, loss of or change to existing visual amenity or landscape character, including illumination from night lighting for the Purari Airstrip House.</td><td>♦ Avoid directly lighting areas at night and minimise fixed night lighting for safe operations, e.g., direct lighting away from the Purari Airstrip House, and the surrounding forest [EM047].</td><td>Biodiversity Action Plan; Community Health, Safety and Security Plan</td></tr>
<tr><td>Decline, loss of or change to existing visual amenity, landscape character or connectivity for people using the PRL-15 oxbow wetlands for fishing, hunting or cultural activities.</td><td>No additional mitigation measures proposed.</td><td>NA</td></tr>
<tr><td>Decline, loss of or change to existing visual amenity due to increased barge traffic.</td><td>No additional mitigation measures proposed.</td><td>NA</td></tr>
<tr><td>Decline, loss of or change to existing visual amenity for river users near the Logistics Base and the Purari Airstrip.</td><td rowspan="4">♦ Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape, e.g.,
– Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g., rip the substrate, replace topsoil, apply mulch.
– Rehabilitate Pandanus habitats, e.g., recreate mounds, re-instate the intertidal surface between Pandanus mounds.
– Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion.
– Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration.
– Use native vegetation to revegetate sites when active rehabilitation measures are required [EM029].
♦ Where practicable, retain a vegetation buffer to screen infrastructure and facilities. [EM048].</td><td rowspan="4">Biodiversity Action Plan; Site Restoration and Rehabilitation Plan.</td></tr>
<tr><td>Decline, loss of or change to existing visual amenity for people in Aivai, particularly during pipeline construction.</td></tr>
<tr><td>Change in landscape connectivity and in views for some communities in Orokolo Bay.</td></tr>
<tr><td>Changes to landform and the introduction of new industrial elements into the landscape.</td></tr>
</table>

Note: NA = Not applicable.

15.4.5 Residual Impact Assessment

The following sections provides the assessment of residual impacts to visual amenity and landscape subject to the embedded design controls in Section 15.4.3 and the successful implementation of the mitigation measures in Section 15.4.4.

15.4.5.1 Visual Amenity Assessment

CPF, Logistics Base and Purari Airstrip

Places of habitation near the CPF, Logistics Base and the Purari Airstrip have been assigned a ***Low*** sensitivity rating, as these viewpoints are not locations where the communities' attentions are focused on the landscape and they are visited/used by less than 500 people per day (Table 15.28). Purari Airstrip House residents are likely to see part of the flare stack (in the background of view, approximately 4.8 km distant), but not the vent or the CPF buildings, due to vegetation and terrain screening effects.

The flare will be a new and permanent feature for these residents; however, its presence in the background of view and in a very narrow field of vision, and the limiting of flaring during upset conditions to daylight hours where practicable, results in a ***Low*** magnitude rating, resulting in a residual impact significance assessment of ***Minor***.

Purari Airstrip House residents will also be able to see the Logistics Base in the middle ground of view, approximately 2.5 km along the river to the northeast, and the airstrip buildings in the foreground, approximately 60 m to the southeast. The Logistics Base will present as a permanent and new form to these residents, but its location in the middle ground of view and filling less than 10° of the field of vision, and the fact that Herb Base exists further upriver, will have an overall visual impact of ***Low*** magnitude, resulting in a residual significance assessment of ***Minor***.

Despite the airstrip buildings being a permanent change in the foreground view from this house, they will be low-lying and are part of an upgrade to the existing airstrip facility, as such blending in with existing features; therefore, the overall impact on visual amenity will be of ***Low*** magnitude, resulting in a residual impact significance assessment of ***Minor***.

Individuals using the PRL-15 oxbow wetlands may see part of the flare, vent, and CPF buildings, approximately 8.5 km in the distance. Viewers will not see buildings at the Logistics Base or the Purari Airstrip due to the screening effects of terrain. Although these features will be a permanent change to the visual landscape from this viewpoint, they will form a very narrow part of the field of vision, providing an overall visual impact magnitude rating of ***Low***. Given the ***Minimal*** sensitivity rating attributed to viewers at this viewpoint, this results in a residual impact significance assessment of ***Negligible***.

River Transport Corridors

Villages along the river transport corridors have been assigned a ***Low*** sensitivity rating as these viewpoints are not locations where the communities' attentions are focused on the landscape and they are predominantly visited/used by less than 500 people per day (see Table 15.28). While the visual impacts associated with increased barge movements (Section 15.4.3.2) may be in the immediate foreground of view for communities on or using the riverways, they will be short-term (i.e., the increase in barge traffic will be focused on the construction period) and transient (i.e., barges pass relatively quickly). Further, as there are already barges operating on the Purari River, the primary Project transport route, this change does not represent the introduction of a new feature to the landscape, only a small increase in barge frequency. For these reasons, the magnitude of additional barges being visible to communities along the Purari River is rated as ***Minimal*** magnitude, resulting in a residual impact significance assessment of ***Negligible***.

A sensitivity rating of ***Low*** was assigned to viewers on the river near the Logistics Base and the Purari Airstrip extension, as while this part of the river is used frequently as a primary transport method, it is used by few people (estimated at fewer than 100 per day based on nearby village and settlement sizes), from local communities, and views are temporary as people move past the infrastructure. The magnitude of any visual impact is rated as ***Medium***, as the proposed modifications will form a permanent change in the landscape, causing an apparent but insubstantial change to the landscape character, as it will be partially screened from view due to the riparian vegetation. Further, with the airstrip and Herd Base already being visible along this stretch of the river, the proposed changes will not represent a major divergence from the current landscape; therefore, the residual impact significance assessment of visual impacts on river users around, and approaching, the Logistics Base and the Purari Airstrip is assessed as ***Minor***.

Onshore Export Pipeline Route

Temporary landscape changes during construction of the export pipeline route will include vegetation clearing, earthworks and the presence of machinery, both onshore and offshore. Operations phase landscape changes will be a permanent, cleared corridor with short vegetation through logged forest, signage and valve stations.

Aivai village residents will experience a temporary decline in visual amenity, in addition to river transport impacts, during the Project construction phase due to the proposed pipe yard and pipeline construction camp on the opposite side of the river, towards the export pipeline right of way.

Most of the decline in visual amenity will be temporary, as the works and infrastructure will blend with the existing logging road, and measures to maintain riparian vegetation and allow regeneration will minimize the amount and length of time that buildings can be seen. This results in a ***Low*** magnitude rating for visual impact on Aivai village residents. Given the ***Low*** sensitivity rating assigned (see Table 15.28), the residual impact significance assessment is rated as ***Minor***.

While most of the pipeline route passes through uninhabited areas, there is the potential for a decline in visual amenity for coastal villagers, inhabitants of outlying residences and pedestrian traffic near the right of way. Coastal villages and land use areas near the export pipeline route have been assigned a ***Medium*** sensitivity rating as the area around the coast at Orokolo Bay is more densely populated and used more frequently for subsistence, cultural and recreational activities than elsewhere in the PAOI (see Table 15.28).

Landscape modification due to construction of the export pipeline shore crossing will not be visible from the nearby villages of Iuku or Mareke due to vegetation screening. Pedestrian traffic along the beach next to these villages may observe the construction activities in the immediate foreground, but these are likely to be visible only as they pass by, or are diverted around, or over, construction activity, or when the pipelay and other support vessels are active. Construction of the export pipeline shore crossing will also be visible to those gathering on the beach for social or recreational reasons. For residential, pedestrian and social/recreational viewers, most of the decline in visual amenity will be temporary (construction); although, the reduced vegetation height will be permanent over the pipeline ROW during operations, causing an apparent but insubstantial change to the landscape character. For these reasons, a ***Low*** magnitude rating is assigned, resulting in a residual impact assessment of ***Minor***.

Plates 4.8 and 4.9 highlight the decline in visual amenity that would be temporarily experienced by coastal communities close to the onshore export pipeline shore crossing.

15.4.5.2 Landscape Assessment

Several oil and gas industrial facilities exist at a regional or national scale in Papua New Guinea, such as the PNG LNG Facilities at Caution Bay or facilities and pipelines at Gobe and Lake Kutubu. No developments of a comparable scale or form to the Project occur in the provincial and local setting.

The introduction of new industrial elements into a landscape characterized by its forest cover, natural landforms and remoteness results in changes to landscape character through reduction in tree cover, modification of local landforms and potentially a reduction in sense of remoteness or perceived ‘untouched’ nature of the place. However, several intrinsic design and location factors combine to mitigate potential impacts to landscape character, such as changes to landform and increased sense of development, and include the:

- Presence of Herd Base near the CPF and Logistics Base that will contribute to visual integration of the Project in this area.
- CPF and associated infrastructure are not the first developments in the area, with oil and gas exploration facilities, and logging operations having been established in the area over the past decade.
- Pre-Project design, which maximizes the use of disturbed land; approximately 20% of the Project footprint in PRL-15 is on previously disturbed land, while most of the export pipeline route is on land previously degraded by commercial logging (see Section 4.10.7). The visual impact of Project pipelines, roads and vegetation clearing will be similar to that of existing logging roads and forest harvesting areas.
- Presence of dense vegetation, elevated topographical features near PRL-15 and the meandering Purari River will help to conceal Project facilities and infrastructure when viewed from the ground.
- Fast-growing vegetation, which will be allowed to regenerate around non-operational Project areas, and post-decommissioning, will help return the Project area to a near-natural condition.

Due to these factors, and the embedded design controls and mitigation measures proposed, changes to the broader landscape character are likely to represent minimal modification to landscape character in and around the Project area.

15.4.6 Summary of Residual Impacts to Landscape and Visual Amenity

A summary of the assessment of residual impacts related to landscape and visual amenity including the Project phase and location, and when and where impacts are expected to occur, is provided in Table 15.32. The table should be read in conjunction with the mitigation measures provided in Table 15.31. The residual visual impacts due to the Project were assessed as ***Minor*** or ***Negligible*** for all inland receptors, given the low sensitivity of receptors and the minimal to low magnitude of visual impacts.

Table 15.32 – Summary of Assessment of Residual Impact Significance Landscape and Visual Amenity

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Purari Airstrip House	Gas flaring. Vegetation clearing. Earthworks. Construction works (Airstrip buildings, Logistics Base and flare).	Decline, loss of or change to existing visual amenity or landscape character. Illumination from night lighting, which may reduce visual amenity for residents in the Purari Airstrip House.	PRL-15	C, O, D	♦ EM047	Low/Low (flare) Low/Low (Logistics Base) Low/Low (airstrip)	Minor
PRL-15 oxbow wetlands	Vegetation clearing.	Decline, loss of or change to existing visual amenity, landscape character or connectivity.	PRL-15	C, O, D	None	Minimal/Low	Negligible
Villages in the river transport corridors	Logistics and transport (barging).	Decline, loss of or change to existing visual amenity.	River transport corridor	C, O, D	None	Low/Minimal	Negligible
Users of the Purari River around the Logistics Base and the Purari Airstrip	Vegetation clearing Construction works (Logistics Base and the Purari Airstrip).	Decline, loss of or change to existing visual amenity.	PRL-15	C, O, D	♦ EM029 ♦ EM048	Low/ Medium	Minor

Table 15.32 – Summary of Assessment of Residual Impact Significance for Landscape and Visual Amenity (cont'd)

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Aivai village on the Purari River	Vegetation clearing. Earthworks. Onshore pipeline construction (including associated infrastructure).	Decline, loss of or change to existing visual amenity, particularly during pipeline construction.	Export pipeline corridor	C, O, D	♦ EM029 ♦ EM048	Low/Low	Minor
Coastal villages and associated land use areas	Vegetation clearing. Earthworks. Onshore pipeline construction (including associated infrastructure).	Change in specific landscape connectivity. Change in view for local community.	Export pipeline corridor			Medium/Low	Minor

C = Construction, O = Operation, D = Decommissioning and closure.

15.5 Commercial Traffic and Transport

15.5.1 Context

15.5.1.1 Coastal and River Shipping

No international shipping lanes traverse the Gulf of Papua near the offshore export pipeline corridor, although tankers arrive and depart from the PNG LNG Facilities in Caution Bay and from the Kumul Marine Terminal in the northern gulf. Shipping routes in the Gulf of Papua primarily center on commercial vessels sailing to and from Port Moresby and the inland river ports in Western and Gulf provinces. Typical vessels include cargo vessels, fuel tankers, bulk carriers, barges and tugs.

Existing traffic in the Project's river transport corridors (Route 6, Figure 10.7) includes barges from Port Moresby to Herd Base supplying TEP PNG's gas exploration activities in PRL-15 (approximately 190 return trips/year), and log barges to and from the Evara logging camp on the Purari River (approximately 24 return trips/year). TEP PNG also uses two small, high-speed barge-punts from Herd Base to transfer local personnel, goods and equipment to local locations up and down the Purari River and to neighboring villages.

At the Caution Bay terminus of the offshore export pipeline route, international LNG carriers, supported by four tugs and a pilot boat, serve the PNG LNG Facilities and complete approximately 200 trips/year to and from Port Moresby (Route 9, Figure 10.7). Supply and passenger ships from Port Moresby to Ihu (Route 7, Figure 10.7) also cross the offshore export pipeline route with an estimated 26 return trips/year.

Kiunga–Port Moresby (Route 2, Figure 10.7) is the busiest of other commercial shipping routes in the Gulf of Papua that may cross the offshore export pipeline route or Project shipping routes to/from Port Moresby, with 212 return trips/year. This is the key route for shallow-draft bulk carriers transshipping copper concentrate from the Ok Tedi mine to Port Moresby. It also serves Kiunga township and is used by cargo ships and barges for hydrocarbon exploration projects.

Other Gulf of Papua shipping routes include those between Port Moresby and Kikori/Kopi, Kumul Marine Terminal, and Baimuru and Daru townships. Timber industry shipping routes exist between Port Moresby and Bamu River tributaries, where there are timber processing facilities, and there are several logging shipping routes from other rivers west of the PAOI. The main overseas shipping lanes to and from Port Moresby are south, to the Australian east coast ports, and to the southwest, joining the Great North East Channel that leads to the Prince of Wales Channel through the Torres Strait and onwards to southeast Asia.

Further information on marine and river traffic and transport is presented in Chapter 10 and Part 22 of Volume 2. Figure 15.9 shows the shipping traffic operating in the Gulf of Papua during 2018.

15.5.1.2 Commercial Fishing Traffic

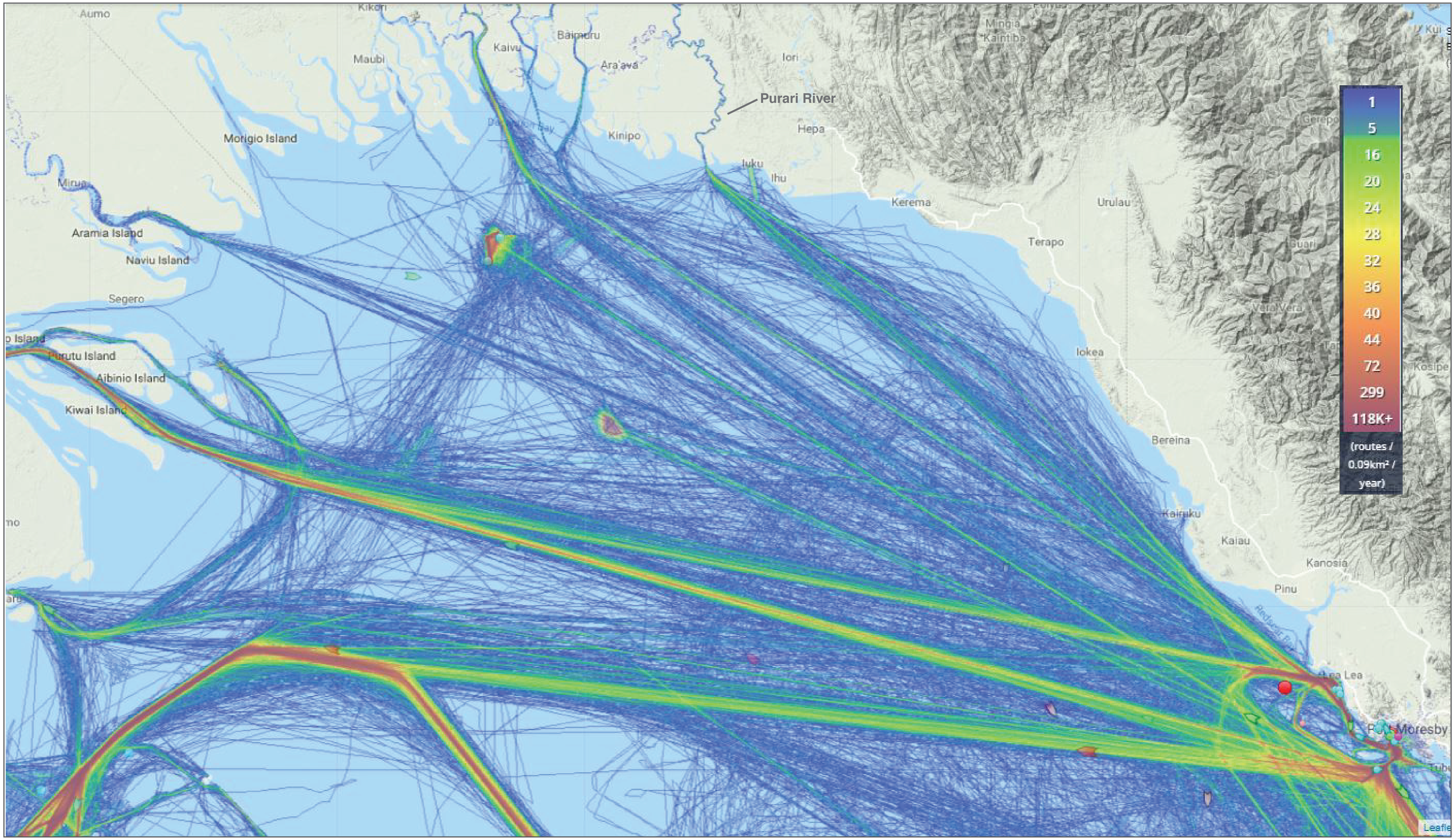
The Gulf of Papua Prawn Fishery currently operates eight trawlers, which are generally 24 to 30 m long, although smaller vessels occasionally trawl in more sheltered inshore waters. Trawling takes place 24-hours-per-day for approximately 250 days per year, between April and November.

The prawn fishing grounds extend seaward of the 3 nautical mile limit to approximately the 40 m depth contour, but trawlers typically operate in the 10 to 35 m depth range. Trawlers also access the 2 to 3 nautical mile zone based on joint venture agreements with local Gulf Province communities that have customary rights to these areas.

VESSEL TRAFFIC IN THE GULF OF PAPUA

Papua LNG Project I Environmental Impact Statement

FIGURE 15.9



Source: Marine Traffic, 2018.

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Rock lobster and bêche-de-mer fisheries in Torres Strait are well outside of the PAOI, and export shipping from Daru is unlikely to traverse close to the offshore export pipeline route or Project shipping routes. A relatively small bêche-de-mer fishery also operates along the coast of the Gulf of Papua, from April to September.

Further information on commercial marine fisheries is presented in Chapter 8 and Part 13 of Volume 2.

15.5.1.3 Road and Air Transport

The main road in Gulf Province is the coastal Hiritano Highway, which extends approximately 300 km from Port Moresby to Kerema. Currently, the condition of this road is variable, being poor in some sections with extensive potholes or unsealed surface, but good near Port Moresby and Kerema.

Public roads are absent in the PAOI itself; only logging roads and minor local tracks are present. Project accessways will be constructed in PRL-15 and along the length of the onshore export pipeline route, as described in Section 4.8.3.

The Jacksons International Airport in Port Moresby is the largest airport in the country and the main entry/exit point by air. The closest airstrip to the Project is the Purari Airstrip, which is currently used by the Project. The airstrip will be upgraded for Project use.

15.5.2 Discipline-specific Impact Assessment Method

The significance assessment method described in Chapter 3 was adopted to qualitatively assess the potential impact on commercial traffic and transport from construction and operation of the Project. This method considers the magnitude of impact on a value and the sensitivity of that value. Impact assessment criteria have been developed specifically for this assessment.

Sensitivity considers the susceptibility of a value to change and its intrinsic importance considering factors such as the:

- Capacity to adapt to change without adverse effects on the value's inherent attributes, i.e., its resilience.
- Rarity or uniqueness of the resource or receptor.
- Importance to local businesses, economies and communities.

Table 15.33 defines the categories for assessment of sensitivity adopted in the commercial traffic and transport assessment.

Table 15.33 – Commercial Traffic and Transport Sensitivity of Receptor Criteria

Category	Description
High	♦ Route that facilitates connectivity between cities or regional centers. ♦ Route that supports more than 250 return tips per year. ♦ Value (i.e., efficiency, safety and amenity) has limited or no capacity for increased use. ♦ Value is unaffected by the impact prior to Project interaction. ♦ Value provides the sole source of income for local businesses. ♦ Many commercial operators depend on the value and cannot access nearby alternatives. ♦ Value cannot be relocated or replaced or is not a type common in the surrounding region.

Table 15.33 – Commercial Traffic and Transport Sensitivity of Receptor Criteria (cont'd)

Category	Description
Medium	♦ Route that facilitates connectivity between townships or villages. ♦ Route that supports 150 to 250 return tips per year. ♦ Value (i.e., efficiency, safety and amenity) has some capacity for increased use. ♦ Some sign of exposure to the impact is already evident for this value prior to Project interaction. ♦ Value upon which commercial operators are occasionally dependent.
Low	♦ Route that facilitates connectivity between other main transport connections. ♦ Route that supports less than 150 return tips per year. ♦ Value (i.e., efficiency, safety and amenity) has significant capacity for increased use. ♦ Value is already affected by the impact prior to Project interaction. ♦ Value upon which local people are rarely dependent for provision of food or income. ♦ Commercial operators can access nearby alternatives to the affected value. ♦ Value can be relocated or replaced or is a type common in the surrounding region.

Magnitude of impact is defined by the impact's severity, and spatial and temporal extents. Table 15.34 defines the categories adopted for assessment of the magnitude of Project impacts on commercial traffic and transport. Assessment of the magnitude of impact is undertaken assuming proposed mitigation measures, or existing operating procedures have been successfully implemented, i.e., provides a residual impact assessment.

Table 15.34 – Commercial Traffic and Transport Magnitude of Impact Criteria

Category	Description
Very High	♦ An impact that extends to a national level, lasting for more than 10 years, and prevents existing traffic using the route. ♦ Significant negative changes to economic activities or access causing major economic loss or business closure. ♦ Collision at sea causing the loss of life and property.
High	♦ An impact that extends to a regional level, lasting five to 10 years, and disrupts existing traffic using the route. ♦ Noticeable temporary negative changes to economic activities or access causing moderate economic loss. ♦ Collision at sea causing the loss of property.
Medium	♦ An impact that extends to a local level, lasting less than five years, and delays existing traffic using the route. ♦ Temporary, partial interruption to economic activities or access causing minor short-term economic loss. ♦ Incident resulting in a near miss.
Low	♦ An impact that is highly localized, predominantly contained in the PAOI, lasting less than five years. ♦ Minimal or no interruption to economic activities or access and commercial activities. ♦ Can be effectively mitigated through standard management controls.
Negligible	♦ No appreciable impact compared with baseline conditions. ♦ The impact is within a normal range of variation.

A matrix combining the magnitude of impact category with the sensitivity category determines the significance of the impact from the Project's activities. Table 15.35 presents the matrix used to establish the significance of Project impacts on commercial traffic and transport values.

Table 15.35 – Commercial Traffic and Transport Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Value		
	High	Medium	Low
Very High	Severe	Major	Moderate
High	Major	Moderate	Moderate
Medium	Moderate	Moderate	Minor
Low	Moderate	Minor	Minor
Negligible	Minor	Negligible	Negligible

15.5.3 Identification of Potential Impacts

15.5.3.1 Coastal and River Shipping

During construction, imported materials, fuel, chemicals, concrete, and equipment comprising CPF modules, pipes, and drilling equipment will be transported to the Project site for five years. Most of the imported materials will arrive through the Motukea Port or the Avenell Engineering Systems Ltd supply base near Port Moresby and be transported by sea and river to the Logistics Base. This will require up to four barges per day during the construction peak moving between Port Moresby and the Logistics Base or Herd Base on the Purari River and back again. An estimated 540 vessel movements per annum will be required during the peak Project construction period (Year 2). Barge movements during the operations phase may be three to five per month.

TEP PNG currently undertakes coastal and river shipping to support exploration activities and implements standard operating procedures in compliance with legislation and consistent safe shipping practices, including:

- Implementing normal maritime regulations to avoid interactions with commercial shipping vessels travelling through the Gulf of Papua.
- Maintaining regular communication with the PNG National Maritime Safety Authority (NMSA) and the National Fisheries Authority (NFA) to advise on offshore Project activities including planned vessel movements.
- Implementing appropriate and compliant (with NMSA regulations) navigation aids and equipment to enable monitoring of and communication with approaching vessels.

The following embedded design controls address the potential impacts identified below:

- Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges) [ED013].
- Liaise with NMSA to establish a safety exclusion zone around offshore export pipeline construction activities [ED042].
- Continue to work with relevant commercial operators to
  - Coordinate barge movements along the Purari River.
  - Notify them, as required, of in river Project activities and the associated hazards [ED043].
- Inform NFA and commercial fishing fleets who operate in the vicinity of the offshore export pipeline route of construction activities, including timing of construction activities and the safety exclusion zone [ED044].

- The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

Coastal Shipping

Vessels supporting TEP PNG's Project development activities currently use the shipping route (Route 6) between Port Moresby and the Purari River mouth, which crosses few other routes identified in Figure 10.7. Other shipping routes operating in the PAOI, and that could intersect with Project barge movements, are Route 7; Port Moresby to Ihu, which operates an estimated 26 passenger vessels each year, and Route 9; Port Moresby to the PNG LNG Facilities, which operates an estimated 200 vessel movements each year, and which is centered around Caution Bay.

There will be a temporary increase in Project-related vessel movements along the coastline focused on the five-year Project construction period. During this period, barge traffic will be highest in Years 1 and 2, thereafter reducing as the main infrastructure components (e.g., the CPF and roads) are completed. The increase in coastal barge traffic associated with Project construction will increase the total number of vessels using the Gulf of Papua coastal shipping routes, which could potentially increase the rate of vessel collisions. However, given the low numbers of ship movements in these coastal routes (Figure 15.9) and the very low likelihood of incidents based on historical data (Butt et al., 2013), vessel collisions due to increased barge traffic is considered negligible and not assessed further.

Potential impacts of vessels on the marine environment (e.g., marine habitat, flora and fauna) are discussed in Chapter 12, and the effects of additional marine traffic associated with other projects in the Gulf of Papua are considered in Chapter 17.

River Shipping

TEP PNG barges made 190 return trips from Port Moresby to Herd Base to transfer local staff, goods and equipment in 2016. Log ships belonging to Frontier Holdings Limited, a subsidiary of Rimbunan Hijau (PNG) Limited, make approximately 24 return trips a year from Port Moresby to the Evara logging camp.

During the peak construction period, up to 10 barges may use the approximately 100 km of river at any one time, and up to 14 barge trips per day will ferry workers approximately 2.5 km between the Purari Airstrip on the southern shore and the Logistics Base on the northern shore of the Purari River. This has the potential to hinder logging barges moving through this river reach. The construction activities required for the offloading facilities at the Logistics Base landing may also hinder river traffic during this time.

Increased river barging also has the potential to disturb community access and amenity, and poses a risk of increased accidents with community members who travel the river in canoes, discussed in Chapter 13.

15.5.3.2 Commercial Fishing Traffic

Any interactions between the coastal zone bêche-de-mer fishery and Project activities are predicted to be spatially restricted to the nearshore approaches in Orokolo Bay, and the segment of the pipeline corridor that intersects with the coastal zone offshore of Cape Suckling. Due to the very low potential for interactions between Project activities and commercial fishers, based on a highly limited spatial and temporal overlap, the coastal zone bêche-de-mer fishery has been excluded from further assessment.

The Project intersects with the offshore area of the Gulf of Papua Prawn Fishery. There are three potential impacts to this fishery relating to commercial traffic and transport; increased interactions between Project barges and commercial fishing vessels, interactions between Project pipelaying vessels and commercial fishing vessels, and interactions between fishing equipment and the export pipeline once laid.

The marine Project transport route is mostly outside the 3 nautical mile zone, which is where most of the commercial prawn fishing activities take place (see Figure 8.26), and therefore there is some, albeit very limited potential for interactions between Project barges and commercial fishing vessels, potentially interfering with, causing collisions or excluding access to fishing grounds. However, given low numbers of vessels in the Gulf of Papua Prawn Fishery and the embedded design controls that minimize the likelihood of collisions, the potential for interactions between Project barges and fishing vessels is considered negligible and is not assessed further.

While the offshore export pipelines are being laid, an exclusion zone will be maintained around the pipelaying barge and supporting vessels. However due to the temporary and transient nature of this activity (i.e., pipelaying will take place over several weeks and the barges will be constantly moving along the length of the future pipeline), and the small areas of overlap with commercial fisheries (see Section 16.5.1.7), the potential for disruption to fishing activities as a result of pipelaying is considered negligible and is not assessed further.

The potential for fishing equipment to become entangled on the offshore export pipeline is very low, given; the fishing fleet is aware of the existing PNG LNG Project pipeline, which the Project pipeline will follow for much of its length; the NMSA has a standard procedure of adding pipelines to navigation charts; and the pipeline will be largely outside the primary areas of fishing effort (see Figure 8.26). For these reasons, and the pipeline design measures discussed in Chapters 4, the potential for fishing equipment to become entangled on the export pipeline has been excluded from further assessment.

15.5.3.3 Road and Air Transport

Road transport from beyond the PAOI is not viable, as no roads access the Project area from outside the province. A local road and access track network will be used to transport equipment from the Logistics Base to work sites in the PAOI, using roads constructed or upgraded for this purpose. There are no public roads in the PAOI and while some logging roads exist, the public use them as walking tracks only. Logging vehicles no longer use the logging roads south and east of the Purari River, as most of the timber resources have been exploited, and logging activities are moving north of the Purari River, beyond the Project area. All planned road movements are distant from current communities. For these reasons, the potential for the Project to impact road traffic has not been assessed further.

Project personnel will be transported to the Project area by air. Air traffic to the Purari Airstrip will increase by up to five to seven airplane landings per day during the construction period. This will increase noise associated with planes larger than those currently using the airstrip, and more frequent take offs and landings, which may have noise implications for local communities; these are considered in Section 15.3.

The construction workforce may also increase the demand for seats on international flights to and from Port Moresby's international airport. This is discussed further as a potential cumulative impact in Chapter 17.

TEP PNG, Rimbunan Hijau (PNG) Limited and the occasional commercial airline charter flight currently use the Purari Airstrip. No regular, scheduled commercial flights use the airstrip. TEP PNG is currently negotiating an access agreement to use the airstrip, and access for other operators currently using the airstrip is expected to continue throughout construction and operations phases; therefore, the potential for the Project to impact on users of the airstrip is not assessed further.

15.5.3.4 Summary of Potential Impacts

The Project has the potential to interact with river traffic on the Purari River, potentially causing the following impact:

- Temporary delay of logging barges using the Purari River resulting from ferrying and/or barge offloading facilities during construction.

15.5.4 Proposed Mitigation and Management Measures

All potential impacts associated with commercial traffic and transport are managed through existing procedures and embedded design controls. No additional mitigation measures are required.

15.5.5 Residual Impact Assessment

The following section provides the assessment of residual impacts to commercial traffic and transport subject to the embedded design controls in Section 15.5.3.

The sensitivity of the Purari River as a transport route is rated as ***Medium***, as it is the primary route that connects towns and villages along the river transport corridor, with no roads available for alternate use. The Purari River is already used by TEP PNG and accounts for most vessel movements, with only one other known regular user; Rimbunan Hijau (PNG) Limited.

While the increase in barge traffic on the river is predicted to more than double during the construction period, a magnitude rating of ***Low*** is assigned to the potential for Project barges to disrupt logging vessels during the construction phase, as any delays or disruptions experienced by other river users would be highly localized, and temporary, and can be effectively managed through standard operating procedures and embedded design controls (Section 15.5.3.1). This results in a residual impact assessment rating of ***Minor***.

15.5.6 Summary of Residual Impact Assessment for Commercial Traffic and Transport

The following section provides the assessment of residual impacts related to commercial traffic and transport subject to the embedded design controls in Section 15.5.3. A summary of the residual impact assessments is provided in Table 15.36, including when and where (in which Project phase and location) these impacts are expected to occur.

Table 15.36 – Summary of Assessment of Residual Impact Significance for Commercial Traffic and Transport

Key Sensitivity	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation and Management	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Commercial vessels on the Purari River	Logistics and transport (barging along waterways)	Temporary disruption or delay of logging barges using the Purari River.	River transport corridor	C	None.	Medium/Low	Minor

C = Construction.

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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 16: Impacts – Ecosystem Services

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

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16. Impacts: Ecosystem Services

16.1 Context and Approach

Ecosystem services represent the intersection of the natural and human environment, and play a vital role in individual and community wellbeing. Accordingly, this chapter draws on relevant baseline information presented in Chapters 7 to 10, and analysis of environmental and social impacts presented in Chapters 11 to 15.

The International Finance Corporation (IFC) defines ecosystem services, as the benefits that people, including businesses, derive from ecosystems, and has divided these services into four categories (IFC, 2019):

- Provisioning services – the goods or products obtained from ecosystems, such as food, timber, fibers, fresh water and medicinal plants.
- Cultural services – the non-material contribution of ecosystems to human wellbeing, such as recreation, spiritual values and aesthetic enjoyment.
- Regulating and maintaining services – the contributions to human wellbeing arising from an ecosystem's control of natural processes, such as climate regulation, disease control, erosion prevention, water flow regulation, surface water purification, carbon storage and sequestration, and protection from natural hazards.
- Supporting services – the natural processes, such as soil formation, nutrient cycling and primary production, that maintain the other services.

Figure 16.1 illustrates the different types of ecosystem services in each category, and Table 16.1 highlights the requirements in each IFC performance standard, as they relate to addressing ecosystem services (IFC, 2012).

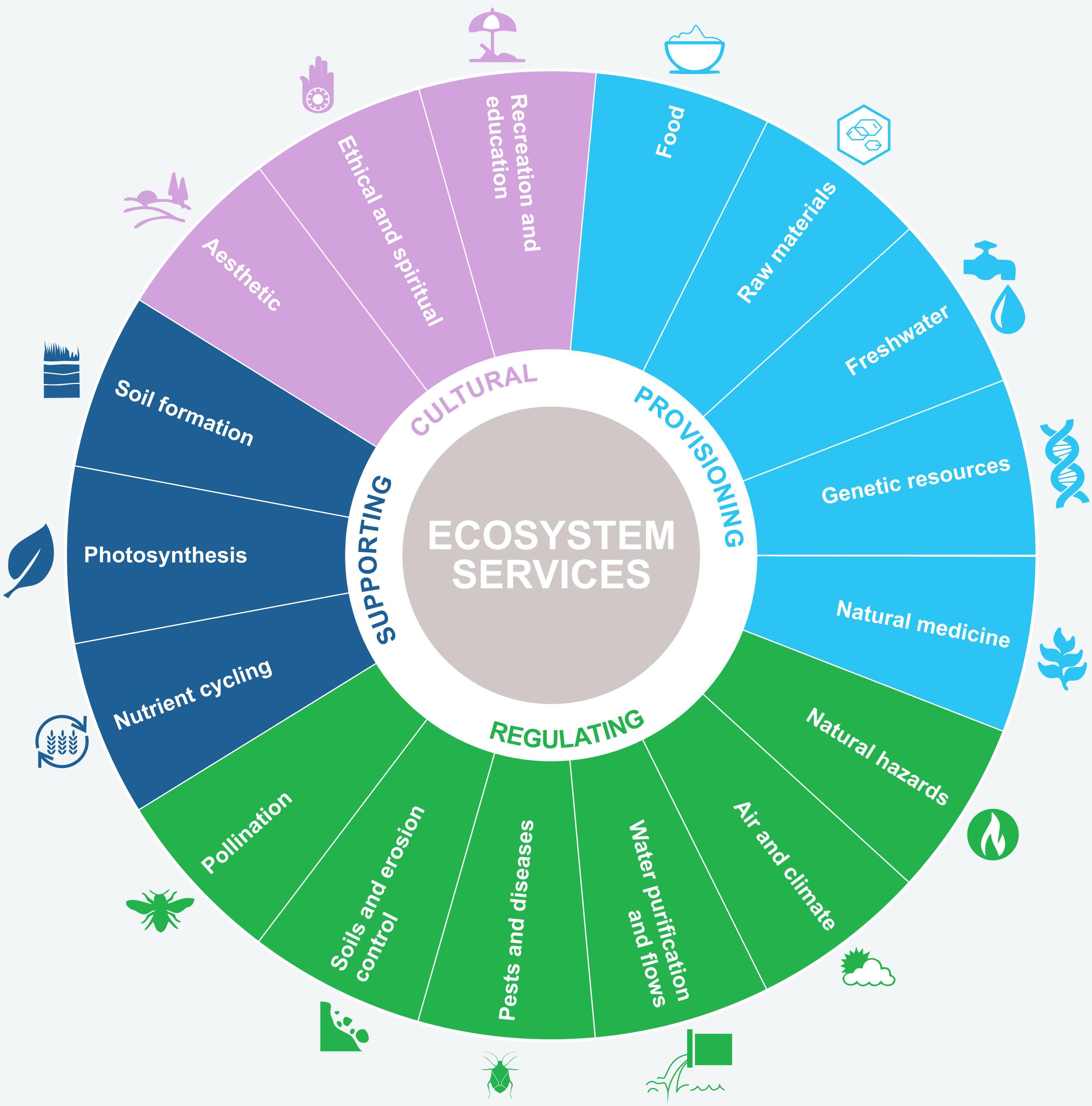
Table 16.1 – Ecosystem Service Requirements in the IFC Performance Standards

IFC Performance Standard	Summary of Requirements
1: Assessment and Management of Environmental and Social Risks and Impacts	Requires all reasonably expected risks and impacts related to ecosystem services to be identified. Requires that the PAOI is broad enough to include indirect impacts on ecosystem services.
4: Community Health, Safety and Security	Requires any impacts on health and safety due to direct impacts on priority ecosystem services to be assessed. For example, the loss of natural buffer areas, such as mangroves that mitigate natural hazards such as flooding, may cause increased vulnerability and community-safety–related risks and impacts.
5: Land Acquisition and Involuntary Resettlement	Loss of access to provisioning ecosystem services needs to be considered when developing a livelihood development plan, particularly when assessing the suitability of replacement land and/or access to natural resources for resettlers.
6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	Requires a systematic review of all ecosystem services a project will impact or depends on to identify priority ecosystem services. The client must demonstrate how they have avoided, minimized and mitigated impacts on priority ecosystem services.
7: Indigenous Peoples	Priority provisioning and cultural ecosystem services need to be assessed and understood in an Indigenous Peoples Plan, as they are likely to be central to the identity and/or cultural, ceremonial or spiritual aspects of Indigenous Peoples' lives.
8: Cultural Heritage	In restoring cultural heritage either in situ or in a new location, any ecosystem processes needed to support that cultural heritage need to be maintained or restored.

TYPES OF ECOSYSTEM SERVICES AND THEIR CATEGORIES

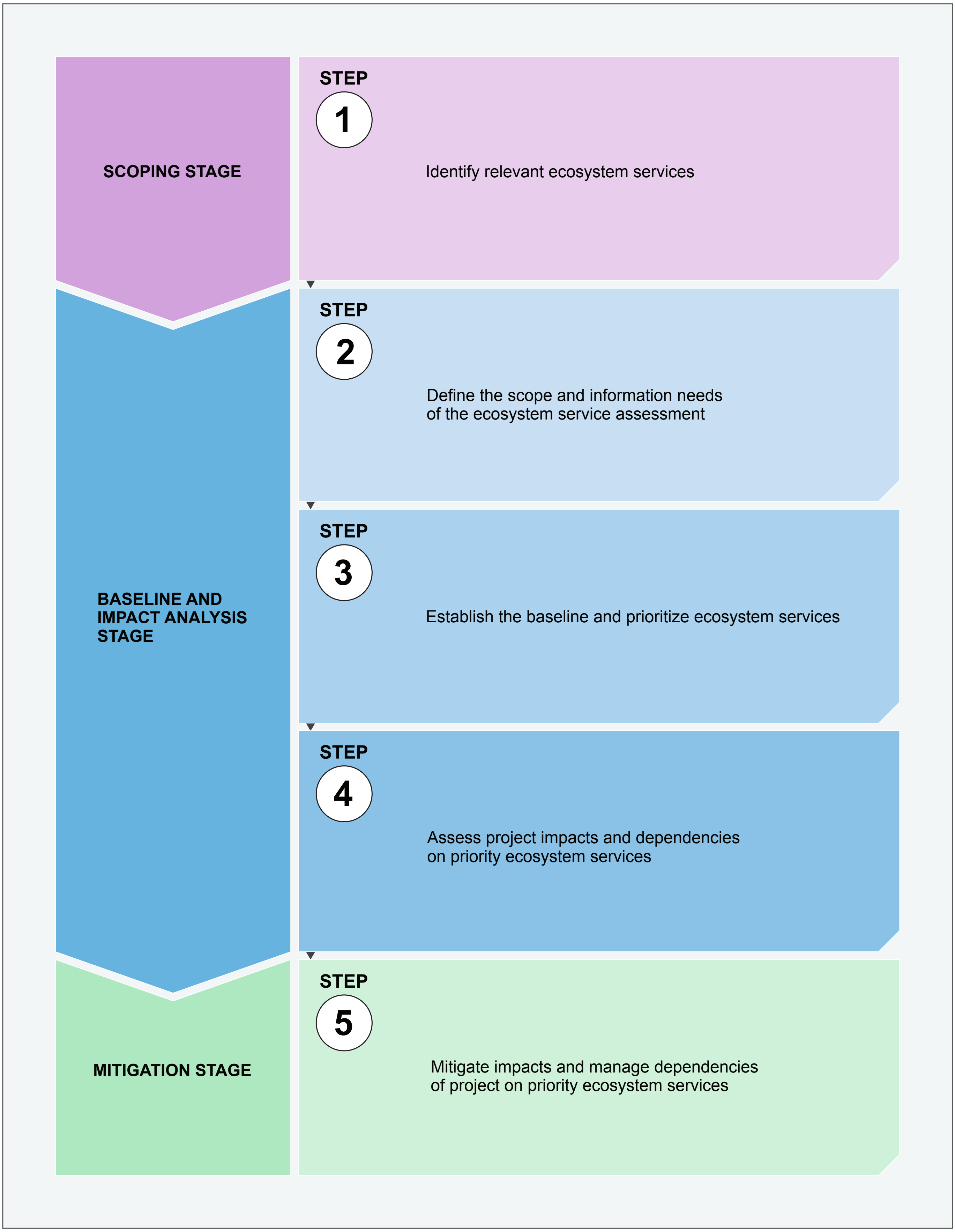
Papua LNG Project | Environmental Impact Statement

FIGURE 16.1



Adapted from WWF (2016).

FIGURE 16.2



Adapted from WRI (2013).

16.2 Discipline-specific Assessment Method

The ecosystem services identification, prioritization and impact assessment approach (see Figure 16.2) used in this chapter is based on the method outlined in the World Resources Institute's (WRI's) Weaving Ecosystem Services into Impact Assessment (WRI, 2013) and on Guidance Note 6 (IFC, 2019).

Section 16.3 describes how relevant ecosystem services were identified and provides a preliminary list of ecosystem services.

An integrated approach was used to collect the information required for the ecosystem services assessment. Information relevant to ecosystem services and movements of communities was collected through consultation with communities in the Project area of influence (PAOI) during the social baseline surveys and ecosystem services interviews (reported in Part 18 of Volume 2). These activities specifically sought beneficiaries' views on the uses of resources from the natural environment and their perceptions of the importance of those resources. Attachment 16.1 describes how this information was captured. Full details on survey methods is provided in Part 23 of Volume 2.

Section 16.4 establishes the baseline for ecosystem services identified as relevant to the Project and prioritizes them based on an assessment of the value of each service, as determined by the importance of the service to ecosystem beneficiaries and the replaceability of the service.

Section 16.5 identifies potential impacts on priority ecosystem services from Project activities, and Section 16.7 assesses these impacts after mitigation measures are applied.

The significance assessment approach described in Chapter 3 was used to characterize the impacts relevant to provisioning ecosystem services. The assessment of residual impacts, assuming the effective implementation of (i) avoidance, mitigation and management measures for adverse impacts and (ii) measures to optimize opportunities, is conducted by examining both the magnitude of the impact (Table 16.2) and the sensitivity of the people, communities and natural resources being impacted (Table 16.3). This interaction between magnitude and sensitivity is expressed in a matrix form (Table 16.4).

Cultural, regulating, maintaining and supporting services are identified but are not assessed in this chapter as they are considered and assessed in Chapters 11, 14, 15 and 17.

Table 16.2 – Ecosystem Services Impact Assessment Magnitude Criteria

Rating	Description
Very High	♦ Irreversible and significant change compared to baseline conditions. ♦ The impact causes the loss of all or a significant proportion of the availability or functionality of an ecosystem service and/or has implications for people outside of the PAOI. ♦ The impact causes commercial industries to shut-down. ♦ The long-term viability of the service is threatened. ♦ Communities are unable to source an alternative or replacement service.
High	♦ Noticeable medium-term (i.e., more than 10 years) change compared to baseline conditions. ♦ The impact causes a high reduction in the availability or functionality of the ecosystem service and/or has implications for more than 50% of the people in the PAOI. ♦ The impact causes commercial industries to partially shut-down. ♦ The impact does not threaten the long-term viability of the service. ♦ Significant increase in community time or effort is needed to source an alternative or replacement service.

Table 16.2 – Ecosystem Services Impact Assessment Magnitude Criteria (cont'd)

Rating	Description
Medium	♦ Noticeable short-term (i.e., 5 to 10 years) change compared to baseline conditions. ♦ The impact causes a medium reduction in the availability or functionality of the ecosystem service and/or has implications for 25 to 50% of the people in the PAOI. ♦ The impact causes commercial industries to be temporarily disrupted and/or to incur additional costs. ♦ Some increase in community time or effort is needed to source an alternative or replacement service.
Low	♦ Limited change compared with baseline conditions, lasting less than 5 years. ♦ The impact is localized and causes a small reduction in the availability or functionality of the ecosystem service and/or has implications for a less than 25% of the people in the PAOI. ♦ The impact causes commercial industries to be temporarily disrupted and/or to incur additional costs. ♦ Limited or no increase in community time or effort is needed to source an alternative or replacement service, or the service is highly replaceable.
Negligible	♦ No appreciable impact compared with baseline conditions. ♦ No appreciable impact commercial industry operations. ♦ The impact is within a normal range of variation.
Positive	♦ Improvement compared to baseline conditions. ♦ The impact improves the availability or functionality of the ecosystem service and/or has positive implications for people in the PAOI.

Table 16.3 – Provisioning Ecosystem Services Impact Assessment Sensitivity Criteria

Rating	Description
High	♦ Limited or no capacity to adapt to change. Limited or no capacity to realize opportunities. ♦ Low replaceability: few to no spatial alternatives; alternatives are difficult to access, costly or unsustainable; low acceptance of alternatives by ecosystem beneficiaries. ♦ Community, service or area is unaffected by this impact prior to Project interaction. ♦ Resource or area has high symbolic importance to cultural or traditional value systems. ♦ Resource provides the sole source of food or income for local people, or resource on which they are frequently dependent. ♦ Many communities depend on the resource or service and have no or limited capacity to access nearby alternatives. ♦ Resource is nationally important to commercial beneficiaries or the Project itself. ♦ Community has no capacity to access nearby alternatives to the affected resource or service. ♦ Resource cannot be relocated or replaced without major loss of cultural values. ♦ Site is protected by local, national and international laws or treaties.
Medium	♦ Some resilience to change. Some capacity to realize opportunities. ♦ Moderate replaceability: some spatial alternatives; alternatives are moderately accessible, affordable or sustainable; moderate acceptance of alternatives by ecosystem beneficiaries. ♦ Some sign of exposure to this impact is already evident in the community, service or area prior to Project interaction. ♦ Resource or area has moderate symbolic importance to cultural or traditional value systems. ♦ Resource is one upon which local people occasionally depend for provision of food or income. ♦ Resource is locally important to commercial beneficiaries or the Project itself. ♦ Community has some capacity to access nearby alternatives to the affected resource or service. ♦ Resource can be relocated or replaced but with some loss of cultural values. ♦ Site is not specifically protected under local, national or international laws or treaties.

Table 16.3 – Ecosystem Services Impact Assessment Sensitivity Criteria (cont'd)

Rating	Description
Low	♦ Easily adaptable to change (or no change required). High capacity to realize opportunities. ♦ High replaceability: many spatial alternatives; alternatives are accessible, affordable or sustainable; high acceptance of alternatives by ecosystem beneficiaries. ♦ Community, service or area is already affected by this impact, prior to Project interaction. ♦ Resource or area has minimal symbolic importance to cultural or traditional value systems. ♦ Resource is one upon which local people rarely depend for provision of food or income. ♦ Resource is not important to commercial beneficiaries or the Project itself. ♦ Community has a high capacity to access nearby alternatives to the affected resource or service. ♦ Resource can be relocated or replaced or is a type common in the surrounding region. ♦ Site is not specifically protected under local, national or international laws or treaties.

Table 16.4 – Ecosystem Services Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Value		
	High	Medium	Low
Very High	Severe	Major	Moderate
High	Major	Moderate	Moderate
Medium	Moderate	Moderate	Minor
Low	Minor	Minor	Minor
Negligible	Negligible	Negligible	Negligible
Positive	Positive	Positive	Positive

16.3 Identifying Relevant Ecosystem Services

Relevant ecosystem services on which the Project may impact were identified by analyzing the ecosystems and ecosystem services that Project activities could impact either directly or indirectly, and the ecosystem beneficiaries that could be positively or negatively affected due to these impacts.

The different ecosystems relevant to the Project areas were identified through baseline studies, and the results are discussed in Chapter 7. Broad vegetation groups were used to categorize ecosystems into habitat and land-use types that will potentially be impacted by the Project (Table 16.5).

Table 16.5 – Habitats and Land Uses Relevant to Ecosystem Services

Habitat/Land Use	Description
Forest	Includes hill forest, alluvial forest, swamp forest, littoral forest and riverine habitat.
Wild stands of sago woodland	Woodlands dominated by sago (Swamp woodland (Wsw)) rather than where sago is a component of other vegetation types.
Rivers and waterbodies	Includes the estuarine zone, rivers, lakes, wetlands and other, generally freshwater, waterbodies in the study area.
Mangrove	Includes fringing mangroves, main mangrove associations, nipa palm and transitional mangrove forest.
Nearshore	Refers to the waters from the top of the high-water mark to the 15-m depth contour. The habitat includes coral reefs and seagrass beds, beaches and intertidal habitats (e.g., mudflats).
Offshore	Refers to marine waters that are seaward of the nearshore environment and generally encompasses deeper waters beyond the 15-m depth contour.

Table 16.5 – Habitats and Land Uses Relevant to Ecosystem Services (cont'd)

Habitat/Land Use	Description
Subsistence land use and villages	Cropping and plantations, temporary gardens, dwellings and community infrastructure.

Ecosystem services relevant to each of these ecosystems were identified based on a review of ecosystem services guidance documents (e.g., Landsberg et al., 2011; WRI, 2013; IPIECA and IOGP, 2011), previous ecosystem services impact assessments, and the experience of the environmental and social technical practitioners on the study team.

Individuals and communities were identified as the primary ecosystem beneficiaries in the PAOI. A list of communities in the PAOI is provided in Section 9.5.1. Extensive consultation with these primary ecosystem beneficiaries, through formal and informal surveys, interviews and focus group discussions, was undertaken during the data collection process (Attachment 16.1). Commercial ecosystem beneficiaries include companies involved in logging and commercial fishing operations.

Project activities and drivers of change, or activities likely to cause impacts, were also considered to identify which ecosystem services were most relevant to the Project and whether the Project had direct management control or influence over them.

Ecosystem services that were screened out by applying these filters were excluded from further investigation. Those that were considered relevant to the ecosystems, Project activities and beneficiaries form the preliminary list of ecosystem services, (Table 16.6).

Table 16.6 – Preliminary List of Ecosystem Services

Provisioning Services	Regulating and Maintaining Services
♦ Wild food (bushmeat). ♦ Wild food (plants, nuts and fruit). ♦ Wild food (freshwater and marine species). ♦ Food (crops). ♦ Food (livestock). ♦ Fuel (firewood). ♦ Traditional medicine. ♦ Timber and other wood products. ♦ Non-timber forest products (fibers, resins). ♦ Fresh water (domestic use). ♦ Rivers (transportation). ♦ Marine transportation. ♦ Commercial marine fisheries. ♦ Timber and logging concessions.	♦ Control of erosion and sedimentation. ♦ Regulation of surface and groundwater (including flows). ♦ Regulation of natural hazards. ♦ Regulation of air quality. ♦ Regulation of climate. ♦ Water purification and waste treatment. ♦ Regulation of soil quality. ♦ Regulation of diseases. ♦ Regulation of pests. ♦ Pollination and seed dispersal. ♦ Seed bank for natural regeneration.
Cultural Services	**Supporting Services**
♦ Cultural sites. ♦ Traditional practices.	♦ Provision of habitat for plant and animal species. ♦ Nutrient cycling. ♦ Primary production. ♦ Water cycling. ♦ Soil formation. ♦ Genetic resources.

16.4 Baseline Characterization and Prioritization of Ecosystem Services

16.4.1 Prioritization Method

The importance of ecosystem services to beneficiaries has been assessed according to the following criteria adapted from ERM (2013):

- Intensity or frequency of use, e.g., daily, weekly, seasonal, occasional.
- Scope of use, e.g., households, villages, commercial.
- Degree of dependence, e.g., contribution to diet, income or employment.
- Importance expressed by ecosystem beneficiaries.

Not all these criteria are relevant to each ecosystem service; but when they are relevant, they are considered in combination to determine the importance of the ecosystem service, e.g.:

- Low importance: Occasional use (intensity) by some households (scope). No or minimal contribution to diet, income or employment (dependence) and is not considered valuable by ecosystem beneficiaries (importance).
- Moderate importance: Regular (weekly) use by some or most households. Contributes to diet, income or employment and is considered to be of some value by ecosystem beneficiaries.
- High Importance: Frequent (daily) use by most households. Significant contribution to diet, income or employment and is considered valuable by ecosystem beneficiaries.

Replaceability of ecosystem services is assessed according to the following criteria adapted from ERM (2013):

- The existence of spatial alternatives, i.e., alternatives are available in other locations or alternatives are otherwise accessible, including both natural and artificial substitutes.
- The accessibility, cost and sustainability of potential alternatives.
- Preference or cultural appropriateness of alternative services.

Again, not all criteria are relevant to each ecosystem service; but when they are relevant, they are considered in combination to determine the overall replaceability of the service, e.g.:

- Low replaceability: Few to no spatial alternatives; alternatives are difficult to access, costly or unsustainable; low acceptance of alternatives by ecosystem beneficiaries.
- Moderate replaceability: Some spatial alternatives; alternatives are moderately accessible, affordable or sustainable; moderate acceptance of alternative by ecosystem beneficiaries.
- High replaceability: Many spatial alternatives; alternatives are accessible, affordable or sustainable; high acceptance of alternatives by ecosystem beneficiaries.

The importance and replaceability of ecosystem services are used to place a value rating on each ecosystem service (Table 16.7). The value ratings for importance and replaceability are based on interpretations of field data, discussions with ecosystem beneficiaries and field observations. The value ratings also reflect beneficiaries' interpretations of the rating criteria and may reflect some biases.

This value rating is used to prioritize the provisioning and cultural ecosystem services that are later assessed in the impact assessment. Those scoring a high or very high rating in the prioritization exercise are considered priority ecosystem services for the impact assessment. Some services rated as medium are also discussed in the impact assessment by exception (and marked with an asterisk (*) in Table 16.9), where they are of high importance to beneficiaries.

Table 16.7 – Value Rating Matrix for Ecosystem Services

Importance of Service to Ecosystem Beneficiaries	Replaceability of Service		
	High	**Moderate**	**Low**
Low	Low	Low	Medium
Moderate	Low	Medium	High
High	Medium	High	Very High

Source: Matrix adopted from ERM (2013).

Professional judgment was used to determine the value rating for regulating, maintaining and supporting services (Table 16.9), based on the data gathered through baseline studies.

16.4.2 Baseline Characterization

Ecosystem services are characterized through a summary of the baseline conditions of the preliminary ecosystem services listed in Table 16.6, incorporating their relevant habitats or land uses in the PAOI, their importance to local communities (where relevant), their replaceability and their assigned value rating as described in Section 16.4.1. A more detailed description of baseline conditions and the data supporting statements in Tables 16.8 and 16.9 can be found in Chapters 7, 8 and 9, and Parts 13 and 18 of Volume 2.

The baseline characterization also takes into consideration external factors (i.e., not Project-related) that may affect current and future service provision such as population growth, economic and land use changes and climate change, and recognizes that regulating, maintaining and supporting services influence cultural and provisioning services. For example, fisheries productivity depends upon regulating and supporting services such as erosion control, and the regulation of pests and diseases, climate and water quality. Benefits to communities and commercial fisheries through provisioning services are derived from these supporting ecosystem services.

Villages have been categorized as either coastal or inland, as a basic way of separating them by ecological system to provide a baseline for the ecosystem services (Attachment 16.1). Some variance exists between villages in each category, e.g., the villages of Aumu and Wabo are both categorized as inland, yet they exist in different ecological zones, some 90 km apart. The communities have been combined under a single value rating when the importance and replaceability ratings are the same for both inland and coastal communities.

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (bushmeat)	Forest	Forests throughout the PAOI provide a range of animals that are eaten and/or sold for income. Inland communities typically have a higher dependence on bushmeat for protein than coastal communities, who have access to marine resources. While game items, such as wild pigs and cassowaries, are highly prized and are actively pursued, most procurement activity is highly opportunistic; and most of the hunting returns comprise many kinds of smaller food items. Many households earn some revenue from occasional sales of hunted or collected animal foods, and a few earn significant annual revenue from the sale of bushmeat.	Inland	High	High	Medium*
			Coastal	Moderate	Moderate	Medium
	Subsistence land use and villages	Bushmeat hunted, collected and consumed from gardens commonly includes: ♦ Small vertebrate (non-volant mammals, birds, reptiles, frogs). ♦ Flying foxes.	Inland/Coastal	Moderate	High	Low
Wild food (plants, nuts and fruits)	Forest	Forests in the PAOI provide at least 46 plant species that are used as a supplementary food to sago and garden food crops. Trees and palms have the most uses, providing edible nuts, fruits and leaves. Various, relatively common, trees are important for fruit or nut production. These trees are widespread across hill forest, alluvial forest and, to a lesser extent, swamp forest.	Inland	High	High	Medium
			Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (plants, nuts and fruits) (cont'd)	Mangroves	Nipa palms that produce abundant edible starchy nuts each year dominate much of the mangroves of the delta. These are seasonally available for the communities in the Mangrove ecological zone and are an important dietary component of people from villages from the Maipua, Koriki, Iare and Kaimare language groups. Mangrove forests do not occur inland of the Purari River tidal limits and are of lesser importance to inland people as a seasonal food source.	Inland	Low	Moderate	Low
			Coastal	High	High	Medium
	Wild sago stands	Sago is the primary staple food in the PAOI, and wild sago is an important famine food. Wild sago stands cover approximately 25,351 ha (9%) of the PAOI. An additional 13,890 ha also contain sago but as a secondary vegetation component (see Figure 9.10). Sago harvested from wild sago stands is less preferred than planted sago, as it is harder to access and has an unfavorable texture and flavor, and many spatial alternatives are accessible for both inland and coastal villages.	Inland/Coastal	High	High	Medium*
Wild food (aquatic species)	Rivers (including estuaries and waterbodies	A range of animal resources are hunted or collected along the larger rivers and channels of the Purari River and delta distributaries. Most of the species caught by local communities are widely available. Fishing is considered an essential subsistence activity and the selling of surplus catch to markets and logging camps is opportunistic; however, commercial-scale activity has reportedly declined as villagers have sought other sources of income.	Inland	Moderate	High	Low
			Coastal	High	High	Medium*

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (aquatic species) (cont'd)	Nearshore	Artisanal fishing is an important provisioning service and is a primary source of village income for several coastal communities in the PAOI. Artisanal fisheries are almost exclusively within the 3 nautical mile coastal zone. Prawn fishing is most commonly undertaken with hand-operated nets in wadable depths during the seasonal prawn migration out of the Purari delta into the coastal zone. Collecting crabs and shellfish is a very regular activity among members of the river and coastal villages. For the two weeks prior to the household survey, 36 to 76% of households devoted effort to collecting aquatic resources.	Inland	Low	High	Low
			Coastal	High	High	Medium*
Food (crops)	Subsistence land use and villages	Agriculture is dominated by a type of subsistence agriculture known as shifting cultivation where staple food crops are grown in temporary 'gardens', which are made by clearing and burning tall woody regrowth, typically over 15 years old. All communities make small household gardens on hill sides, along the banks of the Purari River and other waterways, in logged-over alluvial forest and occasionally in small cleared patches of nipa palms in the mangroves where crops are planted on raised mounds. Larger cultivated areas are more prevalent inland from Orokolo Bay in swamp woodland areas. Crop cultivation is very important for the coastal and inland Orokolo villages where there is greater access to more fertile alluvial plains. Coconut is planted in coastal and inland Orokolo village gardens and is an important famine food.	Inland	Moderate	High	Low
			Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Food (crops) (cont'd)	Subsistence land use and villages	Sago is the main staple food for all the villages and an important famine food, as it is resilient to flood and drought. Planting and harvesting sago are the most important food production activities across the PAOI.				
Food (livestock)	Subsistence land use and villages	Domestic livestock in the PAOI includes pigs and chickens. Pigs are valued commodities and are reared for both meat and bride price or compensation payments. Pig ownership rates vary across the PAOI. Most households in the PAOI keep chickens. Both the eggs and the birds are regularly eaten. Chickens are a moderate source of protein.	Inland/Coastal	Moderate	Moderate	Medium
Fuel (firewood)	Forest	Firewood is the main resource for cooking food in the PAOI. Almost any tree species can be used, provided it is dry; however, several species are preferred. Firewood is collected from as close to the village as possible to minimize carrying the wood.	Inland/Coastal	High	Moderate	High
	Nearshore	Community members from Kaivukavu (coastal Orokolo) collected nearly all their firewood (as driftwood) from the beach; however, firewood collection along the beach is subject to clan ownership restrictions, and frequent disputes arise over ownership of beach firewood in the coastal Orokolo villages.	Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Traditional medicine	Forest	Fifty-eight medicinal plant species were identified in the PAOI, including: ♦ *Myristica* sp. – Fruit of the tree are eaten to cure cough. ♦ *Ficus polyantha* – Sap from the tree is mixed with water and drunk to cure diarrhea. ♦ *Laportea decumana* – Leaves of the shrub are rubbed on skin as a pain killer. Most are relatively common and are collected in forested areas near villages. A full list of medicinal plants can be found in Part 18 of Volume 2.	Inland/Coastal	High	High	Medium
Timber and wood products	Forest	Timber is most commonly used in the PAOI for building materials, particularly house posts and canoes. Many different tree species are available that can be used for house construction, particularly in hill forest; but different species are used for different house components. Preferred tree species are found in natural stands, can be scattered and take a long time to replace or regrow.	Inland/Coastal	High	Moderate	High
	Mangrove	Mangrove cedar (*Xylocarpus granatum*) and blind-your-eye mangrove (*Excoecaria agallocha*) are used for house posts, but these are not the preferred house post species.	Inland/Coastal	Moderate	High	Low
Fibers and resins	Forest	The most widely used plants for domestic purposes are bamboo, palms, rattan and the tree species *Trichospermum*.	Inland/Coastal	High	High	Medium
	Sago and Mangrove	Seventy-three percent of houses in the PAOI are made of traditional materials, i.e., roof made of sago leaves, nipa palm leaves or grass. Many different spatial alternatives are available for sago and nipa palms across the PAOI.	Inland/Coastal	High	High	Medium

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Fresh water (domestic use)	Rivers and waterbodies	Sixteen percent of households in the PAOI rely on a river or creek as their main source of drinking water. People residing in Ura, Wabo, Subu, Subu 2, Poroi 2, Poroi 3, Upaia, Aiere, Kairu'u, Akoma, Evara, Kaevaria, Kairimai, Aivai, Apiope and Mapaio Fish Camp extract water from the Purari River or its tributaries for drinking. Other communities use rainwater, tanks or shallow groundwater wells as their main source of drinking water but may rely on river or creek water during droughts when alternative sources may not be available. Coastal communities obtain fresh water from several sources, including shallow wells, tanks and rivers. They rely less on rivers and lagoon sources than inland communities do. Other than river water, tanks (where they exist) or water containers are used to collect rainwater. Groundwater sources are uncommon inland.	Inland/Coastal	High	Moderate	High
	Subsistence land use and villages (groundwater)	Orokolo villagers use groundwater for drinking and washing. The groundwater is obtained from shallow wells and provides reliable year-round water. The microbial water quality in sampled groundwater wells in these villages is poor, as they have high coliform counts. This could be due to domestic animals and wildlife having open access to wells and springs; and the latter are, in some cases, close to latrines. There are few alternatives to groundwater in coastal areas, even with rainwater tank installation, as the tanks are quickly depleted and do not provide year-round water security.	Coastal	High	Low	Very High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Rivers (transportation)	Rivers and waterbodies	The main mode of transport in the PAOI is on rivers using dugout canoes, motorized dugout canoes or dinghies. The PAOI has no roads other than disused logging tracks; consequently, no motor vehicles or motorbikes were recorded in the PAOI. Most river traffic generally involves one to four hours' travel from villages to access food gardens, sago processing sites, or hunting and gathering sites; to go fishing or to travel to schools and aid posts. Villages along the rivers relocate every few decades, due to rapid siltation.	Inland/Coastal	High	Moderate	High
Marine (transportation)	Nearshore	People living along the Orokolo Bay coastline regularly transit along the coast to sell marine produce, to access markets, and health and education facilities or to visit relatives. Sea travel forms part of the journey to the regional center of Kerema for all people in the PAOI. Sea travel is expensive and can be dangerous. Walking (usually along the beaches, which provide a kind of 'coastal highway') is the only alternative.	Coastal	High	Moderate	High
Commercial marine fisheries	Nearshore	The Gulf of Papua Prawn Fishery is the principal commercial fishery in the PAOI. Licensed trawlers typically operate offshore of the 3-nautical mile limit, but some operators are granted access to the 2- to 3-nautical mile zone via joint venture agreements with specific local communities that allow profit sharing on the value of the catch. The Gulf of Papua Prawn Fishery is principally an export fishery.	Coastal	Moderate	Moderate	Medium

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Commercial marine fisheries (cont'd)	Nearshore (cont'd)	Coastal villagers interact with the prawn fishery by trading trawl by-catch. Prawn trawling is a frequent activity and significantly contributes to the PNG economy and employment. Prawn fishing grounds extend across the Gulf of Papua; therefore, potential spatial alternatives exist for this fishery. The Torres Strait Tropical Rock Lobster Fishery is the other key commercial fishery. Commercial rock lobster fishing does not occur in the PAOI, but migrating lobsters may cross the offshore export pipeline route.	Commercial beneficiaries	High	Moderate	High
Timber from logging concessions	Forest	Seven logging concessions exist in or adjacent to the Project study area of which only Vailala Block 3 and East Kikori are active. The main active logging concession is Vailala Block 3 Forest Management Area, which extends from the south bank of the Purari River to the coast and operates over 196,353 ha, all of which is in the study area. The other active concession is the East Kikori Timber Rights Purchase area of which only 10,900 ha overlaps the study area. Turama Forest Industries is still to develop the Baimuru Block 3 Forest Management Area, which is west of the Purari River. The study area provides extensive forest resources that are suitable for small-scale logging using portable sawmills; however, small-scale forestry is almost absent from the study area other than at Paevera, where the only known portable sawmill is based.	Inland/Coastal	Moderate	Moderate	Medium
			Commercial beneficiaries	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Timber from logging concessions (cont'd)	Forest (cont'd)	In 2016, logging activity contributed to income and employment for some PAOI communities, e.g., Mapaio, Aivai, Upaia and Wabo. Some communities benefit from logging operations; however, survey data indicated general dissatisfaction with these benefits. Currently, there is no known harvesting of the high-value forest products eaglewood and massoy; although, it is possible that these products will be harvested in the future.				
Cultural Services						
Cultural sites	All	Tangible cultural heritage sites in the PAOI are often associated with landscape features, such as hills, caves, river mouths, rocks, individual trees or vegetation stands. Many communities in the PAOI reported spirit sites were of high local importance during consultations. Eight spirit sites were formally recorded in the PAOI during surveys. Many more sites were named during consultations; however, they were not formally recorded because of confidentiality or difficulty in accessing the sites.	Inland/Coastal	High	Low	Very High
Traditional practices	All	Traditional practices, such as hunting, fishing, and making pandanus mats and bilums, rely on natural resources sourced from forests, mangrove, rivers and marine environments. Some examples of resources used for traditional practices are: ♦ Palm (*Actinorhytis calapparia*) used for bow and arrow heads.	Inland/Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Traditional practices (cont'd)	All (cont'd)	♦ Tree (*Heritiera litoralis*) used to make the triangular frame for the prawn fishing nets. ♦ Bark fibers from the tree (*Gnetum gnemon*) used to make traditional rope for string bags (bilums). All villages in the PAOI use traditional tools and materials for processing sago, and 94% and 85% of PAOI villages use traditional tools and materials, for hunting and fishing, respectively. Seventy five percent of villages in the PAOI perform traditional songs and dances at special occasions, and several villages reported using plants in secret chants to assist in hunting, fishing and growing crops. Traditional practices are often linked to specific plant or animal resources and known productive sites, limiting spatial alternatives.				High

* Ecosystem services rated as medium but discussed in the impact assessment by exception.

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services

Ecosystem Service	Habitat/ Land Use	Description	Value
Control of erosion and sedimentation	Forests Mangroves Nearshore	Forest and riparian habitats regulate erosion and sediment delivery to streams, particularly on steep slopes where erosion potential is high, by providing a protective vegetative cover and reducing runoff (i.e., increasing infiltration). Natural vegetation currently covers more than 98% of the upstream study area. Largely undisturbed mangroves line the coast and estuarine areas in the southern part of the upstream Project area. These form part of the broadest coastal band of mangroves found in Papua New Guinea. Mangroves are also found along the coast and in estuarine areas of Caution Bay. Coral reefs and seagrass beds alleviate erosion from waves and storms. Seagrass meadows, such as those found in Caution Bay, stabilize the substrate, while coral reefs, such as the outer reefs in Caution Bay, provide a physical barrier protecting the coastline from waves and erosion.	High
Regulation of surface water and groundwater	Forest Rivers and waterbodies	Forests influence the volume of water available and the timing of water delivery. Stream-flow regulation by forests is due to processes in the forest canopy, on the surface and below the ground; a combination of interception, transpiration, evaporation, evapotranspiration and infiltration (FAO, 2019). The hills and ridges of the study area form the headwaters of the local streams, which eventually feed into the larger Purari River delta and its three main distributaries. The isolated perched, shallow groundwater occurring in the superficial and weathered material, particularly in the areas of steep slopes and incised valleys in PRL-15, is likely to act as an important recharge source for the base flow of streams and creeks.	High
Regulation of natural hazards	Forest Rivers and waterbodies Mangroves Nearshore	Ecosystems, e.g., forest, wetlands, floodplains, mangroves, coral reefs and seagrass beds, particularly those that are intact, assist in regulating natural hazard frequency and intensity, including floods, cyclones, tsunamis and landslides.	High
Regulation of air quality	Forest Rivers and waterbodies	Natural habitats (e.g., forests and lakes) can impede the movement of airborne substances (e.g., particulate matter and gaseous emissions) by providing a physical barrier. These habitats and the organisms in them, also play a role in extracting and/or altering chemicals from, and in, the atmosphere.	Low

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Regulation of climate	Forest Rivers and waterbodies Mangroves Nearshore Offshore	Ecosystems in the study area influence the climate by absorbing greenhouse gases; and they can influence local variations in temperature, precipitation, and other climatic factors, e.g.: ♦ Forests, soils, geological formations and oceans all support carbon sequestration, whereby carbon dioxide is removed from the earth's atmosphere and stored in the long term, helping to reduce greenhouse gases and regulate the planet's climate. ♦ Forests absorb moisture through plant roots and subsequently release vapor into the atmosphere (i.e., evapotranspiration). ♦ In upland areas, cloud and fog are an important moisture source for most of the year, with areas subject to the most cloud receiving the most rain. ♦ Water evaporation from rivers, waterbodies and the ocean into the atmosphere acts as a greenhouse gas, helping regulate the earth's temperature. ♦ Seagrass meadows, marine algae and phytoplankton store carbon (blue carbon) acting as important carbon dioxide sinks.	Medium
Water purification and waste treatment	Forest Rivers and waterbodies	Ecosystems in the study area (e.g., forests, streams and wetlands) play a role in filtering and decomposing organic wastes and pollutants in water and assimilating and detoxifying compounds through soil and subsoil processes. In addition, ecosystems buffer the effects of erosion, and sediment and pollutant runoff into waterways, thereby assisting with regulating the health of river systems.	Very High
Regulation of soil quality	Forest Rivers and waterbodies	Ecosystems in the study area assist in sustaining the soil's biological activity, diversity, and productivity. Ecosystems also assist in storing and recycling nutrients and gases. Vegetation cover is a key component of this process, which assists in regulating soil quality. In addition, water regulation through the soil profile can assist with filtering and breaking down contamination and pollutants, and can assist with assimilating uncontaminated forms of organic waste, while contributing to soil moisture content, and thus habitat suitability for organisms that enhance nutrient regulation and fix nitrogen. Organic matter in soil provides energy for all microbial and faunal activities, allowing them to build the micro-aggregate structures that control soil hydraulic properties, further conserving organic matter (Millennium Ecosystem Assessment, 2005); FAO, 2005).	Low

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Regulation of disease	Forest Rivers and waterbodies	Intact ecosystems, such as those across much of the study area (see Section 7.7), provide natural protection against the transmission of infectious disease. Changes to habitat or forest cover and increasing vector breeding sites or reservoirs of host distribution; and biodiversity, including the loss of predators and changes in the host population density, are two of the main biological mechanisms altering the occurrence of infectious diseases (Millennium Ecosystem Assessment, 2005).	High
Regulation of pests	Forest Rivers and waterbodies	Ecosystems can resist the establishment, growth, survival and reproduction of invasive species, such as those identified in the study area. Ecosystem condition affects its resilience; and, in general, resistance of an ecological community against invasion by introduced species, increases with species and functional-type richness (Millennium Ecosystem Assessment, 2005; Balvanera et al., 2006 in TEEB, 2010). This is likely to be related to the level of disturbance and the intactness of ecosystems.	Medium
Pollination and seed dispersal	Forest	Ecosystems in the study area, comprising rich assemblages of fauna vertebrates and invertebrates, play a critical role in dispersing seeds and transferring pollen between flowering plants.	Medium
Seedbank for natural regeneration	Forest	The presence of intact topsoil is a key component to the success of natural regeneration. The topsoil containing the soil seed bank is essential for providing a medium for vegetation regeneration across disturbed surfaces and may contain almost 1,000 viable seeds per square meter in the top 5 cm of soil (Rogers & Hartemink, 2000). Almost all these seeds (99%) are pioneer species with fast growth rates and short life cycles that quickly reproduce to replenish the soil seed bank, and their seeds remain viable in the soil for several years from which forest regeneration occurs.	High
Provision of habitat	Forest (including the subterranean environment) Mangroves Rivers and waterbodies Nearshore Offshore	Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances. Habitat in the study area includes: ♦ Terrestrial biodiversity focal sites. ♦ Mangroves are nurseries for aquatic fish and invertebrate species, and are key to maintaining the commercial fisheries. ♦ Rivers and estuaries provide nursery habitat for juvenile and sub-adults, including protected elasmobranch species. ♦ Seagrass meadows found in Caution Bay provide food and refuge for marine fauna, including juvenile fish and invertebrates, and commercial and subsistence fauna. ♦ Coral reefs, such as those found in Caution Bay, are feeding and nursery grounds for marine fauna. ♦ Offshore waters and the seabed in the Gulf of Papua along the offshore export pipeline route provide habitat for commercially harvested species, pelagic and demersal fishes, marine reptiles, and mammals of conservation significance.	High

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Nutrient cycling	Forest Mangroves Rivers and waterbodies	The flow of nutrients through ecosystems underpins all other ecosystem services, as it provides elements necessary for life, and alterations to the nutrient cycle can cause nutrient excesses or deficiencies (Millennium Ecosystem Assessment, 2005). Decomposition of organic matter is crucial to nutrient availability, as plant uptake is almost exclusively in the inorganic form (Parton et al., 1988, as cited in Millennium Ecosystem Assessment, 2005). In the study area: ♦ Forests produce organic matter enabling nutrients to be added to the cycle. ♦ Mangroves can act as nutrient sources or sinks. ♦ Fluvial discharges from rivers, such as the Purari River distributaries, deliver or transport nutrients between habitats and into the pelagic zone. ♦ Seagrass meadows trap and recycle nutrients. ♦ Upwelling of nutrient-rich cooler waters from deeper offshore areas brings nutrients to the warmer, shallower nearshore habitats. Also see 'Regulation of soil quality'.	Medium
Primary production	Forest Mangroves Rivers and waterbodies Nearshore Offshore	Primary production is the formation of biological material by plants through photosynthesis and nutrient uptake. The higher the diversity of primary producers, the higher the diversity of primary consumers (e.g., herbivores) (Balvanera et al., 2006, in TEEB, 2010). In the study area: ♦ Natural vegetation covers more than 98% of the terrestrial study area. ♦ Mangroves provide organic matter or are a carbon source to the aquatic environment. ♦ Seagrasses, mangroves, micro- and macroalgae, and phytoplankton are primary producers in the aquatic environment. ♦ Primary production in pelagic environments of the Gulf of Papua is generated from a combination of autotrophic (photosynthetic, i.e., phytoplankton) and heterotrophic (non-photosynthetic, i.e., microbial) sources. Benthic-pelagic coupling is strong in the Gulf of Papua, with detrital input from rivers driving nearshore primary productivity (Robertson et al., 1998).	Medium
Water cycling	Forest; Mangrove Rivers and waterbodies; Nearshore; Offshore	Water flows through ecosystems in solid, liquid, or gaseous forms; and this occurs in the study area via the processes of atmospheric circulation and precipitation; evaporation, evapotranspiration and condensation; surface runoff and stream and river flow; groundwater infiltration, discharge and storage; and freshwater and oceanic storage.	Medium

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Soil formation	Forest Rivers and waterbodies	Soils support many ecosystem services in the study area, including food, fuel, fiber and building materials, by providing baseline infrastructure, such as acting as a medium for vegetation growth (South East Queensland Catchments, 2017).	Low
Genetic resources	Forest Mangroves Rivers and waterbodies Nearshore Offshore	Genetic resources contain information pertaining to a species' evolutionary history (i.e., inherited changes between generations). In the context of the study area where extensive natural vegetation coverage exists, genetic resources are important, as genetic variability within a species supports genetic variability within an ecosystem, thus supporting a variety of other identified ecosystem services. In addition, they contribute to the capacity of organisms to adapt to changed environmental conditions and/or regulate pests and diseases.	Medium

16.4.3 Overview of Priority Ecosystem Services

Table 16.10 summarizes the analysis conducted for the baseline characterization, which identified the priority ecosystem services for the Project. Those that were not rated as high or very high were screened out of the assessment. Identification and assessment of potential impacts on these ecosystem services, focusing on site-specific analysis in relation to the location, extent and nature of Project activities, are discussed in Sections 16.5 and 16.7.

Table 16.10 – Priority Ecosystem Services

Ecosystem Service	Description	Value
Provisioning Services		
Wild food (plants, nuts and fruits)	Forest plants that coastal villages use as a supplementary food to crops.	High
Food (crops)	Planted crops in gardens for coastal villages.	High
Fuel (firewood)	Firewood is used as a primary source of fuel by coastal and inland villages.	High
Timber and wood products	Forest timber is used in the PAOI for building materials, particularly house posts and canoes. House posts are in short supply for some communities.	High
Fresh water (domestic use)	Many coastal and inland villages rely on rivers or creeks as their main source of drinking water.	High
	Orokolo villagers use groundwater for drinking and washing. There are few alternatives, and sampled wells are high in coliforms.	Very High
Rivers and nearshore marine environment (transportation)	Coastal and inland villagers rely on rivers for transportation in the PAOI. Coastal villagers rely on travel along the Orokolo coastline for fishing and access to markets.	High
Commercial marine fisheries	Fishing companies rely on fishing activity for income and employment.	High
Commercial forestry	Logging companies rely on logging activity for income and employment.	High
Cultural Services		
Cultural sites	Coastal and inland villages report spirit sites of high local importance in the landscape.	Very High
Traditional practices	Coastal and inland villages rely on natural resources for making traditional tools, processing sago, body decorations for performing songs and dances, and in sorcery.	High
Regulating, Maintaining and Supporting Services		
Control of erosion and sedimentation	Intact vegetation protects against erosion and increased sedimentation in aquatic environments.	High
Regulation of surface water and groundwater	Recharge and quality of water sources are important as a source of domestic supply and as a source for aquatic ecosystems.	High
Regulation of natural hazards	Intact forest, mangrove and nearshore ecosystems protect villages and Project infrastructure from natural events such as flooding, fire or tsunamis.	High
Water purification and waste treatment	Ecosystems play an important role in filtering wastes and pollutants from water and soils.	Very High

Table 16.10 – Priority Ecosystem Services (cont'd)

Ecosystem Service	Description	Value
Regulating, Maintaining and Supporting Services		
Regulation of disease	Natural vegetation and surface waters play a key role in regulating disease.	High
Seedbank for natural regeneration	The presence of intact topsoil is a key component to the success of natural regeneration.	High
Provision of habitat	Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances.	High

16.5 Identification of Potential Impacts

The Project has the potential to impact on ecosystem services through clearing of vegetation and garden areas that provide food; restricting community access to food resources; changes (through discharges) to surface and groundwaters; detrimental biophysical impacts that cause changes to organism abundance, diversity or distribution. Potential benefits may include providing alternatives to subsistence agriculture and fishing through new economic opportunities.

This section outlines the potential impacts of these activities on the priority provisioning, cultural and regulating, maintaining and supporting ecosystem services. Potential impacts are discussed in relation to the communities residing in and around each of the three onshore Project areas, i.e., PRL-15, the onshore export pipeline corridor and the river transport corridor (see Figure 13.1), and impacts that could occur offshore, which could be relevant to communities residing in Orokolo Bay and around the Purari River delta.

Ecosystem services is a transdisciplinary topic, combining social, cultural and environmental factors. Therefore, this assessment draws from multiple chapters from this EIS, including Chapters 11, 12, 13, 14, 15 and 17.

There is uncertainty on the possible scale of in-migration in relation to the Project, therefore a conservative approach has been applied in the assessment of potential related impacts on Ecosystem Services.

16.5.1 Provisioning Services

16.5.1.1 Direct Loss of Wild Plant Foods

The availability of forest habitat for wild plant food provisioning is a priority ecosystem service only for coastal communities, as inland communities have greater access to forest resources (see Table 16.8). Native forests provide habitat for the highest proportion of wild foods, which are mostly trees and palms that provide edible fruits and nuts. Extensive areas of sago palm occur in Swamp woodland (Wsw) and extensive areas of almost pure nipa palms, which provide edible nuts, occur in the Mangroves ecological zone. These areas occur primarily along the export pipeline corridor and Orokolo Bay.

Construction-related clearing could remove or reduce food sources near villages and/or cause associated forest degradation, causing villagers to have to spend more time and/or effort to source these foods. Table 16.11 shows the estimated areas of sago dominated forest and vegetation complex with sago to be cleared along approximately 5 km of the onshore export pipeline route. The extent of the clearing of sago dominated forest along the onshore export pipeline route close to villages is less than 8 ha.

Table 16.11 – Potential Impacts on Food Sources in the PAOI

Vegetation/Land use	Area in the Study Area (ha)	PRL-15				Non PRL-15			
		Clearance (ha)	Clearance (%)	Degradation (ha)	Degradation (%)	Clearance (ha)	Clearance (%)	Degradation (ha)	Degradation (%)
Primary Hill forest (H)	250,982	554.28	0.22	1,951.39	0.78	1.17	0.00	9.39	0.00
Logged Hill forest (H)	89,996	7.13	0.01	43.77	0.05	13.93	0.02	97.64	0.11
Primary Alluvial forest (P)	85,001	72.91	0.09	151.21	0.18	33.68	0.04	226.83	0.27
Logged Alluvial forest (P)	30,340	85.60	0.28	226.54	0.75	70.41	0.23	461.81	1.52
Swamp forest (Fsw)	111,460	0.00	0.00	0.0	0.00	65.43	0.06	423.84	0.38
Mangrove (M)	60,363	0.00	0.00	0.0	0.00	0.21	0.00	1.57	0.00
Littoral forest (B)	178	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
Sago-dominated*	43,232	0.00	0.00	0.0	0.00	7.92	0.02	52.81	0.12
Vegetation complex with sago #	20,734	0.00	0.00	0.0	0.00	65.43	0.32	423.84	2.04
Wild stands of sago woodland ^	43,232	0.00	0.00	0.0	0.00	7.92	0.02	52.81	0.12
Gardens and hill forest (Hm5, Hs5)	112	0.00	0.00	0.0	0.00	0.0	0.00	NA	NA
Gardens and sago cultivation (O)	1,370	0.00	0.00	0.0	0.00	6.42	0.47	NA	NA

Notes: The study area refers to the area used for terrestrial biodiversity mapping, shown in Figure 7.16. * Sago-dominated is all the FIMS polygons of pure Wsw plus vegetation complexes where Wsw is the dominant vegetation type (i.e., Wsw/Gsw, Wsw/Fsw and Wsw/Hsw). # Vegetation complex with sago includes all vegetation complexes where Wsw is the subordinate vegetation type (i.e., Fsw/Wsw, Gsw/Wsw, Hsw/Wsw & Po/Wsw). ^ Wild stands of sago woodland are sago-dominated.

Clearing in PRL-15 will be remote from villages and is not expected to affect the availability of wild plant foods for Poroi 1, Mapaio Fish Camp or the Purari Airstrip House. Clearing across the Purari River from Aivai will be for a pipe yard and construction camp; but will be temporary in nature.

In-migration and induced access could increase pressure on wild foods; however, in-migration will vary in the Project area and is considered potentially more important in and around PRL-15, where wild food resources are largely replaceable. Thus, the reduction in availability of wild foods due to induced in-migration is considered negligible and is not assessed further. Chapter 13 discusses Project-induced in-migration and associated mitigations in further detail.

16.5.1.2 Loss of Food Gardens and Planted Sago

The main food crops that are grown in gardens are detailed in Part 18 of Volume 2. Some food grown in gardens and associated planted sago in coastal communities will be lost through land clearing associated with construction activities, particularly along the onshore export pipeline route in the Orokolo Bay area, which has the highest density of food gardens and planted sago in the Project area (Table 16.11 and Figure 16.3); however Table 16.11 shows that only 6.4 ha of gardens and planted sago will be cleared along the pipeline right of way.

Planted sago also occurs along the east and west banks of the Purari River in the river transport corridor and in PRL-15; however, clearing of planted sago or food garden resources is not predicted to occur in either of these parts of the Project area.

In-migration and unplanned community expansion could increase pressure on the land available for crop cultivation, particularly for the Orokolo Bay coastal communities or in communities along the onshore export pipeline route; however, in-migration to these areas is not predicted to be high (see Chapter 13). Thus, the impacts of increased pressure on food gardens and planted sago are considered negligible and are not assessed further.

Project activities could introduce new weed species, which have the potential to degrade food gardens; reduce productivity; increase manual labor; and compromise traditional cultivation practices. Construction activities need to occur near gardens and cultivated areas for these impacts to occur. This will occur along approximately 5 km of pipeline as it approaches Orokolo Bay (Figure 16.3) and standard risk-based weed hygiene measures will be applied (see Chapter 11); therefore, the potential impacts on food gardens associated with the introduction or spread of weeds are considered negligible and are not assessed further.

16.5.1.3 Reduced Access to Firewood

Firewood is an essential resource used by communities in the PAOI, as a fuel source for cooking. The Project has the potential to reduce the amount of firewood available near villages and to increase the time and/or effort required to source it, due to construction-related clearing or restricted access to coastal areas.

Firewood availability for residents of Poroi 1 and Mapaio Fish Camp is unlikely to be impacted by Project activities in PRL-15, as firewood is usually collected close to villages, and the Project will not be clearing near villages; therefore, reduction in the availability of firewood in and around PRL-15 is not discussed further.

Clearing is not proposed along the river transport corridor, so firewood availability to villages along the riverways will not be directly impacted due to Project activities; therefore, reduced firewood availability along the riverways is not discussed further.

PROJECT INFRASTRUCTURE IN RELATION TO FOOD GARDENS NEAR OROKOLO BAY

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FIGURE 16.3

Driftwood, collected from the beaches, is an important firewood source for coastal communities along Orokolo Bay. The construction footprint for the onshore export pipeline shore crossing will temporarily prevent access to that area of beach for firewood collection, and the driftwood that would otherwise have washed up on this area, may wash up on another clan's area of beach.

This could temporarily affect the collection and distribution of this resource for nearby villages of Iuku and Mareke.

16.5.1.4 Reduced Availability of Timber and Wood Products

Variation in the preferred house post species occurs across the PAOI, depending upon which species grow near villages. The preferred house posts are the most durable timbers that are in smaller size-classes growing near a village. House post species, particularly kwila (*Intsia bijuga*), which is the preferred species for riverway communities downstream of Pawaia territory, growing close to waterways are also of high value since they can be floated downstream to riverway villages. The Pawaia communities have access to hill forest that supports a greater diversity of tree species compared to the alluvial forests.

Preferred house posts are already in short supply for some communities, so coconut palm stems are used as a less durable replacement. This is due to clearing for subsistence agriculture in coastal communities and overharvesting in some of the river transport corridor communities on the lower reaches of the Purari River.

Dugout canoes are the main form of transport for most villages in the PAOI, except for inland villages such as Paevera, where there is no navigable waterway. Individual households own between one and five canoes suggesting widespread demand for canoe trees (see Part 18 of Volume 2); however, while canoes are an important asset, they generally last for two to three years and do not need to be replaced often.

Canoe trees are usually preferentially harvested from forest close to waterways. Canoe trees for the Pawaia are often harvested from hill forest up to one kilometer inland, made in the forest and then dragged to the nearest creek or river. Project-related clearing of large-diameter trees, i.e., more than 50 cm diameter at breast height near waterways, has the potential to remove canoe tree resources used by villagers, which may increase the time and/or effort to source, harvest and transport them. This is only a potential impact for Mapaio Fish Camp and Poroi 1, as other communities are much further from Project-related clearing.

16.5.1.5 Reduced Quantity and Quality of Fresh Water for Domestic Use

Project-related water extraction, wastewater discharges or accidental spills, and increased pressure from indirect effects, such as in-migration, may reduce the fresh water quality and quantity available for community use. Communities may have to source alternative supplies and/or use lower-quality supplies, which could cause declines in community health.

Water abstraction from the Purari River for the CPF and additional sediment from Project activities entering the Purari River will have negligible impact on water availability and quality, given the existing high sediment loads; therefore, these activities are not discussed further.

No communities in PRL-15 depend on surface waters from Boa Creek and Hou Creek, where water may be extracted for Project use; therefore, water extraction from these creeks is not discussed further.

Chapter 11 discusses the potential for trenching at the shore crossing in Orokolo Bay to cause fresh groundwater drawdown in nearby village wells. This could reduce the freshwater supply to coastal communities that rely on a thin lens of freshwater overlaying saline water.

Wastewater discharges or accidental releases could contribute to reduced water quality and reduced use for domestic purposes. A reduction in water quality could cause reduced use of these sources for domestic use, cause stress and anxiety about consuming these supplies, and ultimately cause more time spent sourcing alternate supplies.

In-migration and induced access could increase pressure on the availability and quality of fresh water. Fresh water is readily available (via the Purari River, family storage tanks) to communities in and around PRL-15, where in-migration is predicted to be highest throughout the PAOI, Therefore, the reduction in the quantity and quality of fresh water due to induced in-migration is considered negligible and is not assessed further. Chapter 13 discusses Project-induced in-migration in further detail.

16.5.1.6 Temporary Disturbance to Transport

Rivers are the main transport routes for communities to access schools, hospitals, markets, food gardens and sago processing sites (see Figure 13.1), and the predicted increase in barge traffic associated with Project construction activities could potentially disturb community use of the Purari River as a transport route to these sites and services.

Chapter 13 discusses the potential impacts associated with community use of the Purari River, nearshore marine environment and beaches along Orokolo Bay during pipeline construction; therefore, these impacts are not assessed further in this chapter.

16.5.1.7 Reduced Access, Catches or the Value of Commercial Fisheries

Two key commercial fisheries are relevant to the offshore Project area, i.e., the:

- Gulf of Papua Prawn Fishery.
- Torres Strait Tropical Rock Lobster Fishery.

The economic value of the Gulf of Papua Prawn Fishery is important to fishery license holders and the Government of Papua New Guinea. An overlap occurs between the commercial prawn fishery and the offshore pipeline route in two small reporting areas of the fishery (see Figure 8.26):

- Area 4 (Orokolo Bay) fishery reporting area.
- Area 5 (West Kerema Bay) fishery reporting area.

Chapter 15 discusses the potential for pipelaying activities to temporarily disrupt access to these fishery areas. The potential impact was considered negligible therefore it is not discussed further in this chapter.

Other potential impacts to the Gulf of Papua Prawn Fishery may include a temporary, localized, deterioration of water quality due to construction activities (e.g., suspended sediment plumes from trenching for the export pipeline, disposal of hydrotest water, and domestic wastewater and bilge water discharges from Project vessels).

The introduction of pests or pathogens from Project vessels and the possible impacts of underwater noise on aquatic fauna (i.e., associated with pipelaying activities and vessel movements) have also been considered. Implications for the prawn fishery are considered negligible and these impacts are not assessed further.

Commercial activities of the Torres Strait Tropical Rock Lobster Fishery, which is jointly managed by Australia and Papua New Guinea with an annual value of nearly AUD$20 million, are centered in the Torres Strait to southwestern Gulf of Papua well outside the PAOI; however, the ornate rock lobster mass migration to spawning sites at Yule Island and other reefs throughout Central Province (see Section 8.6.2.2) crosses the Gulf of Papua and the export pipeline route. The export pipelines may present a physical hindrance to this migration reducing the species population (Chapter 12).

16.5.1.8 Direct Loss of Commercial Forestry Resources and Royalties

Project construction in PRL-15 will clear an estimated 745 ha of commercial production forest based on data collected in 2016, of which 150 ha has already been logged and 595 ha has yet to logged. This would cause a potential loss of 10,710 m^3 of saw logs based on a mean merchantable volume of 18 m^3/ha (PNGFA, 1996) and assuming the 595 ha is not yet logged, is all accessible for logging, and has commercially viable volumes. This equates to a lost export value of US$1,071,000 for the commercial logging industry based on a conservative log export price of $US100/$m^3$ (ITT0, 2019),

Royalties on the logs could also be lost, reducing revenue for the customary landowners. Log royalties vary from K10 to K30/m^3, depending on the log export price (Hasagama, 2014), which would equate to a minimum value of lost royalties of K107,100.

Interactions between logging barges and Project river traffic may occur in the Purari River. This impact is discussed in Chapter 15. For cumulative impacts associated with deforestation and logging, see Chapter 17.

16.5.2 Cultural Services

16.5.2.1 Loss of Access to Cultural Sites

Chapter 14 provides a description of potential impacts on tangible cultural heritage and relevant management measures, including the potential benefits associated with implementation of a Cultural Heritage Management Plan.

Potential loss of access to cultural sites is covered in Chapter 14 and is not assessed further in this chapter.

16.5.2.2 Loss of Knowledge of Traditional Practices

Use of plants and animals for traditional practices requires a diverse range of species that are mostly widely present across hill and alluvial forest, and are used mostly in small amounts. Impacts are likely to be higher if forest is cleared near villages or food gardens, as these forest resources are easily accessed.

Potential impacts could also occur for fauna resources that are used in traditional practices and are highly valued, e.g., the availability of preferred bird feathers and animal skins used for body decoration in traditional ceremonies could be reduced, reflecting degradation of fauna habitat and ongoing disturbance from operational activities causing changes to fauna distribution or abundance. Reductions in fauna populations due to increased hunting (through induced access or in-migration), are expected to be minimal once mitigations are applied (see Chapter 11 and Chapter 13).

The potential for a loss of traditional knowledge and intergenerational transfer of knowledge due to less time being spent undertaking traditional practices as an indirect result of the economic opportunities offered by the Project is discussed in Chapters 13 and 14 and is not assessed in this chapter.

16.5.3 Regulating and Maintaining Services

16.5.3.1 Loss of Ecosystem Function to Control Landform Stability and Erosion

Chapter 11 identifies that Project activities, particularly excavations and earthworks in PRL-15 and along the onshore export pipeline route, may reduce landform stability, increasing the incidence of landslips or mass movements.

Potential impacts associated with major natural hazards and unplanned events, such as landslips due to seismic events, are considered in Chapter 18.

16.5.3.2 Loss of Ecosystem Function to Regulate Surface Water and Groundwater

Chapter 11 describes the potential Project impacts to hydrology and groundwater, highlighting the potential for changes to hydraulic processes, reductions in stream flows, and groundwater contamination. The impacts of changes to fresh water on local communities is discussed in Section 16.5.2.1.

Key ecosystem services, such as water purification (Section 16.5.3.4), water-retention and climate regulation, are also connected to the hydrological cycle (Grizzetti et al., 2016). Surface water and groundwater regulation provides fresh water to ecosystems and local communities, and can reduce flood effects (Grizzetti et al., 2016).

Project activities, such as clearing; dredging; water abstraction; or building dams, culverts or water crossings, have the potential to disrupt natural surface flows or groundwater recharge. Changes to an ecosystem’s natural hydrology and sediment delivery processes have the potential to inhibit the regulatory function of that ecosystem; however, given the minor impacts predicted in Chapter 11, the potential Project impacts on the ecosystem function to regulate surface water and groundwater is anticipated to be negligible and is not assessed further.

16.5.3.3 Loss of Ecosystem Function to Regulate Natural Hazards

The PAOI is subjected to flooding, e.g., near the proposed CPF in PRL-15, landslides and coastal erosion. These are natural events; however, the Project may impact the regulatory function of natural environments by clearing natural vegetation, so that landslides and flooding could become more regular and/or severe. This could be exacerbated by climate change, which is predicted to increase the intensity and frequency of extreme weather and climatic events (Australian Bureau of Meteorology and CSIRO, 2011).

The potential for Project activities to destabilize landforms and trigger landslides is assessed in Section 11.1.5.1 for the various landform types in the PAOI. Clearing forest on slopes increases landslide potential. Storm runoff from Project roads and tracks that generate infiltration excess, can increase landslides and associated surface erosion losses. Road cuts that intercept subsurface flows can exacerbate landslide potential (Sidle et al., 2006). Landslides typically cause the complete loss of vegetation cover and topsoil, all of which is deposited on forest on the lower slopes, causing further forest deterioration.

16.5.3.4 Loss of Ecosystem Function to Regulate Water Purification and Waste Treatment

Ecosystems in the Project area play an important role in filtering and purifying water, and assimilating, detoxifying or sequestering waste through soil or aquatic processes, thereby avoiding harmful effects on humans and the environment.

Activities that are most likely to constrain the regulation of water purification and waste treatment include land and topsoil clearing, modifications to surface waters in and around PRL-15 (see Chapter 11), and the removal or impairment of the aquatic organisms responsible for waste treatment.

Even small emissions to water could have an adverse impact on water quality, with flow-on effects to public health (see Chapter 13), if Project activities impair this ecosystem service. Eutrophication could also occur degrading aquatic habitats and harming species.

16.5.3.5 Loss of Ecosystem Function to Regulate Vector-borne Disease

Natural habitats can influence the spread of vector-borne disease, such as malaria, dengue and Ross River fever, to humans. As discussed in Chapter 13, malaria is the dominant vector-borne disease in the PAOI, and changes to environmental (e.g., through the creation of habitat) and social conditions have the potential to increase the frequency or severity of outbreaks.

The most direct way the Project can influence vector-borne disease regulation is through modifying natural environments, e.g., increasing areas of standing water, which can act as mosquito breeding areas, and increasing the number of people exposed to the disease.

Project impacts on the ecosystem’s ability to regulate disease is negligible given the relatively small areas that the Project will impact relative to the amount of regulating environment available and Project mitigation measures; therefore, these impacts are not assessed further.

16.5.3.6 Loss of Topsoil and the Seedbank for Natural Regeneration

The presence of intact topsoil is a key component to the success of natural regeneration and can be lost from construction-related clearing and associated erosion.

In addition to the soil seedbank, seed rain is also important for maintaining natural regeneration and is a useful seed source for disturbed sites. Seed rain in larger clearings mostly occurs from wind-dispersed seed.

Project-related clearing is minor and localized (see Chapter 11); therefore, impacts on the natural regenerative capacity of the forest ecosystem service is negligible and is not assessed further.

16.5.3.7 Loss of Habitat Provision

Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances; the spatial extent and interconnectedness of habitats are important for recovery capacity. Within the study area, they include:

- Terrestrial biodiversity focal sites (see Section 7.7.7).
- Mangrove forests (see Section 7.7.7.2).
- Mangroves, as nurseries for a range of aquatic (fish and invertebrate) species (see Section 7.6.2.3).
- Rivers and estuaries, which provide nursery habitat for juvenile and sub-adults (see Part 5 of Volume 2).

- Seagrass meadows (found in Caution Bay), which provide food and refuge for marine fauna (see Section 8.5.2.4).
- Coral reefs, such as those found in Caution Bay, which are feeding and nursery grounds for marine fauna (see Section 8.2.2.5).
- Offshore waters in the Gulf of Papua and along the offshore export pipeline corridor, which provide habitat for pelagic fish and marine reptiles, and mammals of conservation significance (and commercial/subsistence importance) (see Section 8.5.3).

Project-related clearing and the laying of export pipelines will result in habitat loss. Chapters 11 and 12 identify and assess potential impacts to habitat and the species they support from Project activities, and therefore it is not assessed further in this chapter.

16.5.4 Non-priority Ecosystem Services

The impacts discussed in this section were not identified as priority ecosystem services during the screening process (see Table 16.10); however, beneficiaries rated them as of high-importance so they are considered in the following sections.

16.5.4.1 Impacts to Hunting and Fishing

Project noise from construction and/or operational activities around Mapaio Fish Camp, Poroi 1 and the Purari Airstrip House, including increased air or barge traffic during the construction phase, could cause local fauna to move out of the area, affecting hunting or fishing practices in and around these communities.

Chapter 15 describes the potential noise impacts from the CPF and Logistics Base in relation to sensitive receptors (i.e., villages). Chapter 11 discusses the potential impacts to fauna from noise and determines that it will just be near Project footprints and that residual impacts associated with noise disturbance to terrestrial species are rated as ***Minor***. Based on these assessments, the potential for construction or operating noise to impact local fauna to the extent that livelihoods are affected is considered negligible and not assessed further.

16.5.4.2 Loss of Wild Sago Stands

No wild stands of sago will be cleared from PRL-15; and less than 8 ha of wild sago dominated vegetation will be cleared from the onshore export pipeline route, which is 0.1% of the resource (Figure 16.4). Approximately 65 ha of vegetation where sago is a subordinate species will also be cleared, which is approximately 0.3% of the resource (see Table 16.11). Edge effects could also degrade a further 424 ha (2%) of this resource.

Wild stands of sago were not identified as a priority ecosystem service; however, forest plant food and wild sago stands are considered together in the residual impact assessment (Section 16.8.1.1), as wild sago is an important food source for many communities and is often found throughout the forest habitats where other wild plant foods are sourced, (i.e., swamp woodland (Wsw) and vegetation complexes where Wsw is dominant). Wild sago is not found in hill (H) or alluvial forest (P), which dominates much of PRL-15.

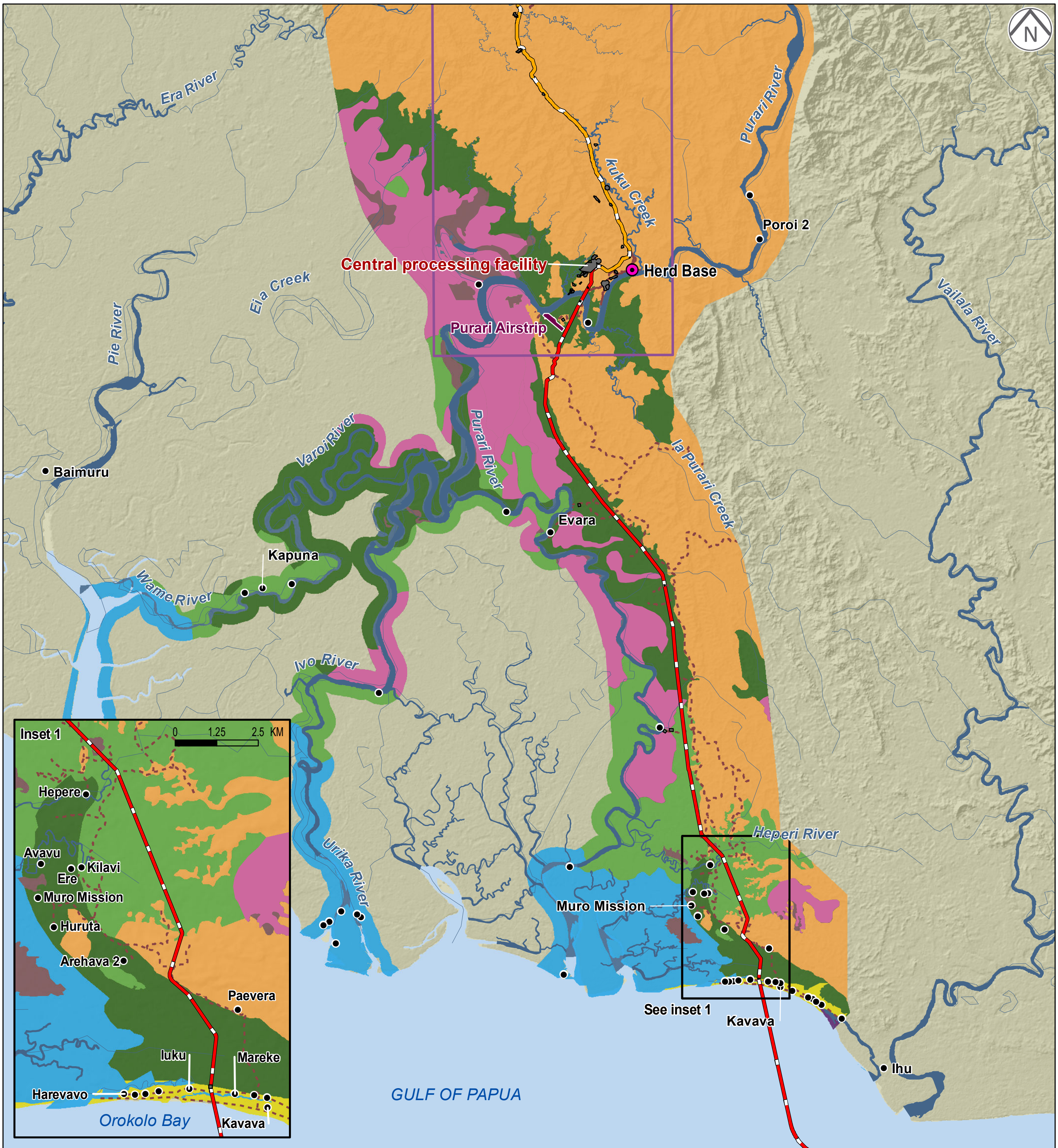
16.5.4.3 Changes to Participation in Artisanal Fisheries

The ornate rock lobster artisanal fishery is focused at Yule Island but occurs at reefs between Yule Island and Redscar Bay. Lobsters gather at the reefs to spawn from November to April,

PROJECT INFRASTRUCTURE IN RELATION TO WILD STANDS OF SAGO

Papua LNG Project | Environmental Impact Statement

FIGURE 16.4



SCALE: 1:450,000 @ A4 | 0 2.5 5 10 15 KM | COORDINATE SYSTEM: PNG94 UTM Zone 55S

•	Town or village	⦿	Base camp	**Natural Resources**			Mangroves
	Existing road		Export pipeline route		Alluvial forest		Rivers and waterbodies
	Former logging road		Trunkline/flowline route (gathering system)		Grassland/herbland		Subsistence land use and villages
	Waterway		Proposed Project arrangement (See Figure 4.4 for detail)		Hill forest		Swamp forest
	Waterbody or major river				Littoral forest		Wild stands of sago woodland
	PRL-15						

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resulting in a seasonal artisanal and subsistence dive fishery (see Chapter 8). A reduction in the abundance of migrating lobsters arriving at the spawning reefs in this region could reduce this fishery, if the laid pipelines hinder migration (see Chapter 12).

Chapter 15 discusses the potential for the Project to temporarily disrupt access to artisanal fishing grounds in Orokolo Bay during pipelaying activities in the 3 nautical mile coastal zone; and considers this impact negligible and it is not assessed further.

Trenching activities in the unconsolidated muds in Orokolo Bay will mobilize sediment suspended into the water column, potentially causing localized and temporary impacts to fish, crabs, mollusks and prawns that are the focus of artisanal fisheries. Any trenching impacts are likely to be negligible, given the large area of this habitat available and the high ability of local fauna, including prawns, to adapt to naturally high levels of suspended sediment in this area; therefore, trenching impacting artisanal fisheries not assessed further.

Trenching for the offshore export pipelines in Caution Bay has the potential, to smother sensitive coral reef and seagrass habitats that support artisanal fisheries with mobilized sediment. These marine habitats are less adapted to high sediment exposure than those in Orokolo Bay, where much of the substrate is mud and large fluvial sediment inputs occur. Impacts on these habitats may temporarily reduce fish foraging habitat but are unlikely to measurably reduce species populations (see Chapter 12). Any impacts on artisanal fisheries due to trenching and pipelaying are; therefore, likely to be negligible and are not assessed further.

Construction activities at the shore crossings, pipelaying and ongoing operations of the export pipeline and barging activities through the Gulf of Papua to the Purari River have the potential to reduce water quality from planned wastewater discharges or accidental contaminant spills or leaks, and harm or kill marine species sought by artisanal fishers. These potential impacts are addressed in Chapter 12 and are therefore not assessed further in this chapter.

Project employment and business opportunities, and an increase in associated income (see Chapter 13) may indirectly contribute to a decline in artisanal fishing participation, which can induce subsequent positive and adverse impacts, including an improvement (i.e., due to an increase in diversity of food consumed) or a decline (i.e., due to an increase in consumption of unhealthy foods) in nutrition, a loss of traditional fishing knowledge, or an increase in demand for local seafood products, which could in turn increase pressure on nearshore fish stocks.

Predicting the positive or adverse impacts on fishery participation associated with an increase in employment or other business opportunities is difficult, as often multiple factors contribute to community investments in time, effort and other resources, and few longitudinal studies exist to draw from. EHL, (2012) identified a decline in artisanal fishing activity in Caution Bay due to increased employment during construction at the PNG LNG Facilities.

On balance, given the paucity of information to predict impacts of Project employment or income on artisanal fishing practices and the subsequent impacts relating to nutrition and health, traditional practices and changes to demand, any changes to artisanal practices (i.e., an increase or decrease in fishery participation) associated with changes to economic conditions cannot be assessed further with any level of confidence.

16.5.5 Summary of Potential Impacts

The Project has the potential to impact on priority ecosystem services, as summarized in Table 16.12.

Table 16.12 – Summary of Potential Impacts on Ecosystem Services

Ecosystem Service	Potential Impact
Provisioning Services	
Wild plant foods	♦ Small, direct loss of wild plant foods, including wild sago, in forest habitat near villages from land clearing along approximately 5 km of the export pipeline route, and an increase in the time/effort required to source these foods.
Gardens and planted sago	♦ Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along approximately 5 km of the onshore export pipeline route and shore crossing.
Timber and firewood	♦ Reduced access to driftwood used for firewood during onshore export pipeline construction activities. ♦ Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it for Mapaio Fish Camp and Poroi 1 communities due to land clearing activities.
Domestic water	♦ Reduced fresh water availability or quality for domestic use in villages along Orokolo Bay due to trenching activities, wastewater discharges or accidental hazardous material releases.
Commercial fisheries	♦ Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges. ♦ Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.
Commercial forestry	♦ Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing. ♦ Loss of royalty payments for landowners due to clearing commercially harvestable trees.
Cultural Services	
Intangible heritage	♦ Direct loss of traditional knowledge of native flora and fauna due to a reduction in availability caused by land use changes.
Regulating and Maintaining Services	
♦ Loss of ecosystem function to control landform stability and erosion. ♦ Loss of ecosystem function to regulate natural hazards. ♦ Loss of ecosystem function to regulate water purification and waste treatment.	
Non-priority Services	
Wild plant foods	♦ Direct loss of stands of wild sago woodlands (approximately 8 ha) near villages due to land clearing along approximately 5 km of the onshore export pipeline route.
Artisanal fisheries	♦ Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island. ♦ Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.

Potential impacts to ecosystem services can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013].

The following embedded design controls address potential impacts to the quantity and quality of fresh water for domestic use, commercial and artisanal fisheries:

- Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as:
  - Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan.
  - Building infrastructure on impervious surfaces where required
  - Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials.
  - Installing interceptor pits or similar to collect contaminated surface water runoff and treat where required.
  - Installing tanks above ground with impermeable liners and bunds around tanks.
  - Regularly inspect and maintain the containers, storage and transfer infrastructure to prevent/control spills or leaks.
  - Installing readily accessible spill kits and training staff in their use.
  - Appropriately treating and disposing of any accidentally contaminated soils [ED003].
- Design Project infrastructure (including workforce accommodation) to minimize vector harborage (e.g., minimize pooling water, proper waste disposal) and human exposure (e.g., screening of doors and windows) to minimize spread of disease [ED035].
- The drilling will be performed using water-based mud [ED004].
- The landfill will be designed to comply with TOTAL’s general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices [ED005].
- Minimize chemical use and select chemicals considering the following criteria:
  - Lowest toxicity, lowest bioaccumulation potential and highest biodegradation;
  - Chemicals subject to bans or phase-outs [ED006].
- Use low-pressure detection alarms to detect pipeline leaks [ED007].
- Use fiber optic cable laid in the same trench to monitor pipelines. This cable will detect intrusions and ground movements [ED008].
- Locate valve stations along the onshore pipeline route to isolate pipeline sections if a leak occurs [ED009].
- The gathering and reinjection system, wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational controls (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring) [ED011].
- Hydrotesting will be undertaken to confirm weld integrity [ED012].
- The CPF will have an open drain system to manage rainwater; the system will have three separate networks:

- OD1 = permanently hydrocarbon-contaminated drains.
- OD2 = accidentally hydrocarbon-contaminated drains.
- OD3 = hydrocarbon-free drains.

Water from each system will be treated separately and discharged to the environment according to applicable limits [ED015].

- All OD1 waters will undergo water treatment by a hydrocarbon/water separation system prior to discharge to the Purari River according to applicable standards. All OD2 waters and water from primary treatment will be sent to an observation basin and treated by the hydrocarbon/water separation system prior to release if required. The clean OD2 water will be discharged to the Purari River. Non-contaminated stormwater (OD3) will be disposed of by natural percolation and evaporation [ED016].
- All OD1 water from wellpads will be collected in a dedicated closed tank and transported to the CPF for treatment prior to being discharged [ED017].
- The produced water generated at the CPF is to be injected back into the reservoir. Produced water will be retained in a tank with a capacity to contain five days of water production, as a backup if injection is unavailable [ED018].
- All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired [ED019].
- Rainwater infiltration into hazardous materials storage areas will be prevented [ED020].
- Requirements for hazardous material transfer, overfill protection, and alarms will be implemented, e.g.,
  - Using dedicated fittings, pipes, and hoses specific to materials in tanks.
  - Providing secondary containment, drip trays, etc. at connection points or other possible overflow points.
  - Using dripless hose connections for vehicle tank and fixed connections with storage tanks.
  - Providing automatic fill shutoff valves on storage tanks to prevent overfilling.
  - Using piping connections with automatic overfill protection (float valve).
  - Fitting tanks with high-level alarms with both audible and visible annunciation [ED021].
- Ballast waters, liquid effluents and waste from vessels will be managed according to the MARPOL 73/78 requirements [ED022]
- Hydrotest water discharges will be managed according to applicable requirements [ED040].

The following embedded design control is relevant to regulating and maintaining services:

- All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is:

– To account for local rainfall conditions and catchment size of works areas.

– To allow avoiding unseasonal waterlogging

– To allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable [ED014].

In addition, the Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

16.6 Proposed Mitigation and Management Measures

Ecosystem services is a transdisciplinary topic, combining social, cultural and environmental factors. Accordingly, this section refers to mitigation and management measures identified in Chapters 11 to 15 which will effectively mitigate potential impacts on the priority ecosystem services.

When mitigation measures identified in previous chapters are insufficient to mitigate the potential impacts on the priority ecosystem services described in Section 16.5, additional measures have been identified. They are described in Table 16.13.

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans

Potential Impact	Mitigation Measures	Management Plan
Provisioning Services		
♦ Small, direct loss of wild plant foods in forest habitat near villages from land clearing along the export pipeline route, and an increase in the time/effort required to source these foods.	♦ Measures to minimize vegetation clearing and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to loss of wild plant foods are described in Chapter 13. Additional management measure include: ♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001].	Land Access Plan; Livelihood Development Plan;
♦ Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along the onshore export pipeline route and shore crossing.	♦ Measures to minimize impacts related to loss of planted sago are described in Chapter 13. Additional management measure include: ♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001].	Land Access Plan; Livelihood Development Plan;

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Measures	Management Plan
Provisioning Services (cont'd)		
♦ Reduced access to driftwood used for firewood during onshore export pipeline construction activities. ♦ Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it due to land clearing activities.	♦ Measures to minimize vegetation clearing and associated impacts are described in Chapter 11. Additional management measure include: ♦ Assess the efficacy of efficient wood burning stove programs in coastal Papua New Guinea and, if warranted, support extension services to promote their use in the PAOI in Orokolo Bay [ESM001].	Biodiversity Action Plan; Livelihood Development Plan
♦ Reduced freshwater availability or quality for domestic use in villages along Orokolo Bay due to trenching activities, wastewater discharges or accidental hazardous material releases.	♦ Measures to protect the quality and quantity of surface water and groundwaters are described in Chapter 11.	Water Management Plan
♦ Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges. ♦ Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.	♦ Measures to minimize impacts on marine water quality and on rock lobsters are described in Chapter 12.	Biodiversity Action Plan; Traffic and Transport Management Plan
♦ Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing. ♦ Loss of royalty payments for landowners due to clearing commercially harvestable trees.	♦ Measures to minimize vegetation clearing, and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to clearing of commercially harvestable timber and trees are described in Chapter 13.	Biodiversity Action Plan; Land Access Plan; Livelihood Development Plan
Cultural Services		
♦ Direct loss of traditional knowledge of native flora and fauna due to a reduction in availability or accessibility caused by land use changes.	♦ Measures to minimize vegetation clearing and fauna habitat degradation are described in Chapter 11. ♦ Measures to minimize impact on Cultural Heritage are described in Chapter 14.	Biodiversity Action Plan; Cultural Heritage Management Plan
Regulating and Maintaining Services		
♦ Loss of ecosystem function to control landform stability and erosion. ♦ Loss of ecosystem function to regulate natural hazards. ♦ Loss of ecosystem function to regulate water purification and waste treatment.	♦ Measures to avoid or control soil erosion, avoid landform destabilization and soil degradation and support natural surface and groundwater systems are described in Chapter 11.	Soil Management Plan; Water Management Plan; Site Restoration and Rehabilitation Plan

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Measures	Management Plan
Non-priority Services		
♦ Direct loss of wild sago near villages due to land clearing along the onshore export pipeline route.	♦ Measures to minimize vegetation clearing, and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to loss of wild sago are described in Chapter 13.	Land Access Plan; Livelihood Development Plan;
♦ Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island. ♦ Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.	♦ Measures to manage impacts to rock lobsters and to minimize impacts associated with offshore construction activities are described in Chapter 12. ♦ Measures to avoid and minimize impacts on water quality are described in Chapters 11 and 12. ♦ Measures to minimize interactions between Project and community vessels are described in Chapter 13.	Biodiversity Action Plan; Water Management Plan; Livelihood Development Plan Community Development Plan Stakeholder Engagement Plan

16.7 Residual Impact Assessment

The following section provides the assessment of residual impacts to landform and soils subject to the embedded design controls in Section 16.5.5 and the successful implementation of the proposed mitigation and management measures and management plans in Table 16.13. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

16.7.1 Provisioning Services

16.7.1.1 Direct Loss of Wild Plant Foods Including Wild Stands of Sago

Wild plant foods and wild stands of sago are attributed a ***High*** sensitivity rating, particularly as communities around Orokolo Bay depend on these food sources and have limited ability to source alternatives, as relatively little forest remains and the population along the coast is denser than other areas of the PAOI.

Preconstruction surveys will allow identifying wild sago stands that are important for local villages. Once construction of the onshore export pipelines has been completed, wild sago will be allowed to regenerate in previously cleared sections outside of the right of way. The Project will follow the process set out in the Land Access Resettlement Framework when Project activities have an unavoidable impact on livelihoods through the loss of wild sago stands or other wild plant foods.

The extent of clearing wild stands of sago, along the onshore export pipeline route near villages is rated as ***Negligible*** due to the small extent of the resource planned to be cleared, i.e., less than 8 ha, or less than 0.1%, of the resource, the ability of some of this area to be recultivated, and the embedded design controls identified in Section 16.5.5; therefore, the residual impact significance rating of direct loss of wild plant foods in the export pipeline corridor communities is assessed as ***Negligible***.

16.7.1.2 Loss of Food Gardens and Planted Sago

The Project area currently has no commercial agricultural production; however, subsistence food gardens exist that are essential for community livelihoods, particularly in the coastal areas up to approximately 1.7 km north of Iuku. Sago is the main staple food for all the villages and an important famine food, as it is resilient to floods and drought. Planting and harvesting sago are the most important food production activities in the PAOI.

The sensitivity of both food gardens and planted sago is rated as ***High***, as these resources are a primary food source for communities in the PAOI.

Table 16.11 and Figure 16.3 show that an estimated 6.4 ha of cultivated land along 5 km of the export pipeline route, which includes an unknown proportion of planted sago, will be cleared or degraded.

One of the main issues with clearing any planted sago is that it is not immediately replaced, given the palm can take 12 or more years to mature sufficiently to be ready for processing (Lal, 2003). The projected clearing of cultivated land represents less than 0.5% of the resource in the coastal Orokolo Bay area (see Table 16.11); however, the impacts could be high for individuals or families if the area cleared contains large numbers of mature palms compared to clearing young sago palms.

Figure 16.3 indicates how the export pipeline route has been sensitively aligned to avoid food gardens along the onshore export pipeline route where possible. Preconstruction surveys will identify any additional established food gardens and planted sago along the route.

Food gardens cleared in the pipeline right of way for construction, may be allowed to be re-established in previously cleared sections outside of the right of way. The Project will follow the process set out in the Land Access Resettlement Framework when Project activities have an unavoidable impact on livelihoods through the loss of food gardens and planted sago.

The magnitude of the clearing, given the small areas to be cleared along the export pipeline route and the livelihood restoration or compensation, is rated as ***Negligible***; therefore, the residual impact significance assessment of direct loss of food gardens and planted sago is ***Negligible***.

16.7.1.3 Reduced Access to Firewood

Firewood is an important resource for all PAOI communities; however, supplies are plentiful in the PAOI; therefore, the sensitivity assigned to firewood as an ecosystem service is ***Medium***.

Construction of the export pipeline shore crossing will form a narrow, temporary corridor across the beach between Iuku and Mareke, and villager access to the beach and sand dunes will be maintained during construction wherever possible.

No long-term loss of access to driftwood is anticipated, as the shore crossing will not be closed to public access once construction is completed, allowing collection to resume as normal. Given these mitigations, the magnitude of any potential loss of firewood for export pipeline corridor communities is assessed as ***Negligible*** and the residual impact significance rating for a reduction in firewood availability and an increase in the time and/or effort to source it is assessed as ***Negligible***.

16.7.1.4 Reduced Availability of Timber and Wood Products

The sensitivity of timber and wood products as an ecosystem service is rated as ***Low***, due to less overharvesting, lower population densities and a greater variety of suitable tree species for inland communities along the inland river transport corridor and, in and around PRL-15, whereas the sensitivity rating for communities along the onshore export pipeline corridor, and particularly around Orokolo Bay, is ***Medium***, as the population is denser than further inland, fewer species are available and forested areas are under pressure from land-use related clearing.

Areas to be cleared near existing villages that have access to other timber resources are small, therefore, the magnitude of the potential impact is rated as ***Negligible*** for communities in and around PRL-15, and inland villages along the river transport corridor and onshore export pipeline route. This results in a residual impact significance assessment of ***Negligible***.

The magnitude of the impact is rated as ***Low***, for villages along Orokolo Bay, where any loss of suitable housing posts could represent a more significant loss due to pre-existing scarcity and a larger population. This results in a residual impact significance assessment for loss of timber and wood products around Orokolo Bay of ***Minor***.

16.7.1.5 Reduced Availability or Quality of Fresh Water for Domestic Use

The services that fresh water provides are essential for maintaining health, wellbeing and livelihoods, and few viable sources are available, which makes PAOI communities vulnerable to any decline in freshwater supply or quality. This results in a ***High*** sensitivity rating for fresh water for domestic use.

Chapter 11 describes the impacts of planned wastewater discharges and accidental hydrocarbon and chemical releases to the Purari River, and the potential impacts associated with trenching the export pipelines for the shore crossing in Orokolo Bay. All residual impacts, once embedded design controls and mitigation measures are implemented are assessed to be ***Negligible*** to ***Moderate*** (the latter rating being applicable to the potential impacts of small accidental hydrocarbon releases on the Purari River water quality and of the reduction in water availability in Orokolo Bay due to trenching activities at the shore crossing). Given the assimilative capacity and high flow volumes of the Purari River, and the availability and use of rainwater capture (tanks or drums) in riverways communities, the potential impact of accidental hydrocarbon release negatively affecting drinking water availability for river transport communities is assessed as ***Negligible*** providing a residual impact significance assessment of ***Negligible***.

Any potential impact to groundwater availability through trenching activities along the coast would be temporally limited and localized, and addressed via adaptive management where required. This is discussed in further detail in Section 11.2.5.2 and not considered further in this chapter.

16.7.1.6 Reduced Access, Catches or Value of Commercial Fisheries

Reduced Economic Value of the Gulf of Papua Prawn Fishery due to Water Contamination

The economic value of the Gulf of Papua Prawn Fishery is important to fishery licence holders and to the Government of Papua New Guinea, and the sensitivity of the fishery is rated as ***High***.

No direct impacts to prawns due to Project activities are predicted to occur; however, contamination of marine waters in the prawn fishery could cause water quality to deteriorate temporarily in a very small area, which could reduce the economic value of the fishery with respect to catch rates and accessibility. Market perceptions that the fishery catch is contaminated may also reduce the economic value of the fishery.

Considering embedded design controls; and mitigation and management measures that will be implemented to prevent, minimize, contain and clean up accidental contaminant leaks or spills in the marine environment, the residual impact significance assessment rating for marine water contamination is ***Negligible*** for planned wastewater discharges and ***Minor*** for accidental contaminant releases. The magnitude rating is assessed as ***Negligible,*** given the mitigation measures described in Chapters 12 and 15, and the large alternative area available for the fishery to operate in***;*** therefore, the residual impact significance assessment rating for contamination negatively impacting the Gulf of Papua Prawn Fishery is assessed as ***Negligible***.

Pipelines Hindering the Rock Lobster Migration with Associated Reduction in Catches for the Torres Strait Tropical Lobster Fishery

Commercial rock lobster stocks in the commercial fishery located in the Torres Strait and the far southwestern Gulf of Papua are contingent on a range of regional-scale biophysical processes. The presence of other breeding sites, larval supply from the Coral Sea, recruitment success and in-migration into the Torres Strait fishery zone from the Great Barrier Reef and other areas, and sequencing of the Gulf of Papua migration with age are among the main regional-scale drivers affecting commercial stocks.

The Torres Strait Tropical Rock Lobster Fishery is a managed fishery, and catch limits are set based on fishery-independent surveys and annual stock assessments. Reported commercial catches are highly variable year by year, as effort and lobster abundance fluctuate. Australian and Papua New Guinean fisheries' authorities have identified some key unknowns related to the fishery, such as the impact of unregulated artisanal fishery in Papua New Guinea, and the dynamics of larval supply and recruitment.

The sensitivity rating of the fishery is assessed as ***Medium***, as the fishery has some resilience to change due to its geographical extent and the management arrangements in place. Given this sensitivity, the magnitude of the impact that the export pipelines may hinder the rock lobster migration such that it affects this commercial fishery is assessed as ***Negligible***. This results in a residual impact significance assessment rating of ***Negligible***. This ranking is contingent on the mitigations listed in Chapter 12.

16.7.1.7 Loss of Commercial Forestry Resources and Royalties

Reduced Harvestable Timber from Commercial Concessions and a Resulting Loss of Revenue

The Project proposes to clear approximately 745 ha of forest that supports commercial timber production. Of this, at least 150 ha has already been logged; and, more of the remaining area is likely to also have been logged by the time Project construction clearing takes place.

The sensitivity of commercial forestry beneficiaries is rated as ***Low***, as the industry is easily adaptable to change, and considerable areas of this resource exist outside the Project footprint. The magnitude of the direct loss of forestry resources for commercial beneficiaries, considering the management measures proposed, is rated as ***Medium***, as the forestry resources may be unavailable to harvest before construction clearing due to their size or accessibility, and will also be unavailable in the PRL-15 Project footprint for the life of the Project. This provides a residual impact significance assessment rating of ***Minor*** for the loss of harvestable timber for commercial beneficiaries.

Loss of Royalty Payments for Landowners from Commercial Logging

Logging activities are complete in the export pipeline route at this time. The sensitivity of commercial forestry, as a source of income for landowning communities is rated as ***High***, and the magnitude of the potential impact is ***Low***, given the embedded design controls and mitigation measures proposed. This provides a residual impact significance assessment rating of ***Minor***.

16.7.2 Cultural Services

Chapter 14 describes the management measures proposed to mitigate Project-related impacts on intangible heritage. The potential for reduced availability of plants and animals used for traditional purposes due to in-migration and Project-related clearing will be managed by measures to document and maintain intangible heritage (see Chapter 14), manage in-migration (see Chapter 13) and by conducting preconstruction surveys to identify local sensitivities (see Chapter 11).

16.7.3 Regulating and Maintaining Services

Management measures to control erosion and sedimentation, landslides and impacts on surface water discussed in detail in Chapter 11 are expected to address the potential decrease in the ecosystem ability to regulate and maintain services.

16.7.4 Non-priority Ecosystem Services – Changes in Participation of Artisanal Fishing

Selling the surplus catch from artisanal fishing is opportunistic and has been declining over recent years, as people have sought other sources of income, and consumers have sought more access to store-bought foods; although, it remains an important source of income for some coastal communities. These changes to participation in artisanal fishing indicate community capacity to realize opportunities and adapt to change. This results in a sensitivity rating of ***Medium*** for artisanal fishing in the PAOI.

16.7.4.1 Pipelines Hindering Rock Lobster Migration to Spawning Sites Near Yule Island, with Associated Reductions in Catches for the Artisanal Fishery

The Project pipelines have the potential to reduce the artisanal lobster fishery in the area between Yule Island and Redscar Bay by hindering lobster migration.

Spatial alternatives in this fishery are limited, as lobsters arrive at nearshore reefs in this area over a defined migration season. The extent to which the export pipelines may hinder the lobster migration, such that the status of the artisanal fishery is affected, is uncertain. Adaptive management measures to mitigate possible impacts, including appropriate management responses as required, are described in Chapter 12; therefore, the magnitude is rated as ***Medium***, and the residual rating of this impact for communities that are involved in the fishery is assessed as ***Moderate***.

16.7.4.2 Water Contamination from Pipelaying or Shipping Impacting Artisanal Fishing in Orokolo Bay or the Purari River Delta

Impacts on water quality due to activities occurring at the Logistics Base and CPF are unlikely to impact the lower reaches of the Purari River delta and are assessed in Chapter 11 as being ***Negligible*** to ***Minor***.

Chapter 12 describes the management measures that will be in place to prevent, minimize, contain and clean up accidental contaminant leaks or spills in the marine environment. The residual impact due to a decrease of marine water quality was assessed as ***Negligible*** for planned wastewater discharges and ***Minor*** for accidental contaminant releases. Communities may avoid fishing in particular areas and for particular species if they believe that Project activities have contaminated the water; therefore, community engagement and water quality monitoring will be important tools for confirming the efficacy of mitigation strategies and communicating Project impacts or lack thereof.

Crabs and mollusks targeted by artisanal fishers are perhaps more susceptible to contaminant releases than more mobile species, such as finfish or prawns; however, the magnitude rating is ***Low*** since the impact is likely to be localized, temporary. The residual impact significance assessment rating for contamination of marine or estuarine waters impacting negatively on artisanal fishing for river transport corridor and export pipeline corridor communities is assessed as ***Minor***.

16.7.5 Summary of Residual Impact Assessment for Ecosystems Services

A summary of the assessment of residual impacts related to ecosystems services is provided in Table 16.14, including the Project phase and location when and where impacts are expected to occur. The table should be read with the mitigation measures provided in Table 16.13. All residual impacts are assessed to be ***Negligible*** to ***Minor***, except for the following impact, which is assessed to have a ***Moderate*** residual impact:

- Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island.

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Provisioning Services							
Wild foods – plants	Vegetation clearing; onshore pipeline construction.	Small, direct loss of wild plant foods in forest habitat near villages from land clearing along the export pipeline route, and an increase in the time/effort required to source these foods.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ See Chapter 13 ♦ EM001	High/Negligible	Negligible
		Direct loss of wild sago near villages due to land clearing along the onshore export pipeline route.		C		High/Negligible	Negligible
Food – crops	Vegetation clearing; onshore pipeline construction.	Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along the onshore export pipeline route and shore crossing.	Onshore export pipeline route	C	♦ See Chapter 13 ♦ EM001	High/Negligible	Negligible
Fuel (firewood)	Onshore pipeline construction.	Reduced access to driftwood used for firewood during onshore export pipeline construction activities.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ ESM001	Medium/ Negligible	Negligible
Timber and wood products	Vegetation clearing.	Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it due to land clearing activities.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ ESM001	Medium/Low	Minor
			PRL-15, river transport corridor			Low/Negligible	Negligible

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment (cont'd)

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Provisioning Services (cont'd)							
Freshwater (domestic use)	Logistics Transport	Reduced fresh water availability for domestic use due to accidental hydrocarbon release to the Purari River.	River transport corridor	C, O	♦ See Chapter 11	High/Negligible	Negligible
Commercial fisheries	Construction, including trenching, of Orokolo Bay export pipeline shore crossing.	Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges.	Offshore export pipeline route	C	♦ See Chapter 12	High/Negligible	Negligible
	Offshore pipeline construction.	Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.		C, O, D		Medium/ Negligible	Negligible
Commercial forestry	Vegetation clearing.	Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing.	PRL-15, onshore export pipeline route	C, O	♦ See Chapter 11 ♦ See Chapter 13	Low/Medium	Minor
		Loss of royalties for landowners.				High/Low	Minor

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment (cont'd)

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Non-priority Services							
Wild foods – freshwater and marine species	Offshore pipeline construction.	Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island.	Offshore export pipeline route	C, O, D	♦ See Chapter 11 ♦ See Chapter 13.	Medium/Medium	Moderate
	Offshore pipeline construction; logistics and transport (barging along the Purari River).	Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.	Offshore export pipeline route, river transport corridor	C, O		Medium/Low	Minor

Note: C = Construction, O = Operations, D = Decommissioning and closure.

16.8 References

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Attachment 16.1
Defining the Scope and Information Needs for Ecosystem Services

Defining the Scope and Information Needs for Ecosystem Services

The World Resources Institute guidance (WRI, 2013) describes the need to establish the geographic boundary of the ecosystem services assessment and determine the data needs for each ecosystem service category.

The geographic boundary (i.e., study area) for the ecosystem services study was defined as the PAOI as described in Chapter 3. The PAOI incorporates the communities that are likely to be affected by the upstream Project, as listed in Section 9.5.1 of this EIS.

An integrated approach was used to collect the information required for the ecosystem services assessment. Data collection methods and the baseline reports, where information relevant to this ecosystem services baseline has been reported, are listed in Table 1 and described further in the following paragraphs.

Table 1 – Data Collection for the Ecosystem Services Baseline

Ecosystem Service	Method	Reports in Which Data Collected is Presented	Other Reports Reviewed
Provisioning Services			
♦ Wild foods ♦ Food (crops and livestock) ♦ Fuel (firewood) ♦ Timber and wood products ♦ Fibers and resins (non-timber) ♦ Freshwater (transportation) ♦ Marine (transportation) ♦ Commercial marine fisheries ♦ Commercial forestry	♦ Observations and informal discussions (terrestrial biodiversity and social survey team). ♦ Key informant interviews and focus group discussions during the community level survey. ♦ Structured questionnaire during the household survey. ♦ Semi-formal interviews during the ecosystem services survey.	♦ Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2). ♦ Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2). ♦ Upstream Community and Demographics Baseline Report (Part 14 of Volume 2). ♦ Upstream Governance and Economics Baseline Report (Part 15 of Volume 2). ♦ Upstream Deforestation Baseline Report (Part 7 of Volume 2).	♦ Upstream Freshwater and Estuarine Biodiversity Baseline Report (Part 5 of Volume 2). ♦ Marine Biodiversity Baseline Report (Part 12 of Volume 2). ♦ Marine Fisheries and Resources Baseline Report (Part 13 of Volume 2). ♦ Upstream Community Health Report (Part 16 of Volume 2). ♦ Marine and River Traffic and Transport Baseline Report (Part 22 of Volume 2).
♦ Traditional medicine	As above	♦ Upstream Community Health Report (Part 16 of Volume 2). ♦ Cultural Heritage and Archaeology Baseline Report (Part 17 of Volume 2).	Not applicable
♦ Freshwater (domestic use)	♦ Key informant interviews and focus group discussions during the community level survey. ♦ Structured questionnaire during the household survey.	♦ Upstream Community and Demographics Baseline Report (Part 14 of Volume 2). ♦ Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2).	♦ Upstream Surface Water and Sediment Baseline Report (Part 3 of Volume 2). ♦ Groundwater Baseline Report (Part 4 of Volume 2). ♦ Upstream Community Health Report (Part 16 of Volume 2).

Table 1 – Data Collection for the Ecosystem Services Baseline (cont'd)

Ecosystem Service	Method	Reports in Which Data Collected is Presented	Other Reports Reviewed
Cultural Services			
♦ Cultural sites ♦ Traditional practices ♦ Plant/animal materials	♦ Key informant interviews and focus group discussions during the community level survey. ♦ Semi-formal interviews during the ecosystem services survey.	♦ Cultural Heritage and Archaeology Baseline Report (Part 17 of Volume 2). ♦ Land and Natural Resources Baseline Report (Part 18 of Volume 2).	♦ Upstream Community Health Report (Part 16 of Volume 2).
Regulating and Maintaining Services			
♦ Control of erosion and sedimentation ♦ Regulation of surface water and groundwater ♦ Regulation of natural hazards ♦ Regulation of air quality ♦ Regulation of climate ♦ Water purification and waste treatment ♦ Regulation of soil quality ♦ Regulation of disease ♦ Regulation of pests ♦ Pollination and seed dispersal ♦ Seedbank for natural regeneration	In-field observations from: ♦ Terrestrial biodiversity surveys ♦ Freshwater and estuarine surveys ♦ Groundwater, soils, terrain and geology surveys Sampling: ♦ Soil sampling ♦ Groundwater sampling ♦ Freshwater and marine water sampling Interviews: ♦ Key informant interviews and focus group discussions during the community level survey ♦ Semi-formal interviews during the land and natural resources survey	♦ Upstream Geology, Terrain and Soils Baseline Report (Part 1 of Volume 2). ♦ Upstream Hydrology and Meteorology Baseline Report (Part 2 of Volume 2). ♦ Upstream Surface Water and Sediment Baseline Report (Part 3 of Volume 2). ♦ Upstream Groundwater Baseline Report (Part 4 of Volume 2). ♦ Upstream Freshwater and Estuarine Biodiversity Baseline Report (Part 5 of Volume 2). ♦ Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2). ♦ Marine Water and Sediment Quality Baseline Report (Part 11 of Volume 2).	♦ Upstream Air Quality Baseline Report (Part 19 of Volume 2). ♦ Seabed and Coastal Geomorphology Baseline Report (Part 9 of Volume 2). ♦ Physical Oceanography Baseline Report (Part 10 of Volume 2).
Supporting Services			
♦ Provision of habitat ♦ Nutrient cycling ♦ Primary production ♦ Water cycling ♦ Soil formation ♦ Genetic resources	As above	As above	As above

Information relevant to provisioning ecosystem services was collected through extensive consultation with communities in the PAOI during the social baseline surveys and ecosystem services interviews (reported in Part 18 of Volume 2). These activities specifically sought beneficiaries' views on the uses of resources from the natural environment, and of their perceptions of the importance of those resources.

Key information was captured through:

- The land and natural resources key informant interviews completed in 34 communities from all language groups, which collected systematic information on topics such as:
  - Gardening – species grown, timing, abundance.
  - Fishing, collecting and hunting on land and in rivers and the ocean – types of resources, resource abundance, when the resource is collected/hunted, who collects/hunts the resource.
  - Cultural uses of resources.
  - Frequency of consumption.
- The household survey, completed at 27 communities from all seven language groups, which collected quantitative data on subsistence activities, livestock kept, consumption of food items, important food items, and availability and income from natural resources.
- The ecosystem services (flora resources) survey, undertaken in 11 communities from the Ahia, Iare, Orokolo and Pawaia language groups, which collected information on:
  - Plant species with an identified use (e.g., domestic, hunting/fishing, cultural, firewood, construction, medicinal, food, canoe trees).
  - Location of plant resources.
  - Availability of plant resources.
  - Perceived threats to plant resources.
  - Plant resources recognized as famine foods by communities.
- The ecosystem services (fauna resources) survey, conducted at nine communities from the Ahia, Iare, Orokolo and Pawaia language groups, which obtained information on the type of fauna resources used and pattern of use.
- Opportunistic discussions with communities and observations made during the other fieldwork programs, in particular terrestrial, freshwater and marine biodiversity studies.

Information relevant to cultural ecosystem services was predominately collected from the cultural heritage key informant interview performed during the community level social baseline survey and extensively reported in Part 17 of Volume 2. This structured survey collected information on both physical sites known to communities and traditional knowledge, practices and rituals.

Information relevant to community movements and their ability to access food resources, health and education services, and work, and participate in cultural activities was obtained during the community level and household surveys. In addition, a traffic and transport study (Part 22 of Volume 2) recorded community movements observed during the freshwater and estuarine surveys (Parts 3 and 5 of Volume 2).

Regulating and supporting services information has been informed by observations, sampling and modeling undertaken for the studies into terrestrial biodiversity, geology, soils and terrain, air quality, hydrology and meteorology and groundwater. This information contributed to the assessment of the replaceability of regulating and supporting services.

Table 2 shows the categorization for each village and the associated ecological zone.

Table 2 – Categorization of Coastal and Inland Villages and Ecological Zone

Village	Language Group	Ecological Zone	Categorization
Evara	Ahia	Delta Swamps and Plains	Inland
Aivai	Iare	Delta Swamps and Plains	Inland
Aumu		Mangroves	Inland
Kaevaria		Delta Swamps and Plains	Inland
Kapai 2		Mangroves	Coastal
Maipenairu		Mangroves	Inland
Mapaio Fish Camp (settlement)		Delta Swamps and Plains	Inland
Mapaio		Delta Swamps and Plains	Inland
Akoma	Koriki	Mangroves	Inland
Ara'ava		Delta Swamps and Plains	Inland
Kairimai		Delta Swamps and Plains	Inland
Kairu'u		Mangroves	Inland
Ikinu		Mangroves	Inland
Aiere	Kaimare	Mangroves	Inland
Mariki		Mangroves	Coastal
Upaia		Mangroves	Coastal
Apiope	Maipua	Mangroves	Coastal
Poroi 1	Pawaia	Delta Swamps and Plains	Inland
Poroi 2		Middle Purari Hills	Inland
Poroi 3		Middle Purari Hills	Inland
Subu		Middle Purari Hills	Inland
Subu 2		Middle Purari Hills	Inland
Ura		Middle Purari Hills	Inland
Wabo & Wabo Station		Middle Purari Hills	Inland
Arehava 2	Orokolo	Southeast Coast	Inland
Avavu		Southeast Coast	Inland
Ere/Kilavi		Southeast Coast	Inland
Harevavo		Southeast Coast	Coastal
Hepere		Southeast Coast	Inland
Herekela		Southeast Coast	Coastal
Hururu		Southeast Coast	Coastal
Huruta		Southeast Coast	Inland
Iuku		Southeast Coast	Coastal
Kaivukavu		Southeast Coast	Coastal
Kavava		Southeast Coast	Coastal
Lariau		Southeast Coast	Coastal
Larihairu		Southeast Coast	Coastal
Marea		Southeast Coast	Coastal
Mareke		Southeast Coast	Coastal
Oru		Southeast Coast	Coastal
Paevera		Southeast Coast	Inland

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 17: Impacts - Cumulative

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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17. Impacts: Cumulative

17.1 Context and Approach

Cumulative impacts are 'those that result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones' (IFC, 2013).

This chapter identifies PNG Government-approved or proponent-proposed projects that might cumulatively contribute to both positive and adverse impacts on the environmental, social and cultural values present in, or that are relevant to the Project area of influence (PAOI).

17.2 Discipline-specific Assessment Method

This cumulative impact assessment is based on the method in the Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (IFC, 2013) (hereafter the IFC Good Practice Handbook for Cumulative Impacts).

Under this guidance, priority for assessing and managing cumulative impacts is limited to those values or impacts generally recognized as important due to scientific concerns or concerns of Project-affected communities. This approach places key environmental, social and cultural values at the center of the assessment and iteratively reviews these in the context of other projects or proposals that might directly or indirectly impact on these values.

The assessment uses baseline information presented in Chapters 7 to 10, findings from the discipline-specific impact assessments presented in Chapters 11 to 16 and Chapter 18, and publicly available information on approved or proposed projects in the spatial boundaries set (Section 17.3).

The steps followed to scope, identify and assess cumulative impacts are presented graphically in Figure 17.1 and described in Sections 17.3 through 17.6.

17.3 Scoping the Assessment

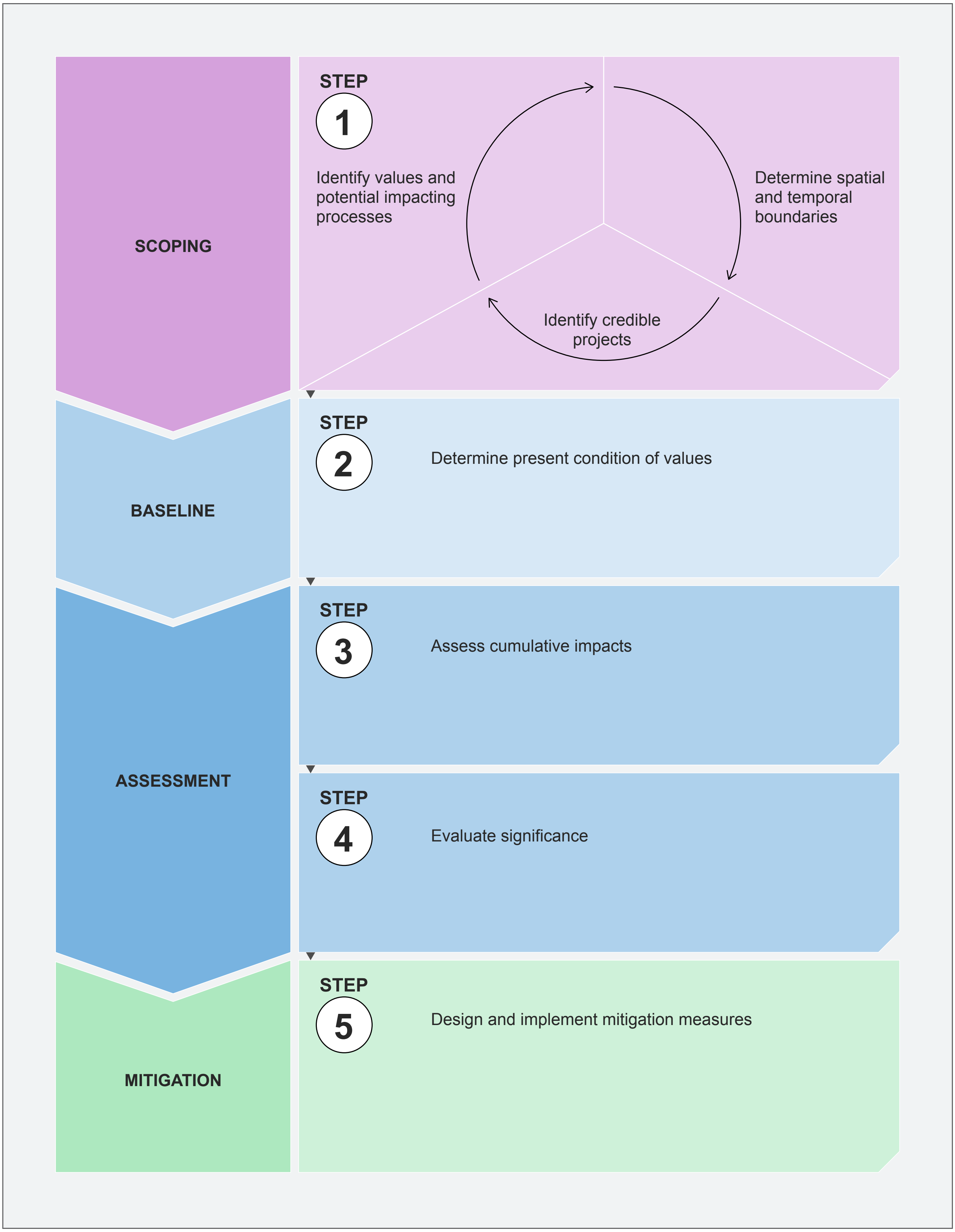
The cumulative impact assessment scope was determined by iteratively examining:

- The spatial boundaries, or geographical connections between Project activities and the identified values, which were derived by combining the PAOI with any likely pathways that would connect the PAOI with other projects, including catchments, transport corridors and access routes.
- The temporal boundaries, or the timeframe over which the analysis takes place, and which are defined as the expected life of the Project (i.e., 25 years), including construction, operations and decommissioning.
- Credible projects, which are defined as those that are existing, planned or reasonably anticipated based on publicly available information are:
  - Currently operating or are expanding.
  - Under construction or being commissioned.
  - Undertaking detailed feasibility studies or a small-scale pilot project in preparation for the full-scale project.
  - Approved by the PNG Government and awaiting final investment decision or are in the final design stages.
  - Midway through their environmental approvals process and are likely to proceed if a permit is granted.

CUMULATIVE IMPACTS ASSESSMENT PROCESS

Papua LNG Project | Environmental Impact Statement

FIGURE 17.1



Adapted from IFC (2013).

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These aspects of the scoping process identified seven existing, planned or reasonably anticipated projects, which are described in Table 17.1 and illustrated on Figure 17.2, and found six licence areas overlapping or adjacent to PRL-15 (Figure 17.3). Six projects are considered credible for the cumulative impact assessment, based on the criteria listed above.

The following were then identified to complete the iterative scoping process:

- The potential impacting processes that might contribute to a cumulative impact. These processes were derived from the impact assessments in Chapters 11 to 16 of this EIS. The information available on the specific activities or predicted impacts of the credible projects is limited, and so the relevance of the potential impacting processes to the credible projects was determined from professional expertise and an understanding of similar projects (e.g., PNG LNG Project, P'nyang Project). The potential impacting processes were refined to six processes that are considered relevant to the identified environmental, social and cultural values.
- The environmental, social, and cultural values that the potential impacting processes could affect. These were identified from Chapters 7 to 10 of this EIS and through engagement with stakeholders (described in Chapter 6).

The IFC Good Practice Handbook for Cumulative Impacts (IFC, 2013) describes 'valued environmental and social components' as 'environmental and social attributes that are considered to be important in assessing risks'. They may include:

- Physical features, habitats, and wildlife populations.
- Ecosystem services.
- Natural processes.
- Social conditions and local populations.
- Cultural aspects.

The term 'value' has been used in this chapter to encompass this definition and includes resources, sites, and other receptors (e.g., humans) as considered relevant.

Key values that could be subjected to cumulative impacts were identified by a team of specialists, drawing upon the environmental and social baseline studies (see Chapters 7 to 10) and the impact assessments undertaken for the Project (see Chapters 11 to 16).

A value was selected for consideration in this cumulative impact assessment when it was:

- Determined by impact assessment to be highly susceptible to change or disturbance.
- Likely to be subject to cumulative impacts (i.e., it exists or is likely to exist within the spatial boundaries).
- Identified by stakeholder engagement as having particular relevance to Project-affected communities (see Chapter 6).

A list of the potential impacting processes and the values that could potentially be affected by cumulative impacts is presented in Table 17.2.

Table 17.1 – Assessment of Potential Credible Projects

Company and Project	Description	Spatial Relationship	Temporal Relationship	In or Out of Scope
Rimbunan Hijau (PNG) Group (forestry) Frontier Holdings Ltd and Turama Forest Industries	♦ Rimbunan Hijau is a Malaysian logging company with two subsidiaries operating in the area; Frontier Holdings and Turama Forest Industries. ♦ Logs are transported from the logging area on barges along the Purari River distributaries.	♦ Frontier Holdings has been logging Vailala Blk 3 southeast of the Purari River, and Turama Forest Industries has a forest management agreement for Baimuru Block 3. ♦ Harvesting is expected to move north of the Purari River, including into areas of hill and alluvial forest in PRL-15, as the Baimuru Block 3 concession is developed.	♦ Vailala Block 3 and Baimuru Block 3 are currently operating; although Vailala Block 3 was reportedly winding down during the Project baseline studies in 2016 (see Part 7 and 18 Volume 2).	♦ In – Forestry operations are current and overlap with PRL-15.
Mayur Resources Bulk Coal Sample Extraction/Depot Creek Coal Project*	♦ Mayur Resources (via Waterford Ltd, its subsidiary) holds a portfolio of contiguous tenements that cover the main coal-bearing geology in the Papuan Basin in southern Papua New Guinea. ♦ Mayur Resources has been granted an environmental permit for coal bulk sample extraction for market and end-user testing in PNG's Gulf Province (exploration licence EL-1875), which includes the Depot Creek Coal Project. ♦ If the full-scale project goes ahead, an estimated 300,000 tonnes of coal would be produced annually to supply a coal-fired generator near Lae.	♦ EL-1875 is approximately 20 km south of Wabo, overlapping PRL-15. ♦ The Depot Creek Coal Project is located approximately 8 km west of PRL-15. ♦ Mayur Resources may use the Purari River to transport coal.	♦ The full-scale project has a projected 25-year life. ♦ It is unknown when the project will commence.	♦ In – The Depot Creek Coal Project meets the credible project criteria, and the licence area overlaps with PRL-15. ♦ The full-scale development is also considered in scope even though it will depend on the outcomes of bulk sample extraction.
Mayur Resources Orokolo Bay Industrial Sands Project*	♦ Mayur Resources' industrial sands tenement portfolio covers more than 12,000 km^2 along the southern coastline and delta regions of the Gulf of Papua. ♦ Mayur Resources is progressing the development of the Orokolo Bay Industrial Sands Project, with an initial plan for surface mining of five million tonnes per annum, from which a range of products, including zircon, would be produced.	♦ Mayur Resources' strategy prioritizes developing the Orokolo Bay Industrial Sands Project. ♦ Although the exact location is undefined, a small-scale bulk samples plant could be developed very close to the proposed offshore export pipeline shore crossing location.	♦ The project has commenced a definitive feasibility study (2018). ♦ It is unknown when the project will commence construction.	♦ In – The Orokolo Bay Industrial Sands Project meets the credible project criteria.

Table 17.1 – Assessment of Potential Credible Projects (cont'd)

Company and Project	Description	Spatial Relationship	Temporal Relationship	In or Out of Scope
Mayur Resources Central Cement and Lime Project*	♦ Mayur Resources is developing a high-grade limestone deposit. ♦ The Central Cement and Lime Project has received an Environmental Permit to extract, process and manufacture quicklime, clinker and cement, to transport product and to build infrastructure. ♦ The resource is expected to produce quicklime, clinker and cement for the domestic market or for export to the Pacific region and Australia.	♦ Located in Central Province, 7 km northwest of the PNG LNG Facilities and 25 km from Port Moresby. ♦ The Central Cement and Lime Project will likely use the Gulf of Papua for shipping.	♦ The project has a projected 25-year life. ♦ The project has commenced a definitive feasibility study (2018). ♦ It is unknown when the project will commence construction.	♦ In – The Central Cement and Lime Project meets the credible project criteria.
ExxonMobil PNG Ltd LNG Facilities#	♦ ExxonMobil PNG Ltd operates the PNG LNG Facilities in Caution Bay. ♦ These facilities are planned to be expanded to receive gas and condensate from the Project (i.e., the upstream facilities of the Papua LNG Project) and the P'nyang Project.	♦ The PNG LNG Facilities are at the southern extent of the Project area, approximately 20 km northwest from Port Moresby, in Caution Bay. ♦ The Project's condensate and gas pipelines will terminate at the LNG plant, which will undergo an expansion to support additional trains to process the gas.	♦ The PNG LNG Facilities are currently operating.	♦ In – The PNG LNG Facilities meet the credible project criteria.
P'nyang Project	♦ The proposed P'nyang Project will commercialize natural gas resources in the P'nyang gas field in the Western Province of Papua New Guinea. ♦ The project comprises a range of onshore infrastructure required to recover and process gas and condensate from the gas field, and to transport gas to the existing PNG LNG Facilities near Port Moresby. ♦ The condensate will be commercialized through the existing oil export infrastructure at the Kutubu Central Processing Facility and Kumul Marine Terminal (operated by Oil Search Limited).	♦ The P'nyang Project gas field and proposed conditioning plant are approximately 400 km northwest of the Project area. ♦ The P'nyang Project will use the Gulf of Papua for shipping condensate.	♦ The P'nyang Project construction period is estimated to commence in 2019 and last four to five years. ♦ The project has a projected 30-year life.	♦ In – The P'nyang Project meets the credible project criteria.

Table 17.1 – Assessment of Potential Credible Projects (cont'd)

Company and Project	Description	Spatial Relationship	Temporal Relationship	In or Out of Scope
Ihu Special Economic Zone (ISEZ)^	♦ The Ihu ISEZ is a Kikori District government initiative to encourage economic growth by facilitating resource development projects in the area. ♦ The ISEZ will consist of a free trade zone, petroleum park, industrial zone, technology park, forestry park, marine park, a deep sea port and airport, a township with hotels and resorts, and a government and administration area.	♦ The ISEZ is in the PAOI, just west of the Vailala River in the Kikori District.	♦ There is no publicly available date to begin construction.	♦ Out – The ISEZ is currently a master plan with no known financial commitments by the PNG Government.

* Information sourced from Mayur Resources (2018)
[#] Information sourced from ExxonMobil (2019)
^ Information sourced from Kikori District (2019)

POTENTIAL CREDIBLE PROJECTS WITHIN THE SPATIAL BOUNDARIES

Papua LNG Project | Environmental Impact Statement

FIGURE 17.2

LICENCES OVERLAPPING OR ADJACENT TO PRL-15

Papua LNG Project | Environmental Impact Statement

FIGURE 17.3

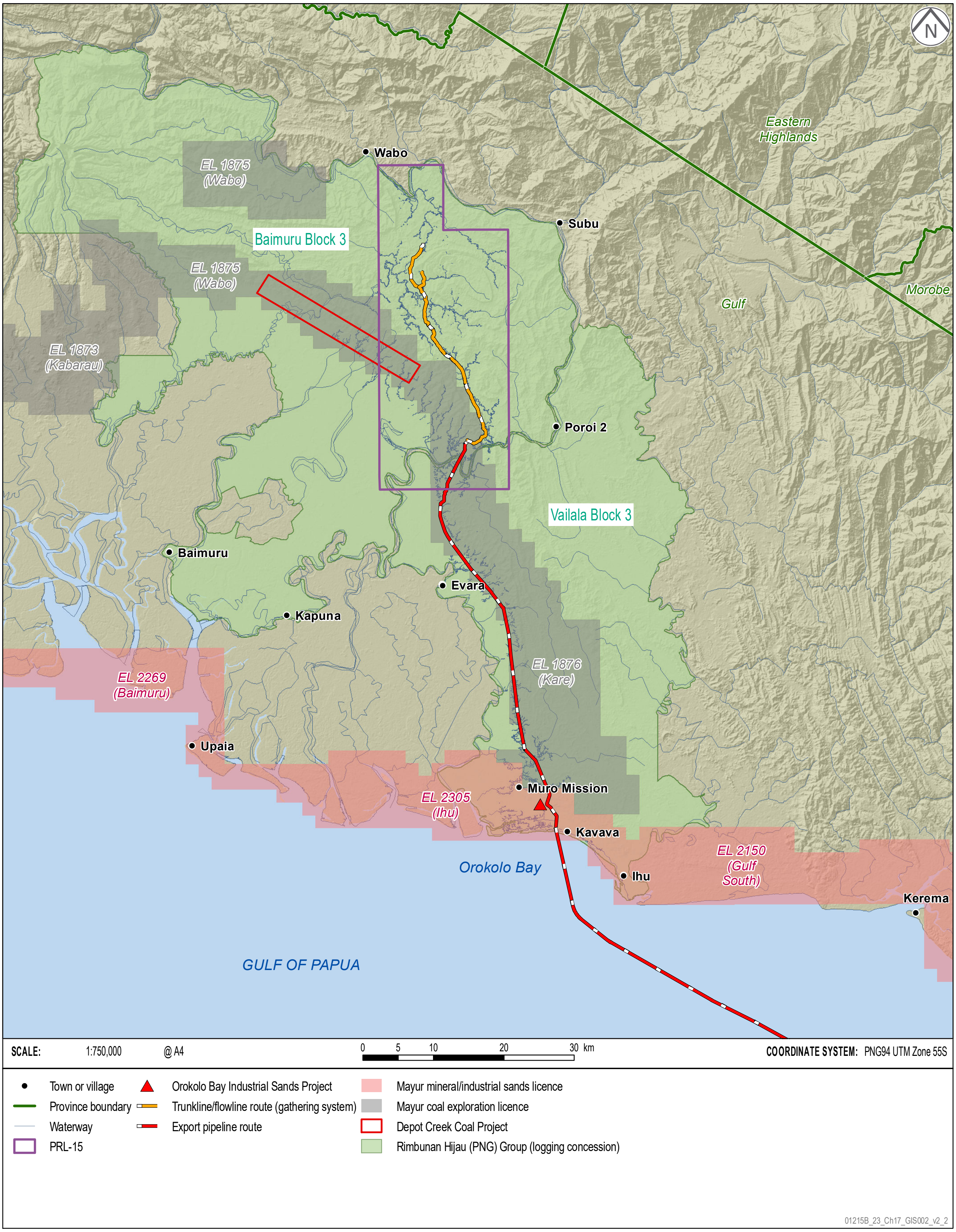

Table 17.2 – Potential Impacting Processes and Values Potentially Impacted

Process	Environmental, Social and Cultural Values
Development of a fossil fuel resource.	♦ Climate change and climate regulation.
Vegetation clearing and habitat disturbance.	♦ IUCN Threatened species, and other Very and Extremely Sensitive species. ♦ Sensitive focal sites and ecosystems. ♦ Landscape character. ♦ Use of land/water for livelihoods (i.e., hunting, collecting wild plants, loss of gardens).
Contamination or sedimentation of marine or surface water.	♦ Water quality. ♦ Drinking water. ♦ Use of land/water for livelihoods (i.e., fishing, hunting, harvesting sago). ♦ IUCN Threatened species, and other Very and Extremely Sensitive species.
Increased pressure on transport corridors and infrastructure.	♦ Commercial transport (shipping, air transport) ♦ Community health and wellbeing. ♦ Use of land/water for livelihoods (i.e., loss of access to waterways, loss or damage to assets). ♦ IUCN Threatened species, and other Very and Extremely Sensitive species. ♦ Sensitive focal sites and ecosystems. ♦ Economic security
Population growth (in-migration and induced access).	♦ Sensitive focal sites and ecosystems. ♦ Access to health and education services. ♦ Community health and wellbeing. ♦ Traditional practices and language.
Economic stimulus, benefits distribution.	♦ Community health and wellbeing. ♦ Economic security.

Note: IUCN = International Union for the Conservation of Nature.

The potential impacting processes are described further in the following subsections.

17.3.1 Development of a Fossil Fuel Resource

The credible projects outlined in Table 17.1 will contribute to Papua New Guinea’s greenhouse gas (GHG) emissions inventory and to anthropogenic climate change through the extraction, combustion and/or emission of GHGs and land use change.

17.3.2 Vegetation Clearing and Habitat Disturbance

While, vegetation and habitat loss or disturbance may be minor on a project-by-project basis, the cumulative loss and fragmentation of native vegetation associated with multiple projects could be significant, particularly in areas that support Critically Endangered species or sensitive focal sites or ecosystems.

The Project area is in largely undisturbed forest, of which approximately 930 ha will be cleared for Project infrastructure, which is less compared with existing and planned resource projects, e.g., the Wafi-Golpu project EIS identified a clearing footprint of approximately 1,400 ha (WGJV, 2018) and the PNG LNG project EIS identified approximately 1,800 ha for the onshore upstream elements of their project (CNS, 2009).

Commercial logging operations use selective timber harvesting, which opens the forest canopy but does not clear-fell forest habitat. Deforestation does occur in the PAOI for logging roads and is estimated to clear 206 ha/year (Part 7 of Volume 2). Small areas are also cleared for subsistence agriculture or settlement expansion.

17.3.3 Contamination or Sedimentation of Marine or Surface Waters

The residual impact significance of Project-related discharges to the Purari River or to the nearshore marine environment in Orokolo or Caution bays have been assessed in Chapter 11 as ***Minor*** to ***Moderate***; however, discharges from multiple projects occurring simultaneously could cause a higher significance rating.

Potential contaminating discharges include hydrotest waters, treated effluent, contaminated stormwater and accidental hydrocarbon or chemical releases, all of which have the potential to degrade water quality.

The Project will involve dredging at the Logistics Base, land clearing, and earthworks, including trenching at the export pipeline shore crossings, all of which could increase suspended sediment and sedimentation levels in fresh or marine waters.

Credible projects operating in and around PRL-15, on the Purari River and on the Gulf of Papua are likely to generate similar discharges.

17.3.4 Increased Pressure on Transport Corridors and Infrastructure

River and marine traffic have the potential to increase the risk of vessel collisions, increase the chance of vessel-related spillages or discharges, and disturb existing river users and riverway or coastal communities. Vessel traffic may also aid the spread of invasive species, which can threaten biodiversity and subsistence activities.

The primary Project transport corridors are the nearshore marine shipping route (Route 6, Figure 10.7) and the Purari River. It is likely that a cumulative increase in both river and marine traffic will occur, as the credible projects listed in Table 17.1 ramp up.

Credible projects are likely to require their workforces to transit through Port Morseby international airport, which could cause congestion and delays, if not appropriately planned for and managed.

17.3.5 Population Growth

Infrastructure development for resource projects can increase access to relatively inaccessible areas, providing increased opportunities for hunting, fishing, exploitation of forest resources, and clearing of land for gardens and houses. Population movements associated with resource projects can also place pressure on existing communities (e.g., community cohesion, food and water supplies, spread of diseases) and improve the ability of people to reach health and education services.

Population influx, due to Project-related workforces and other people seeking employment or other economic opportunities occurs, can place pressure on resident populations and ecosystems (see Chapter 13). In-migration and workforce movement are typically highest during project construction. Consequently, the highest potential for cumulative impacts occurs when construction of multiple projects coincides or overlaps. This is difficult to predict for the credible projects listed in Table 17.1, as publicly available information is scarce and most projects are still in the early planning stages. An examination of small-scale mining operations, like those proposed by Mayur Resources (i.e., coal and industrial sands), indicates that a large workforce is unlikely to be required.

17.3.6 Economic Stimulus

Most resource projects can stimulate local, regional and national economic activity. Provincial and local-level governments will receive direct financial benefits through royalties and development levies, and indirect financial benefits from the stimulation of economic activities. The extent local communities experience this stimulus depends on how governments allocate these royalties.

Additional economic benefits may include increased training, trade and employment opportunities facilitated by government and private investment in public infrastructure and services, and through direct and indirect employment.

The Project will generate financial benefits to Papua New Guinea that will increase gross domestic product and national government revenue. Much of the 2014 and 2015 growth in the PNG economy is attributed to the PNG LNG project (WBG, 2019) and the Papua LNG and P’nyang projects are likely to offer significant employment opportunities during construction.

17.4 Determining the Present Condition and Sensitivity of Key Values

Step 2 of the cumulative impact assessment process (see Figure 17.1) establishes a baseline for the cumulative impacts by determining the present condition of the values identified in Step 1 and listed in Table 17.2. The cumulative impact assessment focuses on understanding whether cumulative impacts will affect the sustainability or viability of a value, as indicated by its predicted or measured condition. The sensitivity reflects the value’s resilience to change, (which may change over time as more projects progress in the area), importance to Project-affected communities, uniqueness or rarity, and intrinsic worth. It builds on existing definitions of valuable social and environmental components described in the International Finance Corporation’s (IFCs) performance standard 6 (IFC, 2012).

The baseline studies and advice from technical specialists informed the sensitivity of each of the key values. The sensitivity ratings used for the key values listed in Table 17.2 are described in Table 17.3; and a summary of the baseline characteristics, sensitivity ratings and relevant trends affecting these values is provided in Table 17.4.

Table 17.3 – Value Sensitivity Rating Criteria

Sensitivity Rating	Description
High	♦ Limited or no resilience. ♦ Value is largely unaffected to date by the potential impacting processes. ♦ The value is largely unmodified with few local or regional replacements, is sensitive to disturbance and requires intervention to recover. ♦ The value is ecologically or socially important on a national level. ♦ A value upon which local people frequently depend for provision of food or income.
Medium	♦ Some resilience. ♦ The value shows some sign of exposure to the potential impacting processes. ♦ The value has not been significantly altered but has local or regional equivalents. ♦ The value is ecologically or socially important on a regional level. ♦ A value upon which local people occasionally depend for provision of food or income.
Low	♦ High resilience. ♦ Value has already been affected by exposure to the potential impacting processes. ♦ A modified or degraded value with some original qualities but is significantly altered. ♦ The value generally enriches or maintains the local area. ♦ A value upon which local people rarely depend for provision of food or income.

Table 17.4 – Key Values: Sensitivity, Baseline Condition and Trends

Key Value	Sensitivity	Baseline Condition	Trends
Physical and Environmental			
Greenhouse gas (GHG) emissions and climate change	Medium	♦ The Land Use, Land Use Change and Forest sector is one of the biggest sectors in Papua New Guinea's GHG emission inventory and has historically acted as a sink. ♦ Estimated GHG emissions from the energy sector increased notably in 2014 and 2015 due to increasing demand for electricity, and increased fugitive emissions associated with increasing natural gas production.	♦ Over the last century, the burning of fossil fuels (which primarily comprise carbon) has increased global atmospheric CO_2 concentration, which contributes to an observed enhancement of the natural greenhouse effect, (i.e., climate change). ♦ Some of the global trends observed in the global climate system include (IPCC, 2014): – Warming of the atmosphere and oceans. – Loss of ice mass in Greenland and Antarctic ice sheets. – Increasing rate of sea level rise. – Increase of atmospheric CO_2, CH_4, and N_2O concentrations to levels unprecedented in at least the last 800,000 years.
IUCN Threatened species, and other Very and Extremely Sensitive species	High	♦ Baseline biodiversity studies have identified the following Threatened or Sensitive species in the terrestrial biodiversity study area: – Three IUCN Critically Endangered terrestrial species and one Extremely Sensitive new-to-science restricted-range plant. – Four IUCN Critically Endangered aquatic species either known, likely or considered possible in the Project area. – Nine IUCN Endangered and 17 IUCN Vulnerable terrestrial species confirmed present or likely to occur in the Project area. A further 37 restricted-range, new-to-science and undescribed species considered to be Very Sensitive are also present. – Two aquatic insect species identified as endemic to the Papuan Gulf Coastal Lowlands.	♦ Endangered and threatened species are at a high or extremely high risk of extinction in the wild. ♦ Habitat loss, degradation and fragmentation; logging; harvesting; and hunting and fishing are key threats.
Sensitive focal sites and ecosystems	High	♦ Baseline biodiversity studies have identified the following sensitive focal sites and ecosystems in the terrestrial biodiversity study area: – Oxbow lakes and wetlands, mangroves, primary alluvial forest, hill forest on limestone and the Purari River tidal wetlands are Very Sensitive ecosystems.	♦ These focal sites and ecosystems are highly sensitive to disturbance with low replacement and recovery potential. ♦ Clearing, habitat degradation, logging, anthropogenic disturbances, hydrological change, invasive alien species competition and erosion are key threats.

Table 17.4 – Key Values: Sensitivity, Baseline Condition and Trends (cont'd)

Key Value	Sensitivity	Baseline Condition	Trends
Physical and Environmental			
Sensitive focal sites and ecosystems (cont'd)	High	– Two IUCN Threatened freshwater turtle nesting sites and two freshwater crocodile nesting sites occur in the Project area. – Caves are also present and are considered Very Sensitive. The Wi'I Creek cave site is Extremely Sensitive. – Three Very Sensitive terrestrial ecosystems are present: Hill forest on limestone (H), primary Alluvial forest (P) and Mangrove (M).	♦ These focal sites and ecosystems are highly sensitive to disturbance with low replacement and recovery potential. ♦ Clearing, habitat degradation, logging, anthropogenic disturbances, hydrological change, invasive alien species competition and erosion are key threats.
Water quality	Medium	♦ Freshwater lakes, rivers and streams, and forest pools in the PAOI generally contain low nutrient and organic carbon levels and low metal concentrations. ♦ Turbidity is high in the Purari River year-round, but peaks during the northwest monsoon season. ♦ Large turbid inflows from the Purari and Vailala rivers reduce water quality in Orokolo Bay. ♦ No evidence was found of anthropogenic contamination of marine waters.	♦ Commercial logging is likely to increase turbidity in PAOI rivers as natural erosion control is lost. ♦ Eutrophication, contamination from runoff, sedimentation, water abstraction, loss or damage to riparian vegetation, erosion and anthropogenic disturbances are key threats.
Social and Cultural			
Landscape character	Medium	♦ No developments of a comparable scale or form to the Project currently exist in the provincial and local setting, and forestry is the primary anthropogenic landscape impact.	♦ The landscape character is becoming more industrialized as more development occurs in areas that are otherwise relatively untouched.
Use of land/water for livelihoods	Medium	♦ People in the PAOI significantly depend on natural resources for survival and wellbeing. ♦ Livelihoods are dominated by subsistence activities, including gardening or hunting, gathering or fishing for wild foods. ♦ Planting and harvesting sago are important food production activities. ♦ Plant and animal resources are highly valued and universally used across the PAOI for construction, hunting and fishing, medicine, domestic items, canoes, firewood and cultural celebrations.	♦ Papua New Guinea relies on subsistence agriculture to feed approximately 80% of its population (Hayward-Jones, 2016). ♦ Successful farmers in Papua New Guinea complain that the younger generation is not interested in tending to family gardens or in commercial agricultural ventures (Hayward-Jones, 2016).

Table 17.4 – Key Values: Sensitivity, Baseline Condition and Trends (cont'd)

Key Value	Sensitivity	Baseline Condition	Trends
Social and Cultural (cont'd)			
Community health and wellbeing	Medium	♦ Diseases are already present in the PAOI. Malaria and tuberculosis are prevalent, with tuberculosis at epidemic levels. ♦ HIV/AIDS and other sexually transmitted diseases are highly prevalent. Accidents and injuries (associated with marine and river traffic or household activities) are an under-appreciated morbidity burden across the PAOI (i.e., 5 to 10% of health center morbidity caseload). ♦ Betel nut, a known human carcinogen, and alcohol, tobacco and marijuana are likely contributors to non-communicable diseases in the PAOI.	♦ A diet based on subsistence agriculture has helped Papua New Guineans avoid the increase of diet-related non-communicable diseases, such as obesity and Type 2 diabetes, that have afflicted their neighbors in Polynesian and Micronesian states. ♦ The number of people affected by non-communicable diseases, including cardiovascular and respiratory disease, cancer, and diabetes, is increasing (Hayward-Jones, 2016).
Access to health and education services	Medium	♦ Health and education facilities in the PAOI are limited and inadequate in some places (particularly in the north), with several facilities only being partially open and others being closed. ♦ Limited transport options mean many communities must travel significant distance by either boat or foot to access health services, with many turning to traditional medicines as a result. ♦ Education and literacy levels are low throughout the PAOI, particularly in the more remote inland areas.	♦ Government expenditure on health as a proportion of total expenditure has increased (Hayward-Jones, 2016). ♦ Papua New Guinea's schooling system has suffered from policy shifts, major curriculum changes and under-resourcing (Hayward-Jones, 2016).
Drinking water	Medium	♦ The most common source of drinking water in the PAOI is rainwater, rivers and streams, including the Purari River, and shallow wells (more common in Orokolo Bay communities). ♦ Microbial quality is poor, with high levels of coliforms detected at most sites.	♦ Strong population growth may have contributed to downward trends in water and sanitation coverage (WHO/UNICEP, 2010).
Traditional practices and language	Medium	♦ PAOI communities practice traditions and customs, including traditional song, dance and dress, ritual practices, oral traditions, and traditional subsistence knowledge such as traditional medicines.	♦ As communities lead less traditional lifestyles, with access to increased income and consumables, many traditional practices throughout the PAOI are declining.

Table 17.4 – Key Values: Sensitivity, Baseline Condition and Trends (cont'd)

Key Value	Sensitivity	Baseline Condition	Trends
Social and Cultural (cont'd)			
Traditional practices and language (cont'd)	Medium	♦ There are seven language groups in the PAOI; Pawaia, Koriki, Iare, Ahia, Kaimare, Maipua and Orokolo.	♦ Communities affected by changing economic situations and in-migration have identified that the use of traditional language is being eroded, and a lack of access to education and employment opportunities is a key factor drawing young people away from villages and compromising the maintenance of traditional languages (Part 17 of Volume 2).
Economic security	Medium	♦ The national traditional economy is based on subsistence farming. ♦ The main industries in Gulf Province are oil and gas extraction, prawn fishing and logging. The province contains five large-scale logging operations; however, benefits from logging are invisible at the community level and the provincial government does not benefit financially. ♦ The greatest contribution to the national economy in 2016 was oil and gas (28% of GDP) followed by agriculture, forest and fisheries (21%) and construction (15%). ♦ Economic infrastructure in the PAOI is limited: No public roads, two small remote airstrips (Purari and Wabo), electricity only from petrol-fired generators or solar power, and no banks or postal services.	♦ The national economy depends heavily on the resources sector, having become focused on petroleum and gas-related activities since 2014 (World Bank Group, 2019). ♦ The growing employment age population has limited formal job opportunities. ♦ Preliminary estimates suggest that real GDP growth slowed from 2.8% in 2017 to 0.3% in 2018, following a contraction in the extractive sector due to the February 2018 earthquake. This is forecast to rebound during 2019 (World Bank Group, 2019).
Commercial transport (i.e., marine and river transport, air transport)	Low	♦ Three shipping routes occur in the PAOI, namely two coastal shipping routes (i.e., barge traffic to Herd Base and logging barges to a logging camp near Evara village) and one international shipping lane (to the PNG LNG marine terminal in Caution Bay). ♦ The Gulf of Papua Prawn Fishery operates a fleet of eight trawlers in the Gulf of Papua.	♦ Logging transport is predicted to continue at the same rate as measured during the Project baseline surveys, i.e., 24 return trips per year between Evara and the Purari River delta. ♦ The Project is predicted to increase use of the Purari River by up to 540 vessel movements per year during peak construction. ♦ The Depot Creek Coal Project may use the Purari River to transport coal. ♦ The P'nyang Project could increase barge trips over its construction period. These barges will likely use the Port Moresby to Kiunga shipping route, which in 2017 had approximately 212 return barge trips per year. ♦ The Mayur Resources projects are likely to involve shipping of coal to Lae and Asian markets, and mineral sands to Australia.

17.5 Potential Cumulative Impacts on Key Values

Step 3 of the cumulative impact assessment process (see Figure 17.1) involves identifying and assessing the potential cumulative impacts of the potential impacting processes on key values and qualitatively evaluates the significance (Step 4) of the potential cumulative impacts where possible. This is consistent with standard industry practice, where the details of developments (e.g., exact locations and footprints, workforce, emissions etc) are not publicly available.

The potential impacts are described, assuming that all of the mitigation measures and embedded design controls outlined in Chapters 11 to 16 of this document have been implemented.

17.5.1 Climate Change and Climate Regulation

Project-related vegetation clearing, gas production, transportation and the operation of fixed and mobile equipment will generate an estimated 20.7 Mt of CO_2-e Scope 1 GHG emissions over the life of the Project. This increases to 61.4 Mt of CO_2-e if the estimated emissions from downstream processing are included.

This compares with predicted Scope 1 emissions for the PNG LNG Project (excluding the expansion due to the Papua LNG Project) of 77.4 Mt of CO_2-e over the 30-year project life (ExxonMobil, 2019).

The Project's GHGs will contribute to Papua New Guinea's national emissions. Chapter 15 identifies that the maximum annual Scope 1 GHG emissions estimated for the Project are 1.48 Mt of CO_2-e., representing a 9.8% increase in the total reported national Papua New Guinea GHG emissions of 15.1 Mt CO_2-e (based on 2015 data).

Emissions from the Project and other credible projects identified in Table 17.1 will contribute to global greenhouse gas concentrations that influence global atmospheric processes and changes to the global climate system (see Part 5 of Volume 3).

Project-related clearing will remove more native forest that acts as a GHG sink, as more resource projects are developed in Papua New Guinea. The Land Use, Land Use Change and Forestry sector is one of the largest sectors in Papua New Guinea's GHG emission inventory and historically has acted as a sink. Due to increasing rates of deforestation and forest degradation, this sector has become an increasingly smaller sink over time; and in recent years, this sector has been a net source of GHGs. This is a significant contributor to Scope 1 emissions (e.g., Project clearing accounts for 62% of construction-related emissions).

17.5.2 Sensitive Species

Sensitive species could be threatened by cumulative clearing of habitat, by direct loss (i.e., through hunting or tree removal), or from indirect effects, such as population increase, increased human activity (such as boat traffic) and land use changes.

17.5.2.1 IUCN Critically Endangered Species

The little known and Critically Endangered timber tree species (*Diospyros lolinopsis*) occurs in primary alluvial forest along the Project onshore export pipeline route. The Project will avoid individuals of this species as far as practicable; however, credible projects that enable greater access to this habitat increase the risk of spreading weeds and increase accessibility to timber and forest products, with the potential for direct loss or indirect (disturbance-related) impacts reducing local numbers of this species.

Bulmer's fruit bat (*Aproteles bulmerae*) is known from only a few restricted areas of Papua New Guinea outside the PAOI. The credible projects listed in Table 17.1 are unlikely to directly destroy or damage potential roosting and maternity caves; however, cumulative impacts to Bulmer's fruit bat may occur from improved access and population influx, increasing hunting pressure on the species. Hunting has already significantly reduced the species population and distribution (see Chapter 7).

The tree *Guioa hospita* is potentially present in the Project study area in hill and alluvial forest. Logging, particularly in Baimuru Block 3, could cause extensive degradation to these habitat types and the loss of or damage to individuals. Degrading or removing the habitat of this rare and poorly known species or the loss of even a few individuals could threaten the viability of the population.

The largetooth sawfish *(Pristis pristis*) and the northern river shark *(Glyphis garricki*) may occur in the main channels of the Purari River. The Purari River is a key transport corridor for the Project, local communities, the logging industry and potentially the Depot Creek Coal Project. These species may be susceptible to increased boat traffic and a decline in water quality from effluent discharges and from runoff from washdown, waste, processing and chemical facilities. While the Project's potential contribution to the deterioration of surface water quality has been assessed as ***Negligible*** to ***Minor*** for most activities, future cumulative impacts of multiple projects operating simultaneously could impact water quality to an extent that adversely affects these species (Section 17.3.3).

17.5.2.2 IUCN Endangered and Vulnerable Species

A high species diversity, including several IUCN Endangered and Vulnerable species and other Very Sensitive species, are known from the foothill zone on well-drained primary alluvial forest and in the area identified by Mayur Resources for their Depot Creek Coal Project (see Figure 17.3).

These species include the IUCN Endangered *Diospyros insularis* and the IUCN Vulnerable lowland tree kangaroo (*Dendrolagus spadix*) and Scheepmaker's crowned pigeon (*Goura scheepmakeri*). Habitat degradation or loss caused by vegetation clearing and the constructing access tracks could cause injury to or loss of individuals and a potential decline in population viability.

The IUCN Endangered giant bandicoot (*Peroryctes broadbenti*) may occur along the southern half of the onshore export pipeline route where a Mayur Resources Industrial Sands tenement is also located (see Figure 17.3). While the habitat loss due to Project activities is minimal, cumulative clearing could contribute to a degradation or loss of habitat that could cause injury to or loss of individuals and a potential decline in population viability.

Habitat loss or degradation may be further compounded by logging activities and increased access to the region along logging tracks; although, these impacts will likely be localized to areas around access routes. No information is available relating to improved land access (i.e., roads or tracks) for Mayur Resources projects in the area. Logging operations are likely to continue to open up new tracks into unlogged hill forest in and around PRL-15.

The lowland tree kangaroo, giant bandicoot and Scheepmaker's crowned pigeon are also sensitive to hunting. If the Project, Mayur Resources projects and logging projects collectively improve access for hunters or increase village populations, an increase in hunting could reduce local species populations. The cumulative impacts on these species may reduce population viability given their sensitivity to disturbance, low population densities and habitat specificity.

Potential cumulative impacts to the IUCN Endangered speartooth shark *(Glyphis glyphis*) will be like those of the Critically Endangered northern river shark (Section 17.5.2.1).

17.5.2.3 Extremely Sensitive Species

The terrestrial herb *Begonia* sp. 5 is an endemic, new-to-science, riparian specialist known from only a few individuals along the northern edge of the central processing facility footprint. If the species is also found in the proposed footprints or areas of operational influence of credible projects and is constrained to a local or small geographical area, the cumulative loss of individuals could reduce the regional population viability.

17.5.2.4 Commercially Important Species – Tropical Rock Lobster

The presence of the PNG LNG and the Project pipelines crossing the tropical rock lobster migration route to spawning grounds near Yule Island has the potential to cumulatively reduce the number of migrating lobsters reaching the spawning area and successfully spawning, and thus the catches of and possibly participation in the artisanal and Torres Strait commercial lobster fisheries. The assessment of potential cumulative impacts is limited by currently unknown potential impacts of the existing PNG LNG Gas Pipeline on lobster migration.

17.5.3 Sensitive Focal Sites and Ecosystems

17.5.3.1 Sensitive Focal Sites

The IUCN Endangered pig-nosed turtle (*Carettochelys insculpta*), the IUCN Vulnerable striped New Guinea soft-shelled turtle (*Pelochelys bibroni*) and freshwater crocodile use the Purari River and its tributaries for nesting sites.

Additional boat traffic associated with multiple projects using the Purari River as a transport route may increase the likelihood of boat strike and subsequent injury to, or loss of individuals. Boat wash could also damage banks used for nesting, which could reduce the viability of these populations.

17.5.3.2 Sensitive Ecosystems

Three Very Sensitive terrestrial ecosystems are present in the Project terrestrial biodiversity study area: Hill forest on limestone (H), primary (unlogged) Alluvial forest (P) and Mangrove (M).

While the predicted vegetation loss in these ecosystems due to Project activities is minimal (i.e., 0.13% of primary alluvial forest, less than 0.01% of mangrove and no direct impacts to hill forest on limestone), cumulative clearing associated with the credible projects identified as overlapping with the PAOI (see Figure 17.3) could contribute to an unsustainable loss of these ecosystems.

Degradation due to edge and barrier effects, and the introduction and spread of invasive alien species will add to any direct loss of sensitive ecosystems from clearing.

17.5.4 Water Quality

Chapter 11 assesses the residual significance of increased suspended sediments and sedimentation in Oyomo Creek, Mena River, Kuku Creek and Boa Creek as moderate. The Purari River is already highly turbid throughout most of its main channel; however, sedimentation due to Project activities is unlikely to affect the channel.

Other resource projects operating in or around PRL-15 (e.g., Depot Creek Coal Project and commercial logging operations) during the same period as the Project's construction phase could contribute to cumulative sediment loading in creeks in the Project area. Changes related to increased sediment loads, were they to occur, are unlikely to be enduring provided disturbed areas are either actively revegetated or left to naturally regenerate.

Accidental release of hazardous materials could occur during the construction, operations and decommissioning phases, and has been assessed as a residual moderate risk for the Project (Chapter 11). An increase in use of the Purari River for transport could increase the potential for accidental discharges occurring from spills during fuel or chemical transfer from barges or from accidents. Hazardous materials could also enter the waterway in runoff during significant rainfall and flooding.

While the residual impact significance has been assessed as ***Negligible*** or ***Moderate*** in the context of the Project's activities (see Chapter 11), where several projects are operating in the one catchment, cumulative discharges, when they occur at the same time near each other, have the potential to degrade water quality for downstream users, including communities reliant on the Purari River for domestic water supply. Provided other projects implement similar management measures as those outlined in Chapter 11, hazardous material releases entering the waterway at the same time and location are unlikely to occur.

17.5.5 Landscape Character

The Gulf Province landscape is typical of Papua New Guinea and comprises mountainscapes that rapidly give way to coastal lowlands. Anthropogenic disturbances, such as extensive commercial logging, infrastructure development and vegetation clearance for oil and gas exploration activities, and previous and contemporary commercial plantations (e.g., coconut) closer to coastal areas, are present.

Impacts to landscape character refer to the relative capacity of the landscape to accommodate the introduction of new features and the loss or modification of existing features, such as those due to Project development.

Multiple resource projects occurring in a relatively natural landscape can change landscape character. Native vegetation removal; natural landform changes (e.g., due to coal or mineral sands mining activities); project infrastructure development; increased river, marine and air traffic; multiple linear corridors maintained for pipeline infrastructure; and nighttime lighting and flaring in a previously low-light landscape, all have the potential to incrementally, yet fundamentally, change the intrinsic character and visual amenity of the landscape surrounding these projects.

The Project on its own is unlikely to significantly change regional landscape character (see Chapter 15); however, the cumulative effects of several resource projects may contribute to a gradual change to its current natural character, which may affect how people perceive and experience the landscape.

17.5.6 Use of Land and Water for Livelihoods

The credible projects identified in Table 17.1 are likely to clear native vegetation and reduce the amount of land available or suitable for growing or hunting food, harvesting building materials, collecting firewood and gathering resources for traditional uses.

The Project will clear approximately 8 ha of forest along approximately 5 km of the onshore export pipeline route that is potentially used for food gardens and planted sago (see Chapter 16).

Forestry activities in PRL-15 and along the onshore export pipeline route between 2000 and 2014 have logged 3,139 ha of hill and alluvial forest (Part 7 of Volume 2). This represents a very low rate of change. The logged forest is being allowed to regrow and continues to be used for livelihood activities, including food gardens.

The clearing footprints of the credible projects outlined in Table 17.1 are unknown; however, given the extent of the licence areas identified in Figure 17.3, large areas of native vegetation could be cleared in and around PRL-15, and along the Orokolo Bay coastline, with potential adverse implications for community land use and livelihoods (e.g., loss of land available for gardens or collection of wild foods or firewood).

Population increases due to employment opportunities or financial payments related to credible projects could put further pressure on land used to support livelihoods, e.g., around Orokolo Bay, where some resources (e.g., wild plants and timber) are already under pressure due to overharvesting or land use changes. The extent to which the Orokolo Bay Industrial Sands Project will induce in-migration, or whether the timing of any such population increase will overlap with the construction of the Project's onshore export pipeline route shore crossing is unknown.

17.5.7 Community Health and Wellbeing

Chapter 13 outlines the potential for the Project to contribute to an increase in the frequency or severity of diseases such as sexually transmitted infections, malaria and tuberculosis, and to increase the incidence of accidents and injuries. The residual impact significance assessments for most of these health risks are ***Minor*** to ***Moderate***; however, additional projects operating in the PAOI may increase these risks.

Poor sanitation practices and substandard living conditions in areas experiencing growth can lead to an increase in the risk of disease spread and infection rates (Chapter 13). If the credible projects identified as overlapping the PAOI (see Figure 17.3) all commence construction simultaneously, short-term, localized population influx could result; which could increase the frequency, severity and risk of disease (see Section 13.6.2.3).

People earning higher incomes and with increased mobility (i.e., the credible projects' workforces) have a greater chance of participating in high-risk behaviors, which have implications for sexually transmitted infections, including HIV/AIDS, and developing non-communicable diseases associated with an increase in consumables such as alcohol and store-bought foods.

The incidence of accidents and injury could increase due to increased population, river traffic, interactions with construction machinery and vehicles, and potentially a greater incidence of fighting or domestic violence associated with increased alcohol and drug consumption.

Community health may also improve due to investment in infrastructure and services, detailed in Section 17.5.8.

17.5.8 Access to Health and Education Services

Resource developments in Papua New Guinea can place additional pressure on health care and education infrastructure and services; however, an overall improvement in the services can occur if resource developments or local/provincial governments invest in these services.

Adverse effects from increased pressure on these systems could include:

- An increase in untreated diseases and injuries.
- A reduction in school enrolment and attendance.
- A shortage of teachers and/or healthcare workers.
- A decrease in literacy rates.

Positive effects could include:

- Improved health outcomes such as lower disease rates and improved health education.
- Improvements to school attendance, literacy, training and workforce skills.

The projects identified in Table 17.1 are unlikely to place additional pressure on the health and education services in the PAOI. The Mayur Resources projects are small-scale mining operations that are unlikely to require large workforces, and the other credible projects are outside of Gulf Province and are unlikely to impact on health or education services in the PAOI. If the credible projects identified as overlapping the PAOI (see Figure 17.3) all commence construction simultaneously, short-term, localized population influx could result; however, given the geographic spread of these projects, this is unlikely to result in a significant impact to Community access to health and education services.

Collectively, multiple resource projects may improve national workforce skills and work experience, and improve literacy and education levels, providing project benefits paid to local-level or provincial governments are invested in these services. Multiple projects operating in the region could also lead to improved training and skills development through on-the-job training, vocational courses and the stimulus to local training providers of increased demand.

17.5.9 Drinking Water

The main sources of drinking water for PAOI communities is from rainwater containers (37% of households), tanks (32% of households), rivers and creeks (16% of households) and shallow wells (8% of households). Rainwater is untreated, and longevity depends on the rate of consumption and the quantity stored for each family.

Many people in the PAOI extract water from the Purari River or its tributaries for drinking and cooking. The extent to which the Purari River is relied upon depends on the availability of and distance to better water sources. There is a greater dependency on the Purari River as a water source during extended dry periods, when alternative sources may not be available. Many communities in Orokolo Bay rely on wells in shallow groundwater, which overlies more saline groundwater.

The Project is unlikely to significantly affect fresh surface or groundwater supplies for domestic use in the PAOI (see Chapter 16); however, multiple projects operating upstream of communities that use the Purari River for drinking water could contribute to a deterioration of water quality. This could occur through discharge of wastewater or accidental releases of contaminants; however, it would depend on when and where in the catchment the releases occur, and the assimilative capacity of the Purari River. Any impacts on water quality could have subsequent impacts on food security, health and nutrition, as villagers may choose to avoid washing sago or fishing in the Purari River and spend greater time and effort sourcing alternative supplies.

Similarly, developments along the Orokolo Bay coastline (i.e., the Papua LNG Project, Mayur Resources mineral sands project) could result in a cumulative decrease in groundwater quantity or quality, which could reduce community health, particularly given the groundwater wells are readily susceptible to microbiological contamination.

17.5.10 Traditional Practices and Language

PAOI communities maintain intangible cultural heritage values, such as the local language, oral traditions, oral histories, ritual practices, traditional knowledge about medicines and knowledge of the physical world related to subsistence activities. Chapter 14 identifies potential Project-related impacts to intangible heritage, including a decline in inter-generational knowledge transfer, reduced use and knowledge of traditional sites and practices, and a decline in use of local languages.

These impacts are likely to become more wide-reaching and inherent, as the traditional subsistence economy shifts to adopt the opportunities associated with resource development.

More people are likely to spend less time working the land and to have greater access to modern health services and store-bought products, which may improve nutrition and health outcomes. Conversely, an erosion of subsistence-based and traditional knowledge may lessen food security when economic circumstances change, e.g., when employment opportunities decline after construction and after Project decommissioning.

17.5.11 Economic Security

Resource projects contribute significantly to the PNG national economy, and multiple resource projects in operation simultaneously could generate considerable income for the national, provincial and local-level governments, and for local communities. The development of one or more additional resource projects could also increase income levels in the PAOI, depending on the location, size, duration and benefit-sharing arrangements for each project.

Resource projects bring local employment, business opportunities and diversification of the predominantly subsistence-based economy. The existing logging industry and the proposed Mayur Resources developments in Gulf Province have, or are projected to have small workforces, unlikely to contribute significantly to economic development. The Project’s construction and operations are likely to be the primary stimulus for local business opportunities through increasing demand for goods and services, such as food, accommodation, transportation and consumables. Although not yet in operation, the Project has already provided a source of local employment and associated services, particularly among Pawaia villages (in PRL-15), during its exploration and development stages.

An adverse impact of multiple resource projects operating simultaneously is that subsistence labor requirements for women and children may increase, as men seek employment with different projects, and increase economic vulnerability. Conversely, a positive impact can include women being provided with more training, education and business opportunities, increasing their employment potential.

Multiple projects are likely to contribute positively to improvements to economic infrastructure, which is currently very poor in the PAOI. This may include improvements to communications, transport and electrical infrastructure.

17.5.12 Commercial Marine Traffic

The P’nyang project could generate several hundred return barge trips over its construction period, using the Port Moresby to Kiunga shipping route (Route 2, Figure 10.7).

The Project will use the Port Moresby to Purari River route (Route 6, Figure 10.7). This route could also be used by Mayur Resources’ Depot Creek Coal Project and Orokolo Bay Industrial Sands Project, which would increase barge traffic along these nearshore shipping lanes.

A cumulative increase in nearshore shipping increases the risk of marine accidents and/or accidental release of contaminants (discussed further in Chapters 12, 15 and 18). Chapter 15 identifies the Project’s contribution to commercial marine traffic as negligible, given the low existing use of the shipping routes, (except for the area approaching the port of Port Moresby), and the short time (approximately five years) that most of the increase in shipping would occur. Given the lack of publicly-accessible information on the credible projects listed in Table 17.1, it is difficult to predict any potential cumulative increase in marine traffic; however, given the low use of nearshore routes, any increase is unlikely to significantly impact other route users or the environment, providing all parties operate under standard communications and safety procedures.

17.5.13 Airport Capacity

The international airport in Port Moresby will experience an increase in demand for flights in and out of the capital to support the Project's peak construction workforce estimated to be up to 6,000 people. Other credible projects, if they occur at the same time, are likely to require their workforce to fly through Port Morseby to regional airstrips/airports. This combined increase in demand could exert pressure on airport infrastructure and capacity, potentially affecting other users.

17.6 Proposed Mitigation and Management Measures

Step 5 of the cumulative impact assessment process (see Figure 17.1) involves the design of mitigation measures to treat the potential cumulative impacts to key values.

TEP PNG will manage the contribution of its activities to cumulative impacts by implementing the mitigation measures, monitoring and management plans outlined in Chapters 11 to 16. TEP PNG will also work with national, provincial and local-level government authorities and other resource companies and government agencies to help identify strategies to manage potential cumulative impacts. This may include participation in joint planning initiatives with relevant stakeholders, and sharing best practices and lessons learnt from the implementation of mitigation measures addressing environmental and socio-economic impacts due to each project. Where feasible, other developers could be invited to invest expertise or resources in the joint implementation of initiatives addressing cumulative impacts.

17.7 Conclusion

Papua New Guinea is a developing country that is endowed with natural resources. Multiple projects are in various stages of planning, exploration and operation to develop these resources consistent with the PNG's national goals and directive principles.

This cumulative impact assessment identified six potential impacting processes from six credible projects that could potentially impact identified key values. Some of these projects (i.e., the P'nyang Project, the PNG LNG Facility at Caution Bay and the Project) are inter-related and inter-dependent, relying on transportation and processing facilities operated by partner companies.

The Project's contribution to the potential cumulative impacts is predicted to be minor relative to the credible projects listed, recognizing that little publicly available information exists to support a detailed assessment.

The assessment does highlight the following key areas that require PNG Government-led strategies to address the potential cumulative impacts:

- Management of overlapping licence areas and multiple resource extraction activities occurring in PRL-15 and along the Orokolo Bay onshore export pipeline shore crossing.
- Management of potentially significant impacts on sensitive species, ecosystems and community land use/livelihoods due to land clearing.
- Improvements to economic infrastructure in Gulf Province, and support for business and employment diversification to reduce long-term economic reliance on resource projects.

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PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 18: Major Hazards

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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Chapter

18. Major Hazards

18.1 Introduction

Predicted, credible environmental, socio-economic, cultural heritage and amenity impacts associated with the Project that are part of normal operating conditions are discussed in Chapters 11 to 17. Major hazards associated with very low likelihood accidental, upset or abnormal events have been identified and are discussed in this chapter. While rare, such events can be either natural or due to human activity, and may cause injury, loss of life, serious environmental harm, asset loss and reputational damage. These are essentially unplanned impacts, to be anticipated as possibilities, for which preventative action and reactive responses are embedded in Project design and operating processes.

18.2 Discipline-specific Impact Assessment Method

18.2.1 Framework

Risk management is integral to TOTAL's business and is addressed in company documents, e.g.:

- Safety Health Environment Quality Charter that 'Total implements, for all of its operations, appropriate management policies regarding safety, security, health, the environment, quality, societal commitment and a periodic risk assessment of relevant policies and measures. Any development of a project or launch of a product is undertaken upon full lifecycle risk assessment.'
- Group Directive One-Maestro HSE Principles (DIR-GR-HSE-001):
  - Principle 3 addresses risk management that requires 'For any activity the hazards to which people, the environment and assets are exposed are systematically identified, the associated risks assessed and the measures for reducing them defined and implemented.'
  - Principle 7 addresses emergency preparedness and 'The emergency situations potentially critical for people, the environment and assets are identified based on a risk assessment.'

This is also reinforced in TEP PNG's HSE Charter:

> In order to achieve our standards, we shall, in all our activities: Perform appropriate HSE assessment to identify, minimize and manage the risks to personnel, the environment and assets.

18.2.2 Methods

Major hazards have been identified and assessed during the pre-Project phase in a social and environmental aspects and impacts identification (SENVID) study and hazard identification (HAZID) studies.

The SENVID focuses on environmental and social risks whereas the HAZID focuses on safety risks.

The purpose of the SENVID was to identify, at an early stage, the aspects that can potentially impact the environment or society including major hazards. The SENVID examined all Project phases to identify the components and activities that may cause environmental and social harm due to major accidental, upset or abnormal events.

The HAZID followed a similar approach to the SENVID but focused on upstream operations. The purpose of the HAZID was:

- To identify the hazards and associated risks that can impact infrastructure design.
- To identify the major hazards and put in place robust measures/preventative barriers and corrective actions.
- Where necessary propose recommendations to:
  - Better analyze the hazard and associated risks (e.g., collect more input data or carry out specific studies).
  - Consider the implementation of additional barriers or alternatives.

During the pre-Project phase, a hazard analysis (HAZAN) was also carried out to evaluate safety distance requirements.

Major hazards discussed in this chapter are extracted from the various assessments mentioned in this section. Related controls and mitigation to reduce risks from these hazards to as low as reasonably practicable are discussed in the following sections.

18.3 Major Hazards

The principal major hazards relate to the following:

- Loss of containment of product, gas, fuel and other hazardous materials through failure or damage to equipment from natural causes (e.g., earthquake, landslide, wildfire, tsunami, storm surge and flood events), equipment or system failures or third-party interference, (including intentional or unintentional vessel collisions).
- Fire and explosion, caused by ignition (e.g., from wildfire, lightning strike or electrical equipment) of a product release or leakage (e.g., of fuel, gases or chemicals).

These major hazards have the potential to cause a range of adverse impacts to people, facilities and the environment, including:

- Contamination of soil, surface water, groundwater or air posing a risk to human and ecological health.
- Loss of terrestrial and aquatic habitat, flora and fauna.
- Damage to property or cultural heritage sites.
- Reduced livelihoods (e.g., through loss or damage to land or water resources).
- Compromised health or safety, potentially including fatalities of Project personnel or third parties.
- Financial hardship or increased vulnerability for persons or dependents in the event of a major life-changing injury or fatality.

18.3.1 Wells and Wellpads

The following major hazards have been considered at wells and wellpads, which are in the northern part of PRL-15:

- Fire during well drilling or operations.
- Loss of well control during well drilling or operations.
- Release of high levels of H_2S due to equipment failure.

18.3.2 Central Processing Facility

The following major hazards have been considered at the CPF:

- Major fuel spill from plant, machinery and equipment or system failures during construction and production.
- Fire at the CPF during construction.
- Release of high levels of H_2S due to equipment failure.
- Fire or explosion of gaseous or liquid hydrocarbons during processing.
- Seismic events damaging processing facilities causing a large-scale hazardous material release.

18.3.3 Flowlines, Trunklines and Export Pipelines

The following major hazards have been considered for flowlines, trunklines and export pipelines:

- Major release of liquid contaminating surrounding areas.
- Explosion or fire during production.

18.3.4 Transport Routes

The following major hazard has been considered in relation to transport routes:

- Fuel spills due to rupture of a vessel bunker or bulk fuel and chemical containers, e.g., from a vessel grounding, collision or fire, in the Gulf of Papua and river transport routes.

18.4 Mitigation and Control

18.4.1 Facilities Location

As described in Chapter 5 (Project Options and Analysis), social sensitivity has been a key criterion used in defining the location of facilities and exclusion zones. This results in avoiding populated areas to the best extent, hence minimizing communities' potential exposure to major hazards.

18.4.2 Safety Concept

Based on the outcome of the studies referred to in Section 18.2.2, a Project Safety Concept has been developed. It defines the basis for the specific safety engineering requirements to be adopted for the Project design, so that facilities are designed to a recognized safety standard, and the systems required to protect personnel, the environment and Project assets from the identified hazards are provided.

The Project Safety Concept establishes the measures to:

- Avoid or limit exposure to potential hazards.
- Minimize the potential (frequency) for hazardous occurrences.
- Contain and minimize the consequences of an incident.
- Provide the means of escape and evacuation for personnel from an incident.

The Safety Concept; therefore, defines design mitigation and controls, in relation to site layout, safety shutdown systems, specific requirements associated with flare and vent systems, drainage and spill management, fire and gas detection, fire protection and the fire-fighting philosophy, emergency power, alarm and telecommunications systems, escape and evacuation, personnel safety and contingency planning.

An overview of those embedded design controls is provided in Chapter 4 (Project Description) and some are discussed further in 18.4.3. Contingency planning is discussed in 18.4.4.

18.4.3 Mitigation and Control Measures

18.4.3.1 Layout Requirements

The following main principles have been considered in the layout of the wellpads and CPF:

- Process, utilities, storage and flares are segregated into different fire zones.
- Separation distance between fire zones is computed according to TOTAL General Specification, Impacted Area, Restricted Area and Fire Zones (GS EP SAF 253), to minimize the potential for escalation of credible hazardous events.
- Ignition sources are located upwind or perpendicular to the flammable sources, as far as reasonably practicable.
- Ignited vents and flares (ignition sources) are located perpendicular to the prevailing winds.
- Escape evacuation and rescue routes and systems are located upwind of hazardous areas, as far as reasonably practicable.
- Attention is paid to the potential for transport impacts, dropped objects or swinging objects with protection measures put in place at specific locations to prevent impacts.

The land acquisition process takes into consideration safety distance requirements. In addition, access to site will be restricted and security managed as described in Chapter 4 (Project Description).

18.4.3.2 Pipeline Requirements

The pipeline network will be buried. The pipeline design considers a corrosion allowance amongst other parameters, and corrosion inhibitor will be injected into the production manifold at the production wellpads, as defined in Chapter 4 (Project Description).

The pipeline will be designed with a pipeline fiber optic monitoring system that will detect ground movement and any intrusion for the onshore sections. The equipment will be designed considering corrosion risk and chemical corrosion.

18.4.3.3 Drainage and Spill Management

The drainage system comprises open and closed drain systems. As described in Chapter 4 (Project Description), the general philosophy is for the system to segregate and manage runoff via three separate networks, with a design based on extreme rainfall events:

- OD1 - permanent hydrocarbon-contaminated drains.
- OD2 - accidental hydrocarbon-contaminated drains.
- OD3 - hydrocarbon-free drains.

In addition, hydrocarbon storage tanks and some other very large liquid hydrocarbon inventories require containment systems (e.g., bunded areas, impounding basins) designed to contain large, accidental leaks.

This minimizes spillage and the risk of hydrocarbon ignition and subsequent fire escalation.

Operational controls in relation to hazardous materials transport, bunkering and transfer will be defined in the Hazardous Materials Management Plan.

18.4.3.4 Fire and Gas Detection

A fire detection system will be installed and equipped with flame, heat and smoke detectors at the CPF and wellpads. Flammable gas detection, and manual alarm call points will be provided.

A toxic gas (H_2S) detection system will be installed at the CPF. A toxic gas detection system is not installed at the wellpad, as it is not a permanently manned facility. An individual portable gas detector shall be provided for personnel visiting the wellpad and CPF.

The objective of the fire and gas detection system is to alert personnel in case of a major failure, such as a flammable gas cloud, toxic gas cloud or fire, and to reduce escalation by initiating automatic or manual actions, e.g., shutdown processes.

18.4.3.5 Safety Shutdown System

A safety shutdown system, which comprises field sensors, logic solvers and final elements (e.g., valves or circuit breakers), will be in place. Its prime function will be to shutdown facilities to a safe state in an emergency situation, thus protecting personnel, the environment and the Project asset. In general, emergency shutdown (ESD) and emergency depressurization (EDP) systems contribute to the following objectives:

- Contain hydrocarbon: Limit the loss of containment by isolating incoming and outgoing hydrocarbon flows (ESD).
- Prevent ignition: Isolate and de-energize potential sources of ignition (ESD).
- Mitigate: Depressurize equipment under fire (EDP); reduce or minimize the hydrocarbon inventory by routing hydrocarbons to the flare/vent (EDP); reduce the quantity released through a leak (EDP); initiate active fire-fighting.

18.4.3.6 Fire Protection and Fire-fighting Philosophy

Fixed fire-fighting means will be provided only on the CPF (i.e., manned facilities). The main features of the fixed fire water system comprise firewater deluge systems, monitors and hydrants, a firewater distribution network, pumps and a firewater storage tank.

Mobile fire-fighting support (e.g., fire trucks and fire teams) will be provided to access the wellpad (from the CPF) and will include wheeled, portable dry chemical units and portable extinguishers.

18.4.3.7 Escape and Evacuation

Primary and secondary escape routes will be provided to facilitate personnel evacuation in critical situations. Escape routes will be as straight as possible and lead to muster points or other safe areas and will be further defined in the detailed design phase of the Project.

18.4.3.8 Blowout Contingency Planning

Accidental blowout scenarios have been assessed during the pre-Project phase and a general philosophy to manage an accidental blowout defined. Blowout management will be refined under the Blowout Contingency Plan that will be generated during the detailed design phase of the Project.

18.4.3.9 Seismicity and Landslide Risk

The presence of geohazards is a key criterion that has been used to define facilities' locations and pipeline routing, as identified in Chapter 4 (Project Description) and Chapter 5 (Project

Options and Analysis). Seismicity and landslide risk have been considered when defining design and safety requirements.

Potential increases in the incidence of landslides due to Project activities and infrastructure with related mitigation are discussed in Chapter 11 (Impacts: Terrestrial).

18.4.4 Emergency Preparedness and Response

Principle 7 of the TOTAL Group Directive One-Maestro HSE Principles (DIR-GR-HSE-001) states:

> An organization is set up to ensure that emergency plans, appropriately-trained personnel and suitable equipment necessary for dealing with such situations are constantly on hand.
>
> Emergency and associated external assistance plans are drawn up, tested during periodic exercises and updated on a regular basis.
>
> Where appropriate, these emergency plans consider local communities, mutual aid organizations and authorities. All employees, contractors, suppliers and visitors are informed about what to do in the event of an emergency.

TEP PNG has an Emergency Response Plan that provides a systematic approach to managing incidents and emergencies. It is based on a risk assessment process that identifies potential credible emergency scenarios.

The Emergency Response Plan is reviewed regularly and will be updated as needed to include the following:

- Description of the emergency response team organization (e.g., structure, roles, responsibilities and decision makers).
- Elements for managing emergency scenarios, with contact details for relevant personnel.
- Description of response procedures (e.g., details of response equipment and location, procedures, training requirements and duties) for the following:
  - Major spills.
  - Fire and explosions.
  - Vessel and vehicle collisions.
  - Loss of well control.
  - Evacuation.
  - Emergency medical evacuation (MEDEVAC) procedures for injured or ill personnel.
  - Attack by third parties.
- Descriptions and procedures for alarm and communications systems.
- Description of available first aid supplies and backup medical support.
- Description of other available emergency facilities and response times.
- Description of emergency response equipment.
- Policies defining measures for limiting or stopping events, and conditions for terminating actions.

TEP PNG has established on-call emergency response and crisis management teams that are capable of mobilizing and responding to the extent required for an emergency situation, and without delay. The teams are staffed with competent individuals, organized into teams with allocated and clearly defined roles.

The teams are trained to respond to emergencies, rescue injured persons and perform emergency actions in coordination with other agencies and organizations that may be involved in emergency response.

Personnel are provided with suitable emergency response equipment, including medical emergency, spill response and firefighting equipment. These are managed and located for effective use, with sufficient equipment available as required.

Exercises in emergency preparedness are and will continue to be practiced regularly.

The Emergency Response Plan will be developed to manage preparation for and response to emergency events. It will contain (Chapter 19, Environmental Management, Monitoring and Reporting):

- Site contingency plans, that will consider fire management measures.
- Oil Spill Contingency Plan, that will consider spill risks for all Project activities and all Project phases.
- Blowout Contingency Plan, including contingency measures.

18.4.5 Next Steps

Major hazards assessment and management will be progressively updated and refined, as required, as the Project proceeds through detailed design. Hazard and operability studies will be undertaken and their outcomes addressed in the Project design.

A detailed Emergency Response Plan will be prepared and will include the modeling of accidental releases to assess the risk associated with major hazards, as part of the Oil Spill Contingency Plan and response definition. Other aspects of emergency response will be defined in the Hazardous Materials Management Plan, and a Traffic and Transport Management Plan will be in place to define safe driving and vessel movement requirements. Operational controls in relation to major hazards prevention and control will be further defined as part of the Project’s health, safety and environment (HSE) management system deployment (Chapter 19, Environmental and Social Management, Monitoring and Reporting).

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Chapter 19: Environmental and Social Management, Monitoring and Reporting

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TOTAL E&P PNG LIMITED

December 2019
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Figures

19. Environmental and Social Management, Monitoring and Reporting

This chapter outlines how the Project's predicted impacts, identified in Chapters 11 to 18, will be managed and documented in the Project's Health, Safety and Environment and Social Management System. It describes the framework for environmental and social management, monitoring and reporting under which the Project will operate.

The Project Environmental and Social Management Plan (ESMP) will be developed and implemented within this framework, from which detailed management plans will be developed. The management plans will support further implementation of the mitigation and management measures, and will define the monitoring requirements to assess the performance and efficiency of the mitigations. Specific Project and contractor management plans will; therefore, provide additional prescriptive detail, objectives, specific measures, targets and responsibilities.

19.1 Policy, Legislation, Guidelines and Standards

The *Oil and Gas Act 1998* and the *Environment Act 2000* are the key pieces of legislation regulating the Project. These Acts govern the activities and standards for environmental protection and sustainability under which the Project will operate. Other applicable legislation, guidelines and standards are detailed in Chapters 1 and 2. These extend to the Project's suppliers and contractors.

The key Total E&P PNG Limited (TEP PNG) health, safety and environment (HSE) commitments that underpin the development and implementation of the Project's ESMP are defined in the following documents:

- TEP PNG Health Safety and Environment Charter (L0-CHT-MAN-01-R0).
- TEP PNG Biodiversity and Ecosystem Charter (L0-CHT-MAN-02-R0).
- TEP PNG Societal Policy (L1–POL–MAN–05).

The Project ESMP will be further developed when required to meet potential additional Lender requirements.

19.2 Environmental and Social Management System Overview

19.2.1 One-MAESTRO Overview

The Project's environmental and social management. is guided by TOTAL's health, safety and environment (HSE) framework, Management and Expectations Standards Toward Robust Operations (abbreviated to One-MAESTRO). One-MAESTRO is based on the Occupational Health and Safety Management System OHSAS 18001, the International Organization for Standardization ISO 14001 standard for environmental management systems, and industry best practice.

One-MAESTRO's principle elements are:

1. Management Leadership and commitment: Management at all levels demonstrates exemplary conduct, rigor, vigilance and professionalism regarding HSE in all activities.

2. Compliance with laws, regulations and group requirements: Comply with applicable laws, regulations, relevant industry standards, voluntary commitments and group requirements in all activities.
3. Risk management: Systematically identify hazards and assess the level of risk of any activities, and define and implement the required mitigating measures. Risk reduction measures will be periodically assessed.
4. Operational accountability: All employees and contractors are responsible for managing risks and limiting adverse impacts at their level.
5. Contractors and suppliers: Contractors and suppliers are assessed and selected by considering their HSE performance, expected to comply with the applicable HSE obligations and responsibilities, and to control inherent risks of contracted activities.
6. Competencies and training: Competencies are defined for all activities, taking HSE into consideration. Training and development plans are provided, and personnel competencies regularly assessed.
7. Emergency preparedness: Emergency plans are developed based on the outcome of a risk assessment, and an organization set up so that the plans and appropriate resources are constantly on hand. Plans are regularly tested and updated.
8. Learning from events: All incidents are reported and analyzed to determine their root cause. Corrective actions and preventive measures are defined, and the process appropriately documented and reported.
9. Monitoring, audits and inspections: Management regularly assesses the HSE performance through monitoring, audits and inspections. Any shortfalls against the set of objectives are analyzed and corrective actions or improvement plans defined, implemented and monitored.
10. Performance and improvement: The HSE management system effectiveness is monitored through key HSE performance indicators. Corrective and preventative actions are prioritized according to the risk level or associated impacts.

These principles are entrenched in the Project's environmental and social management system, providing guidance and a structured approach to managing environmental and social impacts, and to continually improve environmental and social performance.

19.2.2 Feedback and Improvement

One-MAESTRO's principles operate under a 'plan, do, check, act' cycle to continually improve processes and practices. The steps are:

- Plan – define the policy and conduct planning to effectively consider, in the context of the operation, the hazards and risks, legal and other requirements, the company's objectives and targets, and the requirements for management programs.
- Do – execute the plan and take steps, such as training and awareness, in an organized manner to implement the management programs in line with the policy, objectives and targets.
- Check – conduct monitoring, auditing and inspections to verify conformance with the company's objectives, targets and management plan requirements.
- Act – follow a systematic performance review and take action to implement early preventive and corrective actions, and to standardize or improve the process.

Figure 19.1 illustrates this process.

This process follows the principles of adaptive management, in line with the IFC Performance Standard requirements (IFC, 2012), whereby management accommodates for uncertainty in mitigation and management planning, and allows it to be appropriately managed through feedback mechanisms.

The ESMP and monitoring procedures will be subject to periodic review and evaluation to identify any deficiencies. The ESMP will address the outcomes of commitments made in this environmental impact statement, the environment permit conditions when they become available, design refinements as Project development progresses, and any changes in regulatory requirements.

Unplanned incidents will also trigger an investigation and review of the ESMP; procedures will be revised, and management measures updated if necessary when deficiencies are identified.

19.3 Organizational Structure

19.3.1 TEP PNG

TEP PNG environmental and social management teams will oversee the Project's environmental and social responsibility, and will:

- Further develop and implement the Project's environmental and social management framework for the respective Project phases.
- Communicate expectations, including legal obligations, standards and targets that must be met, and the commitments of the workforce and contractors.
- Assist contractors to implement the Project's ESMP.
- Train or induct the workforce and contractors appropriately.
- Support and monitor the implementation of the management measures throughout all Project phases and activities.
- Monitor defined performance indicators and evaluate results against performance objectives.
- Systematically audit and assess environmental and social management to evaluate conformance, compliance and integrity.
- Review management measures and strategies, and revise, adapt and improve the ESMP when necessary.
- Maintain management systems and documentation.
- Undertake regulatory and Lender reporting as required.
- Interface with government bodies and other authorities regarding HSE requirements.
- Maintain community engagements in relation to Project activities, grievances, and mitigation programs.

19.3.2 Contractors

Multiple contractors will be involved in the various Project phases. All personnel and contractors are responsible for the quality of their work, conformance and compliance with the applicable ESMP and legislation requirements, managing risks and limiting their impacts. The contractors undertaking activities on behalf of TEP PNG will be contractually obligated to implement and comply with the ESMP and all relevant legislative requirements. The environmental obligations

OneMAESTRO IMPROVEMENT PROCESS: PLAN, DO, CHECK, ACT

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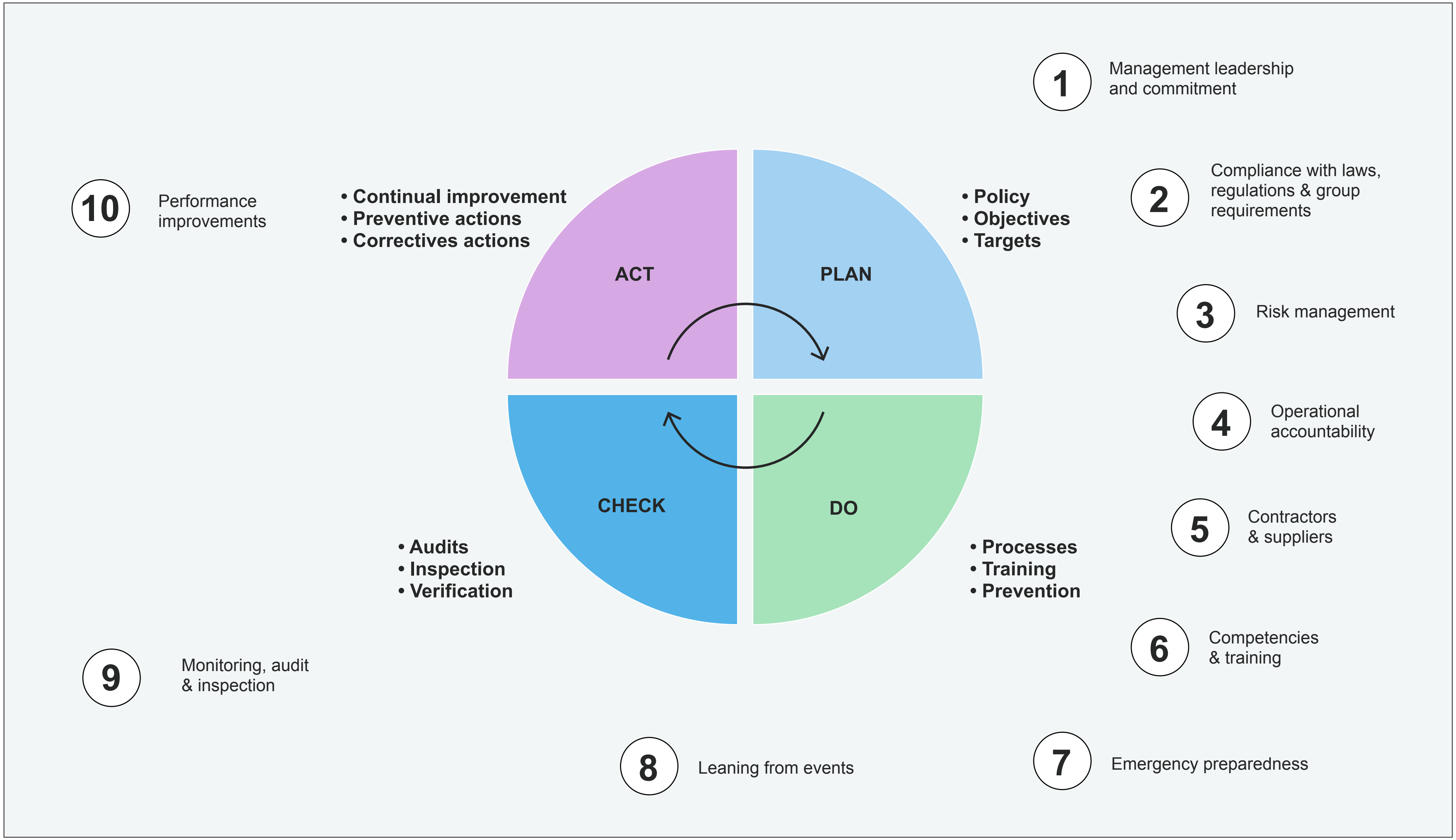
FIGURE 19.1



Source: TOTAL, 2018.

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consigned to TEP PNG will also flow contractually to the contractors. TEP PNG is liable for contractor conformance and adherence to the ESMP and will monitor the contractor's social and environmental performance to verify conformance with the ESMP and all legislative and environment permit conditions.

The contractor must have adequate resources available to allocate on an ongoing basis to effectively implement aspects of the ESMP applicable to their activities. The contractor's management plans and procedures will describe the resources, responsible parties of each management task, training and competency requirements, detailed mitigation measures, monitoring, reporting and communication requirements. The contractor will regularly report to TEP PNG on the performance of the contracted activities.

19.4 Environmental and Social Management Plan

The Project's ESMP is being prepared in the One-MAESTRO environmental and social management framework. The ESMP's objectives are to:

- Demonstrate compliance with regulations, and internal and Lender requirements.
- Provide supporting documentation for regulatory approvals.
- Document the implementation of the management system at the Project level.
- Assign responsibilities for environmental management so that all requirements are understood and completed, and actions and outcomes are appropriately documented and communicated.
- Provide consolidated guidance to line management on the implementation of Project-specific environmental and social management commitments identified in this environmental impact statement.
- Identify and communicate the legal obligations and expected standards in relation to contractors' environmental performance.
- Provide information on the mitigation and management measures, monitoring requirements and activities, objectives, performance indicators, corrective actions, and procedures for communication, evaluation and reporting.
- Manage the potential for unplanned events and incidents including prevention, response, reporting and corrective action.

Project ESMPs will be prepared for the construction, operations and decommissioning phases and will be submitted to CEPA. Each will address:

- Legal and other requirements.
- Roles and responsibilities.
- Competencies and training.
- Notification and reporting requirements.
- Management plans that make up the ESMP.
- Engagement and interactions.

Detailed management plans will be developed, based on the Project's environmental and social management framework, to implement the commitments and define the monitoring requirements.

The Project's approach to impacts mitigation consists of, avoiding impacts where possible, minimizing impacts when avoidance is impossible and when they remain, considering rehabilitation or restoration, and ultimately compensation/offsetting. Potential impacts may be addressed in one or more of the management plans, as impacts overlap various sensitivities.

Figure 19.2 illustrates the Project environmental and social management framework, detailing the management plans that will form part of the CESMP. The management plans will be revisited and/or specific ones created when required, to meet additional Lender requirements. These plans will be completed according to the environment permit prior to the respective Project phases commencing. The CESMP will also be revised when required based on the outcomes of the pre-construction surveys.

The operator (TEP PNG) will manage the Project's environmental and social aspects included in the environmental and social management framework in the first instance with management obligations also passed on to the contractor as appropriate.

19.5 Monitoring, Auditing and Reporting

Monitoring is a key component of the management system and is required to determine the effectiveness of the design, and construction and operational measures implemented to mitigate predicted environmental and social impacts. Such monitoring will consider internal and regulatory requirements, including the environmental permit conditions.

The ESMP will include details of the performance indicators and monitoring approach including frequency. Detailed monitoring programs will be finalized prior to construction, and will be periodically revised and updated as necessary. Records management will also be defined.

19.5.1 Environmental Impact Monitoring

Compliance with applicable standards, and the effectiveness of the Project's design controls and commitments, will be monitored and assessed against measurable performance indicators. Environmental monitoring will target air quality and air emissions; noise and vibration; vegetation clearance, disturbance and revegetation; weeds, pests and pathogens; biodiversity; groundwater, surface water, discharges and sediment; contaminants, waste management, and any further monitoring the environmental permit conditions require.

19.5.2 Social Impact Monitoring

The effectiveness of the Project's social management initiatives (see Chapters 13 and 14) will be monitored and assessed against measurable socioeconomic performance indicators. Social monitoring will target training and employment, livelihoods, community health and safety, governance, archaeology and cultural heritage, grievances and any further monitoring the permit conditions require.

19.5.3 Auditing

Inspecting and auditing of contractor activities will form part of the management system, and will comprise self-assessment and assessment of the contractor at regular intervals by TEP PNG or external independent resources when required, for quality assurance and control, and to guarantee integrity.

The audit frequency will depend on the HSE level of risk of the contracted services, as defined in TEP PNG's HSE requirements for contractors. A corrective action plan will be established when non-conformance or non-compliance is identified.

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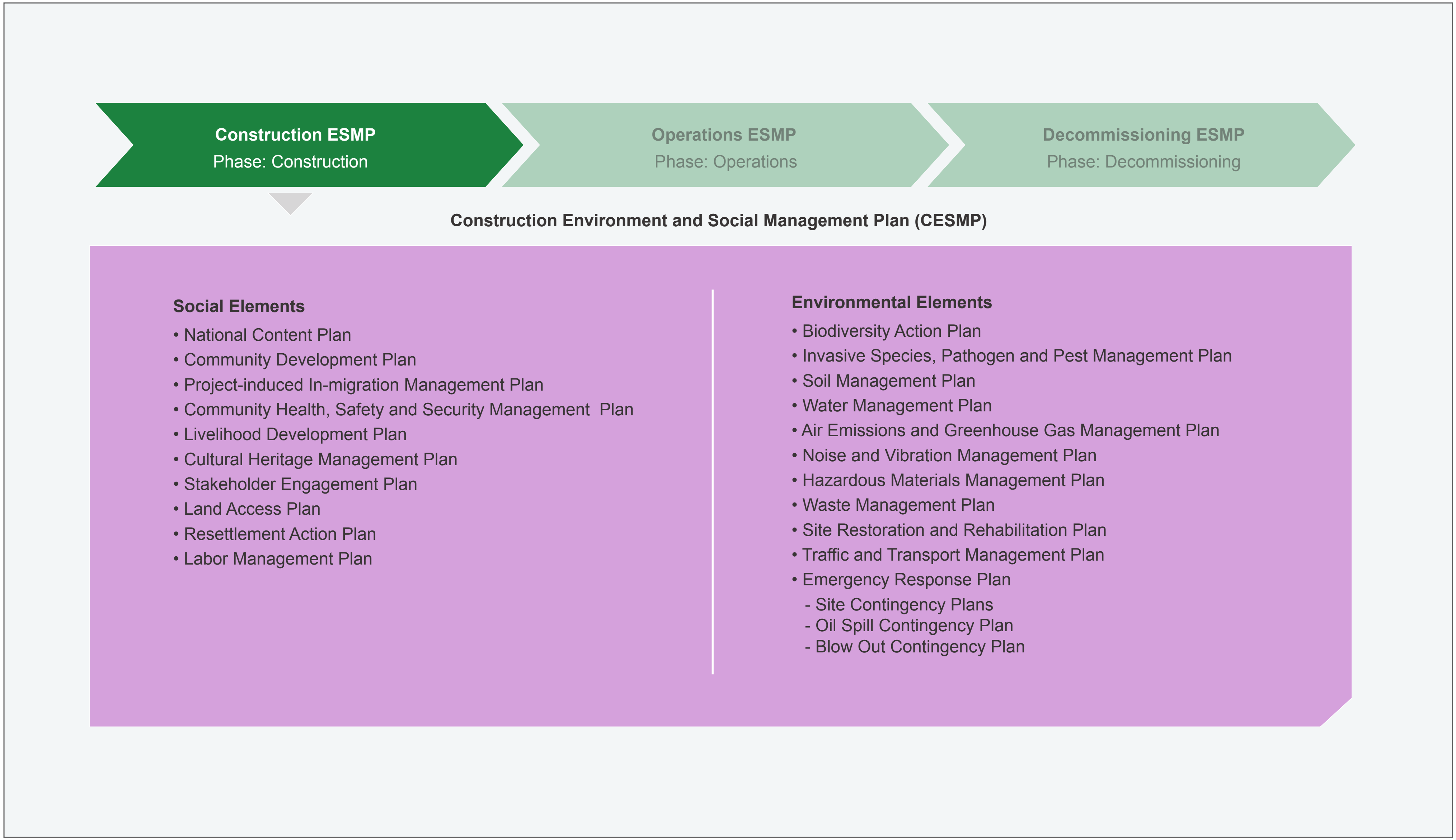
FIGURE 19.2



19.5.4 Recording and Reporting

Social and environmental performance, and incident reporting will be undertaken according to the internal applicable requirements, and externally according to relevant statutory requirements.

TEP PNG will prepare an environmental and social performance report at a frequency agreed to with CEPA that will provide the information required to satisfy any conditions stipulated in the environment permit.

Monitoring, auditing and reporting documentation will be recorded and retained according to applicable document retention policies.

19.6 Project Evolution and Adaptive Management

Refining the Project design is an ongoing process that will evolve from front-end engineering and design through to detailed design, as with any complex development project. Some changes may also occur during the construction and operations phases. This process will consider where significant impacts remain, and explore additional opportunities for mitigation.

Design amendments and changes will be managed and tracked through a management of change process. Changes will be assessed with respect to potential environmental and social impacts, and the ESMP updated accordingly.

Major changes, if they occur, will be communicated to CEPA and other relevant authorities, and appropriate actions in terms of regulatory requirements will be determined with CEPA and those other authorities.

19.7 References

IFC. 2012. Performance Standard 6 biodiversity conservation and sustainable management of living natural resources. World Bank Group. Washington, D.C.

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VOLUME 1: MAIN REPORT

Chapter 20: Commitments Register

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20. Commitments Register

This chapter collates the mitigation and management measures that have been identified in Chapters 11 to 18, to address potential impacts caused by the Project. The mitigation and management measures (commitments) in Table 20.1 were provided by technical specialists and/or are standard industry practice.

Table 20.1 – Mitigation and Management Measures/Commitments

No.	Discipline	Mitigation Measure/Commitment
Environmental Mitigation and Management Measures		
EM001	All disciplines	All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures.
EM002	Landform and soils; hydrology, fluvial geomorphology and sediment processes; terrestrial biodiversity	Progressively clear vegetation and rehabilitate cleared areas as soon as practicable to minimize the time cleared areas are exposed; and allow fauna to move away from areas to be cleared, where practicable.
EM003	Landform and soils; hydrology, fluvial geomorphology and sediment processes	Cut trees where practicable to retain the rootstock and maintain soil stability.
EM004	Landform and soils	Erosion and sediment control measures will be implemented for infrastructure components in accordance with good international industry practice to effectively manage stream and river flows, stormwater, surface erosion, sedimentation and scour, e.g., drainage diversion into surrounding vegetation, rip-rap aprons, rock armoring, energy dissipaters, sediment control ponds, mulch berms and sediment fences, where required, until the area has been effectively stabilized and/or rehabilitated.
EM005	Landform and soils; hydrology, fluvial geomorphology and sediment processes	Stabilize spoil stockpiles and areas of ground disturbance as soon as practicable after initial disturbance using, e.g., mulched vegetation, aggregates and soil binders.
EM006	Landform and soils; hydrology, fluvial geomorphology and sediment processes	Areas of higher risk of landslides e.g., steep gradients, previously disturbed land, likely to occur from the works, or likely to be exacerbated by the works, will be stabilized to reduce the landslide risk.
EM007	Landform and soils	Avoid disturbing acid sulfate soils, potentially in soil Complex 4 coastal soils, and Soil Complex 2 and 3 on alluvial flood plains, beach ridge and plains in the lower Purari River delta, wherever possible, otherwise handle, store, treat, manage and dispose of Acid Sulfate Soils according to good practice guidelines.
EM008	Landform and soils; surface water quality; and freshwater and estuarine biodiversity	Sewage effluents from Project facilities will be treated to meet the environment (waste discharge) permit before discharge, in accordance with applicable standards.
EM009	Hydrology, fluvial geomorphology and sediment processes	Backfill trenches as soon as practicable after disturbance, using material originally excavated from the trench as much as possible. The backfilled trenches should not exceed the preconstruction levels after the material has settled.
EM010	Hydrology, fluvial geomorphology and sediment processes	Minimize or avoid sidecasting during construction (e.g., for road, pipeline, well pad and CPF works). Any sidecasting that does occur will avoid defined stream channels.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Environmental Mitigation and Management Measures (cont'd)		
EM011	Hydrology, fluvial geomorphology and sediment processes	Water from trenches will be discharged in accordance with applicable water quality standards with erosion and sediment controls where relevant.
EM012	Hydrology, fluvial geomorphology and sediment processes	Maintain buffer zones between permanent surface water and Project infrastructure, except to carry out works associated with the construction of watercourse crossing or where facilities are proposed to be located within that buffer.
EM013	Hydrology, fluvial geomorphology and sediment processes	Minimize in-stream and stream bank disturbance during high rainfall.
EM014	Hydrology, fluvial geomorphology and sediment processes	Implement low speed limits through areas sensitive to vessel wash impacts.
EM015	Hydrology, fluvial geomorphology and sediment processes; freshwater and estuarine biodiversity; and surface water, marine water quality	Hydrotest water management will consider: ♦ The definition of volume and discharge rates and discharge locations. ♦ Chemicals additives selection, according to requirements defined in embedded design controls ♦ Reusing hydrotest water to minimize the discharge volume. ♦ Reducing the need for chemicals by minimizing the time hydrotest water remains in the pipeline. ♦ Monitoring hydrotest water discharges to the environment against applicable limits.
EM016	Surface water quality; freshwater and estuarine biodiversity	Training and test releases of firefighting foams at the CPF are to be contained within appropriate drainage water treatment networks.
EM017	Surface water quality	Vehicle wash down and fuel handling will be undertaken considering possible receptors e.g. streams, Purari River and the marine environment
EM018	Surface water quality; freshwater and estuarine biodiversity; marine water quality	An Emergency Response Plan will be developed to effectively manage the preparedness and response to emergency events. It will contain: ♦ Site contingency plans, that will consider fire management measures. ♦ An Oil Spill Contingency Plan, that will consider spill risks for construction, operation and decommissioning of facilities and associated infrastructure, and supply services on land and in aquatic and marine environments. ♦ A Blow Out Contingency Plan including well blowout control and contingency measures.
EM019	Surface water quality; marine water quality; marine biodiversity	Vessels will be required to have shipboard Oil Pollution Emergency Plans/Oil Spill Contingency Plans as per TOTAL requirements and *Marine Pollution (Ships and Installations) Act 2013*.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Environmental Mitigation and Management Measures (cont'd)		
EM020	Hydrology, fluvial geomorphology and sediment processes; freshwater and estuarine biodiversity	Maintain hydraulic and biological connectivity during construction and operations in natural flow lines across linear infrastructure, such as pipelines and roads, and in relation to water extraction, e.g. dams, including: ♦ Install appropriately sized culverts, drains and structures to allow fish passage, according to good international industry practice standards. ♦ Rehabilitate waterways after construction and decommissioning to a sustainable, stable state, that reflects the original character, and maintains waterway flows and connectivity.
EM021	Freshwater and estuarine biodiversity	Minimize fish entrainment by water extraction equipment, e.g., screens.
EM022	Freshwater and estuarine biodiversity	Implement lower speeds past aquatic fauna when observed in the water.
EM023	Freshwater and estuarine biodiversity; marine water quality; marine biodiversity	Management controls will be developed for weed, pathogen and pest that pose a significant threat to biodiversity, including: ♦ Specific risk-based control methods, and procedures targeting Priority 1 and 2 weeds and pest fauna. ♦ A quarantine management program for moving people, equipment and supplies in accordance with PNG law. ♦ Tools for field personnel to identify Priority 1 and 2 weeds and pest fauna.
EM024	Terrestrial biodiversity	Maintain a minimum practical distance from sensitive features to minimize potential degradation and disturbance. Buffer distances shall be ecologically relevant, considering: ♦ Sensitive habitats, i.e. primary alluvial forest, mangroves, riparian vegetation along forest streams. ♦ Habitats that provides focal breeding, roosting or feeding sites for sensitive fauna, e.g. caves, rock shelters, rock outcrops, large trees with hollows, large trees with nests, bird-of-paradise display trees, forest pools, large fig trees (Ficus spp.) and vines of the family Aristolochiaceae. ♦ Sites that support populations of IUCN Threatened or rare and localized plant species.
EM025	Terrestrial biodiversity	Minimize damage to habitat surrounding planned footprints by safely felling trees into planned footprints or into less environmentally sensitive natural spaces between standing trees.
EM026	Terrestrial biodiversity	Avoid burning cleared vegetation, wherever practicable.
EM027	Terrestrial biodiversity	Project personnel, workers, contractors or third-party operators, while engaged in Project activities, will be prohibited: ♦ To light and use fire except for specific work requirements controlled under the 'Hot Works' permit procedure and in designated smoking areas. ♦ To hunt, fish, collect or disturb forest or wildlife resources. ♦ To possess hunting or fishing equipment, including firearms, bow and arrows, spears, rubber guns, slingshots and other hunting tools. ♦ To keep pets or to purchase, acquire or possess any wildlife or wildlife products.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Environmental Mitigation and Management Measures (cont'd)		
EM028	Terrestrial biodiversity, Freshwater and estuarine biodiversity; marine biodiversity; cultural heritage	All Project personnel, workers, contractors and 3rd party operators will be educated during inductions and safety training about: ♦ Fire risks, including the heightened risk during extreme drought years and smoking. ♦ Wildlife values. ♦ Weed, pathogen and animal pest hygiene and control measures. ♦ Identification of cultural heritage, cultural heritage awareness, measures for avoiding impacts and the Chance Finds Procedure.
EM029	Terrestrial biodiversity; air quality	Actively or passively rehabilitating bare sites as soon as possible to promote a stable self-sustaining landscape, e.g.: ♦ Allow forest edges to naturally regenerate or create appropriate conditions to facilitate natural regeneration, e.g. rip the substrate, replace topsoil, apply mulch. ♦ Rehabilitate Pandanus habitats, e.g. recreate mounds, reinstate the intertidal surface between Pandanus mounds. ♦ Rip compact surfaces across the slope, as appropriate, to facilitate revegetation and minimize erosion. ♦ Spread stockpiled topsoil, organic matter and cleared vegetation over the rehabilitation area to promote natural regeneration. ♦ Use native vegetation to revegetate sites when active rehabilitation measures are required.
EM030	Terrestrial biodiversity; hydrology	Dispose of excess spoil material from Project earthworks in designated spoil disposal sites
EM031	Terrestrial biodiversity	Use a suitably-trained fauna handler to relocate fauna, where practicable, before vegetation clearing.
EM032	Terrestrial biodiversity	When a significant impact remains on IUCN Threatened species or rare and localized plant species, translocation and propagation shall be considered when ecologically feasible.
EM033	Terrestrial biodiversity	Develop traffic and transport management controls that include: ♦ Posting speed limits on Project roads via posted speed limit signs. ♦ Requiring vehicles to keep to posted speed limits. ♦ Keeping vehicles and mobile machinery to marked trafficable areas and work sites.
EM034	Terrestrial biodiversity	Install ramps, e.g., unexcavated or backfilled earth plugs, in the pipeline trench at regular intervals and at other high-risk locations to permit fauna to exit.
EM035	Terrestrial biodiversity	Visually inspect open trenches and excavations in the morning and evening and use a suitably-trained fauna handler to remove trapped wildlife, where practicable.
EM036	Landform and soils; terrestrial biodiversity	Where possible, separate and stockpile cleared topsoil (with the inherent seed bank and any coarse woody debris) to use for future rehabilitation.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Environmental Mitigation and Management Measures (cont'd)		
EM037	Freshwater and estuarine biodiversity; marine physical and sediment processes; marine biodiversity	Where required, implement adaptive management to minimize dredging impacts on sensitive habitats and species.
EM038	Marine biodiversity	Where required, implement adaptive management to minimize the Project's impacts on lobster migration.
EM039	Underwater noise	Provide for a 'soft start' for impact hammer piling activities to allow nearby transitory and resident fauna the opportunity to move out of the noise exclusion zone before sound levels reach maximum levels.
EM040	Underwater noise	If noise-sensitive aquatic species are sighted during the piling activities, initiate shut down procedures and stop the operations until the animal is observed to leave the noise exclusion zone or a set period has passed.
EM041	Air quality	Implement dust control, where required.
EM042	Air quality	Use low sulfur fuel, as far as practicable.
EM043	Air quality	Waste incineration shall: ♦ Use appropriately designed incinerators commensurate with proposed inventory. ♦ Be considered for waste that will effectively combust. ♦ Be operated within the required specification and by competent personnel.
EM044	GHG	Implement standard practices to minimize fuel consumption, e.g., reduce speeds and idling times, maintain good road conditions, reduce site gradients, optimize vehicle tire pressure and maintain vehicles.
EM045	GHG	Implement fugitive emissions measurement controls.
EM046	Noise	Limit construction work, where practicable, to daytime hours.
EM047	Landscape and visual amenity	Avoid directly lighting areas at night and minimize fixed night lighting for safe operations, e.g., direct lighting away from the Purari Airstrip House, and the surrounding forest.
EM048	Landscape and visual amenity	Where practicable, retain a vegetation buffer to screen infrastructure and facilities.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Social Mitigation and Management Measures		
SM001	Economic displacement and livelihoods	Development of Project Land Access and Livelihood Development Plans (LALDP) consistent with the goals, objectives, principles and processes described in the Land Access and Resettlement Framework (LARF) and continuously drawing on lessons learned from the land access and resettlement activities. The LALDP will adequately cater for the respective interests of the Project Affected Persons (PAPs) in accordance with criteria for eligibility and the PAPs' choice of type of compensation (e.g. cash or in-kind). The LALDP will: ♦ Describe processes for appropriate disclosure of information, consultation and the informed participation of Project-affected persons with the aim of obtaining their free, prior and informed consent. ♦ Provide a compensation framework with compensation for loss of assets at replacement cost. ♦ Design livelihood programs which aim to improve or at least restores the livelihoods and standards of living of displaced persons which choose to remain in the Project area of influence; and ♦ Include special provisions for identified vulnerable individuals or groups. ♦ physical displacement of primary residents is required; include provisions to improve living conditions among displaced persons which have chosen in-kind compensation through provision of replacement housing. ♦ Provide a monitoring framework for the implementation of LALDP.
SM002	Economic displacement and livelihoods	The Project will, in consultation with local communities, government and civil society, design and deliver a diversified livelihood program that provides eligible Project-affected people which choose to remain in the Project area of influence with opportunities for improving their existing livelihoods and that contributes to the diversification of skills with the aim of triggering income generating activities. Livelihood programs will consider how Project-affected persons can be involved in Project employment opportunities (direct and indirect) and how skills learned on the Project can be applied to other sectors in the local area.
SM003	Economic development and employment	Establish a set of local employment and procurement policies that: ♦ Ban employment applications 'at the gate'. ♦ Includes measures to protect the workforce, in particular to identify and avoid child labor and forced labor. ♦ Gives priority to Project-affected persons and members of Project-affected communities (and in particular women) for local employment opportunities. ♦ Maximizes the employment and training of national citizens including persons from Project-affected communities. ♦ Includes measures for gender-fair hiring and workplace policies.
SM004	Economic development and employment	Institutional capacity building: Provide support to capacity building programs aiming to enhance national and local government capacity to foster diversified economic growth and their capacity to deliver local public services.
SM005	Economic development and employment	Community owned company capacity building: Provide support to governance and capacity building programs to improve business development and planning.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Social Mitigation and Management Measures (cont'd)		
SM006	Economic development and employment	The Project will maximize the procurement of Goods and Services from local companies including community owned companies. Major contractors will be required to demonstrate measures and staff organization they will implement to maximize national content. The Project will support eligible small-scale enterprises through capacity building programs and advisory/mentoring services aiming, e.g. to improve business plans, to strengthen management capabilities and to facilitate access to information on Project employment and business opportunities. At a local level, business development officers will be appointed to identify and assist eligible small and very small-scale businesses in the Project area.
SM007	Economic development and employment	Develop initiatives to enhance education and training of youths from the PAOI, e.g.: ♦ A scholarship program to provide opportunities for eligible students from the Project-affected communities to pursue their studies. ♦ Internships and/or training opportunities with the Project or its contractors specifically focusing on transferable, nationally recognized trade skill development.
SM008	Economic development and employment	Undertake a feasibility assessment in consultation with local stakeholders on delivering capacity and resilience building programs for Project-affected communities and clan/village leaders, e.g., on financial literacy training and conflict resolution training.
SM009	Economic development and employment	Investigate options to work with local partners to support the development of sustainable ward development plans in the PRL-15 area and along the export pipeline route.
SM010	Economic development and employment	Partner with development organizations to deliver an education and awareness program (or include such awareness in other community development programs) to enhance the understanding of women's rights, e.g., their right to work, their right to education, more equitable labor activities, and to tackle gender-based violence.
SM011	Education and workforce training	In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve education infrastructure and capability, and to strengthen education outcomes. While having a focus on elementary and primary schools in the PAOI, secondary and vocational schools in the province might also be considered.
SM012	Community health and safety	In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to improve health services and infrastructure, and to strengthen health outcomes.
SM013	Community health and safety	Partner with relevant organizations to develop a Health and Wellness Awareness Program for the Project workforce and Project-affected communities, particularly in high-risk, in-migration areas. Topics may include preventing and managing communicable and noncommunicable diseases, women's health, nutrition, hygiene and sanitation, and transport safety.
SM014	Community health and safety	In areas of high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives aimed at improving water, waste, sanitation and hygiene services (WASH).

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Social Mitigation and Management Measures (cont'd)		
SM015	Community health and safety	Develop a tuberculosis (TB) prevention and control program for the Project workforce, including measures to screen and confirm the medical status of TB prior to employment or assignment in the Project area. Project workers diagnosed with active TB will be demobilized to their point of hire, they will be advised to seek treatment and the government will be notified to follow-up with their immediate family members as part of the national TB program. After treatment, a medical evaluation and fitness to work certificate will be required to resume work.
SM016	Community health and safety	In consultation with relevant stakeholders, develop a community emergency preparedness and response policy and procedure that clearly define roles of stakeholders in the event of Project-related emergencies or accidents affecting the community.
SM017	Community health and safety	Provide healthy and culturally appropriate food choices at workforce accommodation.
SM018	Community health and safety	Restrict community access to Project sites.
SM019	Governance and leadership	Enhance compliance with business ethics: ♦ The Project and its contractors will require that all direct and contracted workers undertake anti-bribery, corruption, ethics and compliance training. ♦ The Project will establish an employee whistleblowing system, thereby providing a confidential mechanism to report, e.g. any cases of bribery and corruption, or labor rights infringements in the workforce.
SM020	Governance and leadership	Develop and implement targeted engagement activities with women in the Project-affected communities to help build their knowledge of the Project so that their views and rights are considered throughout its ongoing development.
SM021	Governance and leadership	The Project will work with traditional leaders and ward councilors to encourage community volunteers to participate in the Project's social monitoring and evaluation.
SM022	Conflict, law and order	In areas at high risk of Project-induced in-migration in the PAOI, undertake a feasibility assessment in consultation with relevant stakeholders on initiatives to encourage regulation and monitoring of in-migration.
SM023	Conflict, law and order	The Project will establish governance arrangements for the implementation and monitoring of community investment and development programs.
SM024	Conflict, law and order	Support sustainable initiatives to strengthen village law and order organizations (e.g., village courts, local police and churches).
SM025	Conflict, law and order	The Project will ensure private security personnel are screened and trained on the Voluntary Principles on Security and Human Rights.
SM026	Transport and access	Maintain designated crossing locations during construction of the onshore export pipeline and shore crossing to enable community access.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Social Mitigation and Management Measures (cont'd)		
SM027	Transport and access	Engage with communities potentially affected by barging operations about the barge movements and define a community development program recognizing the inconvenience that waterway communities may experience.
SM028	In-migration	Engage with communities and local-level governments to discourage the development of informal settlements along Project access routes and near Project facilities.
SM029	In-migration	Establish Project recruitment centers away from PRL-15 and construction areas to prevent in-migration.
SM030	In-migration	Demobilize all Project workers to their point of hire after their shift/employment is completed.
Cultural Heritage Mitigation and Management Measures		
CHM001	Tangible cultural heritage	Develop and implement archaeological clearance procedures related to all early works and construction activities. This will include: ♦ Establishment of a buffer area around identified sensitive sites near the planned Project facilities, prior to early works and construction activities, to avoid accidental or inadvertent impacts. ♦ Management of potential direct impact to any known site where impact is unavoidable, in consultation with local affected communities. ♦ A chance finds procedure for managing the discovery of ancestral remains, burial sites, and human remains. ♦ Other measures, e.g., on site-specific recording, marking, erosion prevention, relocation, clearance distances and monitoring. ♦ Provisions for notification of relevant parties in case of chance finds, and the notification of relevant parties in case of direct impacts to any known site.
CHM002	Tangible cultural heritage	Develop and enforce the Project Material Culture Policy, which prohibits Project workforce from obtaining items of material culture from local communities through purchase or by way of a gratuity.
CHM003	Tangible cultural heritage	Maintain traditional access to significant cultural places through consultation with relevant communities.
CHM004	Tangible cultural heritage	Appoint a Project cultural heritage officer during the construction phase to oversee the implementation of the chance finds procedure, to conduct training as appropriate and to act as key contact for Project workers and contractors on all matters related to cultural heritage.
CHM005	Intangible cultural heritage	Develop intangible cultural heritage workshops in collaboration with relevant Project-affected communities, with guidance and oversight provided by cultural heritage specialists.

Table 20.1 – Mitigation and Management Measures/Commitments (cont'd)

No.	Discipline	Mitigation Measure/Commitment
Stakeholder Engagement Mitigation and Management Measures		
SEM001	Stakeholder engagement	Through its stakeholder engagement programs and activities, the Project is undertaking a process of free, prior and informed consent (FPIC) with the Project-affected persons in the Project area in accordance with the International Finance Corporation (IFC) Performance Standard (PS) 7. For example: ♦ The Project will engage an independent organization to provide legal support to Project-affected persons regarding land access, so that they are fully informed of their rights and obligations, and that they enter into agreements willingly and without duress. ♦ The Project will document a mutually accepted process between the Project and Project-affected persons, and evidence of agreement between the parties as the outcome of negotiations.
SEM002	Stakeholder engagement	The Project will prepare an updated stakeholder engagement plan for the Project's construction, operations and decommissioning phases, according to TOTAL's general specifications and IFC PS1 and PS7. The updated stakeholder engagement plan will include the following key requirements: ♦ Regular engagement with Project-affected communities on Project impacts, action plans and grievance mechanism. ♦ Notification as early as possible to affected communities in advance of Project works, which describes the activities and how long they are expected to take. Particular focus is to be given to communities affected by Project-induced in-migration. ♦ A mechanism for enquiries and feedback. ♦ Ongoing grievance and issues management.
SEM003	Stakeholder engagement	As part of the Land Access and Resettlement Framework (LARF): ♦ Provide a framework for stakeholder engagement on land access and livelihoods including public consultation, disclosure and grievance resolution. ♦ Provide preliminary information to stakeholders (e.g., government, civil society) about the standards and procedures for the LARF.
SEM004	Stakeholder engagement	Once the Project begins construction, an independent consultant will be engaged to monitor stakeholder engagement and other activities.
Ecosystem Services Mitigation and Management Measures		
ESM001	Ecosystem services	Assess the efficacy of efficient biomass stove programs in coastal Papua New Guinea and, if warranted, support extension services to promote their use in the PAOI in Orokolo Bay.

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 21: Glossary

TOTAL E&P PNG LIMITED

December 2019

(Report No. 01215B_23_v5)

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21. Glossary

21.1 Acronyms and Abbreviations

€	Euro
µg/m^3	microgram per cubic meter
/d	per day
/y	per year
AASS	actual acid sulfate soils
AES	Avenell Engineering Systems Ltd
AIDS	Acquired Immunodeficiency Syndrome
AGRU	acid gas removal unit
ALARP	as low as reasonably practicable
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand
ARI	average recurrence interval
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
asl	above sea level
AU$	Australian dollar
B	billion
bar	unit of pressure (100 kilopascals)
bbl	barrel
Bcf	billion cubic feet
bcpd	barrels condensate per day
bgl	below ground level
BHP	bottom hole pressure
BHT	bottom hole temperature
boe	barrel of oil equivalent
BOD	biological oxygen demand
BOP	blowout preventer
BSA	benefit sharing agreement
BTEX	benzene, toluene, ethylbenzene and xylene
Btu/scf	British thermal unit per standard cubic foot
BUR	Biennial Update Report

BVG	broad vegetation group
bwpd	barrels of water per day
°C	degrees Celsius
CALMET	California Meteorological Model
CALPUFF	California Puff Model
CAPEX	capital expenditures
CCR	central control room
CCS	carbon capture and sequestration
CCTV	closed circuit television
CEPA	Conservation and Environment Protection Authority (formerly DEC)
CFC	chlorofluorocarbon
CFU	colony-forming unit
CH_4	methane
CESMP	Construction Environmental and Social Management Plan
CHMP	Cultural Heritage Management Plan
CLO	Community Liaison Officer
CLUCA	Clan Land Use and Compensation Agreements
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
COD	chemical oxygen demand
CHM	cultural heritage mitigation
CP	cathodic protection
CPF	central processing facility
CR	company rule
CVS	condensate valve station
dB	decibel(s)
DEC	Department of Environment and Conservation (now CEPA)
DNPM	Department of National Planning and Monitoring
DoH	Department of Health
DoP	Department of Petroleum
DPE	Department of Petroleum and Energy (now DoP)
DWT	deadweight tonnage
ED	embedded design control

EDP	emergency depressurization
EER	escape, evacuation and rescue
EHS	environmental, health and safety
EIA	environmental impact assessment
EIR	environmental inception report
EIS	environmental impact statement
EITI	Extractive Industries Transparency Initiative
EM	environmental mitigation
EMP	environmental management plan
EMS	environmental management system
ESBS	environmental and social baseline study
ESHIA	environmental, social, and health impact assessment
ESD	emergency shutdown
ESM	ecosystem services mitigation
FAO	Food and Agriculture Organization
FEED	front-end engineering design
FID	final investment decision
FIMS	Forest Inventory Mapping System
FPIC	free, prior, informed consent
FTE	full time equivalent
GEL	generally expected level
GHG	greenhouse gas
GIIP	good international industry practice
GIS	geographic information system
GPWG	Gulf Province Working Group
GRA	global restricted area
GS	general specification
GVS	gas valve station
H_2S	hydrogen sulfide
ha	hectare
HAZID	hazard identification
HDD	horizontal directional drilling
HDPE	high-density polyethylene
HP	high-pressure
HIV	human immunodeficiency virus

HV	high-voltage
Hz	hertz
hPa	hectopascals
HSE	health, safety, environment
IAQM	Institute of Air Quality Management
ICP	informed consultation and participation
IDLH	immediately dangerous to life and health
IFC	International Finance Corporation
IMO	International Maritime Organization
in	inch
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
k	thousand
K	kina
kboe/d	thousand barrels of oil equivalent per day
kb/d	thousand barrels per day
kHZ	kilohertz (1,000 Hz)
kL	kiloliter
km/h	kilometer per hour
kW	kilowatt
kWh	kilowatt hour
L	liter
L/s	liters per second
Landco	landowner companies
LAT	lowest astronomical tide
LCM	loose cubic meter
LIDAR	light detection and ranging
LLG	local-level government
LNG	liquefied natural gas
LP	low pressure
LPG	liquefied petroleum gas
m	meter
M	million
m/s	meters per second
Mbbl	million US petroleum barrels

MEG	monoethylene glycol
MAESTRO	Management and Expectations Standards Towards Robust Operations
mg	milligram
mg/cm^2	milligrams per square centimeter
mg/L	milligrams per liter
mg/Sm^3	milligram per standard cubic meter
ML	megaliters
ML/d	megaliters per day
Mm^3	million cubic meters
MMscfd	million standard cubic feet per day
MP	medium-pressure
MSDS	material safety data sheet
Mt CO_2-e	million tonne of carbon dioxide equivalent
MTO	methanol to olefins
Mtpa	million ton per annum
MW	megawatt = one million (10^6) watts
MWh	megawatt hour
MWp	megawatt peak
NaHSO4	sodium bisulfate
NA2SO3	sodium sulfite
NFA	National Fisheries Authority
NGA	Australian National Greenhouse Accounts
NGO	nongovernmental organization
NMAG	Papua New Guinea National Museum and Art Gallery
NMSA	Papua New Guinea National Maritime and Safety Authority
NO_2	nitrogen dioxide
NOx	nitrogen oxides
NORM	naturally occurring radioactive material
NTU	nephelometric turbidity unit
OD	open drain network
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPEX	operating expenditures
PAC	Project-affected community
PAH	polycyclic aromatic hydrocarbons

PAOI	Project area of influence
PAP	Project-affected person
PASS	Potential acid sulfate soils
PCCSP	Pacific Climate Change Science Program
PDL	petroleum development license
PGK	Papua New Guinean Kina
PL	pipeline license
POM	Port Moresby
PM_{10}	particulates with aerodynamic diameter less than 10 µm
$PM_{2.5}$	particulates with aerodynamic diameter less than 2.5 µm
PNG LNG	Papua New Guinea Liquefied Natural Gas (project)
PNGFA	Papua New Guinea Forest Authority
PPE	personal protective equipment
PPFL	petroleum processing facility license
PPL	petroleum prospecting license
ppm	parts per million
PRAEC	petroleum resource area economic corridor
PRL	petroleum retention license
PRL-3	petroleum retention license-3
PRL-15	petroleum retention license-15
PTS	permanent threshold shift
ROW	right of way
SEP	stakeholder engagement plan
SENVID	social, environmental aspects identification
SIA	social impact assessment
Sm^3	standard cubic meter
SIMOPS	simultaneous operations
SO_2	sulfur dioxide
SOx	sulfur oxides
sp.	singular of species
spp.	plural of species
SRU	sulfur recovery unit
STI	sexually-transmitted infection
t	metric tonne(s)
t CO_2-e	tonne of carbon dioxide equivalent

t/d	tonnes per day
TCEQ	Texas Commission on Environmental Quality
Tcf	trillion cubic feet
TEG	tri-ethylene glycol
TEP	Total Exploration & Production
TEP PNG	Total E&P PNG Limited
TOC	total organic carbon
TOTAL	TOTAL S.A. (see also TEP PNG)
Total E&P	a division of TOTAL S.A.
tpa	tonnes per annum
tph	tonnes per hour
TPH	total petroleum hydrocarbon
TSP	total suspended particles
TSPZ	Torres Strait Protected Zone
TSS	total suspended solids
TTS`	temporary threshold shift
TVD	true vertical depth
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
UXO	unexploded ordnance
V	vulnerable
VHF	very high frequency radio communication
VOC	volatile organic compound
VLO	Village Liaison Officer
WHO	World Health Organization
WHRU	waste heat recovery unit
WMA	wildlife management area
WTO	World Trade Organization
WWF	World Wildlife Fund

21.2 Glossary of Terms

abandonment	(oil & gas wells) wells are abandoned when they reach the end of production or they are dry holes. Cement plugs are placed in the borehole to prevent migration of fluids between different formations. Surface components are then decommissioned and removed from site. This term can also apply to abandonment of facilities during decommissioning.
abiotic	of or relating to the non-living components of an ecosystem; physical rather than biological; not involving biological activity.
abundance	(biological and other sciences) the quantity or amount of something present in a particular area, volume, or sample e.g., total numbers of individual animals or of taxonomic groups of animals.
acidify	to make acid; convert or change into an acid. To become acid; turn acidic.
acoustic	relating to sound or the sense of hearing.
ambient noise	environmental background noise not of direct interest during a measurement or observation.
anadromous	of a fish that spends most of its life feeding in the open ocean but that migrates to spawn in fresh water.
ancestral village	a village that is no longer in use and known through oral traditions.
anoxic	lacking in oxygen.
antifouling	preventing growth of marine organisms on the hull of a ship or boat. An antifouling agent, usually in the form of a paint, i.e., substances applied to the hulls of vessels to prevent attachment and growth of marine organisms that could affect the performance of the vessels and introduce exotic marine organisms.
arboreal	living in trees.
Aristolochiaceous	a plant belonging to the family Aristolochiaceae.
aspect	a particular part of a subject (see also 'environmental aspect').
associated facility	facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable.
A-weight	a frequency filter, the intention of which is to approximate the subjective response of human hearing. A-weighted sound pressure levels are designated as dB(A).
background	the circumstances, situation, or levels of a particular parameter prevailing at the time of assessment; natural or pre-existing level of a variable.
ballast	any heavy material carried by a ship or boat for ensuring proper stability, so as to avoid capsizing and to secure the greatest

	effectiveness of the propelling power; extra weight taken on to increase a ship's stability to prevent rolling and pitching. Most ships use seawater as ballast. Empty tank space is filled with inert (non-combustible) gas to prevent the possibility of fire or explosion.
barrel	(bbl) measure of crude oil equal to 42 US gallons, 35 Imperial gallons or 159 L.
baseline	an initial value of a measure, parameter or variable used as a starting point for comparison.
bathymetry	the measurement of underwater depth of ocean or sea floors or other large bodies of water.
benthic zone	the ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers.
benthos	organisms that live at or associated with the seafloor. Examples include burrowing clams, sea grasses, sea urchins and acorn barnacles.
bentonite	a material composed of clay minerals, predominantly montmorillonite with minor amounts of other smectite group minerals, commonly used in drilling mud. Bentonite swells considerably when exposed to water, making it ideal for protecting formations from invasion by drilling fluids. It is widely used as a mud additive for viscosity and filtration control.
bilge water	water that collects in the bilges of a vessel and can become contaminated with chemicals or hydrocarbons from the engine room.
biocide	a chemical agent intended to destroy, deter, render harmless, or exert a controlling effect on any organism/s. In the oil and gas industry, biocides are added to water-based muds to control bacterial growth.
biodiversity	biological diversity; the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in relation to a particular habitat. A high level of biodiversity is usually considered to be desirable and/or important.
biogenic/biogenous	produced or brought about by living organisms/producing or produced by living organisms.
blowout	uncontrolled release of formation fluids (water, crude oil and/or natural gas) from a well after pressure control systems have failed. I.e., when downhole pressure overcomes the weight of drilling fluid and rises in a well to the surface, combined with failure of blowout preventer. An underground blowout is where the overpressuring enters another formation higher in the well, but before it reaches the surface.
blowout preventer (BOP)	a large series of valves at the top of a well which can be closed successively to counteract the uncontrolled rise of oil or gas from a reservoir below.

burial platform	platforms where human remains are placed.
calcareous	made of calcium carbonate.
CALMET	a diagnostic meteorological model which reconstructs three-dimensional temperature and wind fields according to meteorological measurements, land use data and topography.
CALPUFF	a transport and dispersion model that advects ‘puffs’ of material from modelled sources, simulating dispersion and transformation processes.
carnivore	an organism that satisfies its nutrient requirements from a diet consisting mainly or exclusively of animal tissue.
carrying capacity	the number of people, animals, or crops which a region can support without environmental degradation.
cartilaginous	having a skeleton of cartilage.
casing	steel pipe threaded together to line the inside of a well bore, lowered into the open hole and cemented into place. Used to prevent the bore from caving in, to prevent water and other fluids from entering the bore, and to maintaining control of drilling fluids.
catadromous	fish that spawns in seawater but feeds and spends most of its life in estuarine or fresh water.
ceremonial site	a place where traditional ceremonies are or were carried out.
cetacean	the group of marine mammals that includes whales, dolphins and porpoises.
clay	a fine-grained earth/soil material, defined by AS1726-1993 as being composed of particles finer than 0.002 mm. When used as a soil texture group such soils contain at least 35% clay particles.
comb jellies	members of the phylum Ctenophora, a group of gelatinous forms feeding on smaller zooplankton.
commissioning	process of testing, checking and inspecting all systems and components of a newly constructed facility, plant or piece of equipment to verify that it is installed and functioning according to design specifications and operational requirements.
completion	(of an oil or gas well) all operations (tubing, installation of valves, wellhead, etc.) to enable production and bring a production well into operation.
compression (gas)	the act, process, or result of compressing; the state of being compressed; e.g., the containment of gas at a higher pressure than it exists in its natural state.
condensate	a low-density mixture of hydrocarbon liquids that generally occurs in association with natural gas. Its presence as a liquid phase depends on temperature and pressure conditions in the reservoir, allowing condensation of liquid from vapor.
conductor	the first casing string in a well.

construction	a project phase that comprises the building of an installation (i.e., gas processing facilities, pipelines etc).
contaminant	something which contaminates, i.e., renders impure via pollution. In ecology, a substance which may degrade an environment (e.g., soil or water) due to toxicity to humans, animals or plants, or detriment to beneficial uses.
contamination	making or being made contaminated; to pollute a substance with another substance. Considered to have occurred when the concentration of a specific element or compound is established as being greater than the normally expected (or quantified) background concentration.
continental shelf	an underwater landmass which extends from a continent; a broad expanse of seafloor sloping gently and seaward from the shoreline to the shelf-slope break at a depth of 100 to 200 m.
controlled discharge	release of a substance (e.g., wastewater) from a project area onto/into receiving land/water under conditions that meet a predetermined quality standard.
coral reef	a wave-resistant structure resulting from cementation processes and the skeletal construction of hermatypic corals, calcareous algae, and other calcium carbonate-secreting organisms.
cumulative impact	an impact that result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones.
cutter suction dredger	dredger equipped with a rotating cutter head, for cutting and fragmenting harder soils and rock. The material is sucked up by means of dredge pumps, and discharged through a pipeline to a deposit area.
cuttings	(oil and gas drilling) rock fragments dislodged by the drill bit which are brought to the surface in the drilling mud.
decibel (dB)	a logarithmic unit used to express the ratio of two values of a physical quantity, often power or intensity. Used to described sound – the base 10 logarithmic function of the ratio of the pressure fluctuation to a reference pressure.
decommissioning	a project phase that comprises the removal, disposal or reuse of an installation when it is no longer required for its current purpose.
degradation	the process by which the inherent quality or value of something is being destroyed or diminished.
density	(botany, zoology, population geography) the quantity of plants, animals or people within a given area, or the average number of individuals per area sampled or assessed. For example, the number of animals or plants (individuals or taxa) per unit area.
denudational soil	soil formed from the weathering of the earth's surface

deposit feeder	an organism that derives its nutrition by consuming some fraction of a soft sediment.
detritus	particulate material that enters into a marine or aquatic system. If derived from decaying organic matter it is organic detritus.
diffusion	(physics) the intermingling of molecules/substances by the natural movement of their particles; the net movement of molecules from a region of high concentration to a region of low concentration (concentration gradient).
direct impacts	impacts that result from primary planned interactions between a planned Project activity and environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity.
dispersion	the act of dispersing; the state of being dispersed. A mixture of one substance dispersed in another medium, such as water or air. Ecology: the movement of individual animals, plants, etc., between sites; the pattern of distribution of individuals within a habitat.
distributaries	a branch of a river that does not return to the main stream after leaving it (as in a delta).
disturbance	the interruption of a settled condition. Ecology: a temporary change in environmental conditions causing a change or impact to an ecosystem.
diversity	the state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat.
doline	see “sinkhole”
dosimetry	determination and measurement of the amount or dosage of radiation absorbed by a substance or living organism by means of a dosimeter.
drilling fluid (mud)	any of a number of liquid fluids and mixtures of fluids and solids (as solid suspensions) used to drill boreholes into the earth. Synonymous with ‘mud’ in general usage. May be classified (for example) as water-based or non-water-based.
drill string	a column, or string, of drill pipe, collars and other tools including the drill bit that transmits drilling fluid (via the mud pumps) and torque (via the kelly drive or top drive) to the drill bit.
early works	a project phase that comprises the preliminary or enabling works required to support full construction of an installation (e.g., roads, camps etc).
easement	the area of land legally acquired to contain the pipeline and over which the operator can exercise access restrictions, e.g., for safety and security, during operations.

ecoregion	an ecologically and geographically defined area comprised of distinct assemblages of flora and fauna
ecosystem	a community of living organisms and their interactions with each other and the physical environment.
ecosystem service	the benefits that people gain from functioning ecosystems.
El Niño	the warm phase of the El Niño Southern Oscillation associated with a band of warm ocean water that develops in the central and east-central equatorial Pacific.
ensonified	man-made underwater noise above background ambient levels as in an ‘ensonified zone’.
environmental value	particular values or uses of the environment that are important for healthy ecosystems or for public benefit, safety or health and that require protection from the effects of pollution.
epibenthic	living on the surface of the seafloor.
epifauna	animals living on the surface of the seafloor or a riverbed, or attached to submerged objects or aquatic plants or animals.
euphotic zone	the upper region of a body of water into which light penetrates, allowing photosynthesis.
eutrophication	enrichment of waters with nutrients causing abundant aquatic plant growth and often leading to deficiencies in dissolved oxygen.
fault	(geology) a type of fracture (separation in a geologic formation) that divides a volume of rock into two or more pieces, along which there has been displacement.
fecundity	the number of eggs produced per female per unit time (often: per spawning season).
fly camp	used when referring to remote temporary camps.
flaring	burning off waste gas during well testing or emergency situations.
fluvial	of or found in a river.
foliar necrosis	Death or degeneration of a living organism's cells or tissues. In a plant, necrosis causes leaves, stems and other parts to darken and wilt. Necrosis weakens the plant and makes it more susceptible to other diseases and pests.
frequency (sound)	the pitch or number of oscillations per second of a sound wave, measured in cycles per second or hertz (Hz).
frugivore	an animal that eats fruit.
gastropod	a mollusc of the class Gastropoda; the slugs and snails (including sea snails).
gathering system	comprises a network of flowlines that take the gas and condensate from the wells to the processing facilities.

gradient	the degree of inclination of a slope. Physics: increase or decrease in the magnitude of a property, such as temperature, pressure or concentration, between one point or moment and another.
grazer	a predator that consumes organisms far smaller than itself (e.g., copepods graze on diatoms).
greenhouse gas	any gaseous compound in the atmosphere that is capable of absorbing and emitting infrared radiation, thereby trapping and holding heat in the atmosphere.
hazard	something that can cause harm; a situation that poses a level of threat to the environment, life, health or property.
heavy metals	a metal of relatively high density, or of high relative atomic weight. There is no universally agreed definition, however, heavy metals include (among others) cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), tin (Sn) and zinc (Zn).
herbivore	an organism that consumes plants as a main component of its diet.
herbivory	the act of animals feeding on plants
home range	the area in which an animal lives and moves on a periodic basis.
hybrid	the offspring resulting from combining the qualities of two organisms of different breeds, varieties, species or genera through sexual reproduction.
hydrocarbon	any of the class of organic compounds containing only hydrogen and carbon, such as any of those which are the chief compounds in petroleum and natural gas.
hydrocarbon, volatile	a hydrocarbon which evaporates readily at normal temperatures and pressures, i.e., with a low boiling point (high vapour pressure). Normally taken to mean those with ten (or less) carbon atoms per molecule.
hydrostatic test/ing	(often abbreviated as hydrotest/ing) a method by which pressure vessels such as pipelines, gas cylinders and fuel tanks can be tested for strength and leaks. Hydro-testing involves filling the vessel or pipe system with a liquid, usually water, and pressurisation of the vessel to a specified test pressure.
impact	a marked effect or influence. Negative or positive effect/s caused directly or indirectly by an event or activity, or by the release of a substance into the environment, causing a change in the biological, physical and/or socio-economic environment.
indirect impacts	impacts that are subsequent to the primary planned interactions between the Project and its environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity with subsequent potential impact on health of fish species and economic livelihood of fishing dependent villagers.

induced impacts	successive impacts that have no direct relationship to a planned Project activity, but may nonetheless result from flow on activities associated with the Project, e.g., in-migration, increased hunting.
influx	an arrival or entry of large numbers of people.
injection well	a well in which fluids are injected rather than produced; the primary objective is usually to maintain reservoir pressure. Injection may be of water or gas. For example, the separated gas from production wells may be reinjected into the upper gas section of the reservoir.
in-migration	process of moving into or coming to live in a new region or community.
in situ	in the original place.
intangible heritage	the practices, representations, expressions, knowledge and skills that individuals recognize as part of their cultural heritage.
interstitial	of, forming, or occupying interstices; living in the pore spaces among sedimentary grains in a soft sediment.
introduced species	plants, animals, pathogens and other organisms that are living outside their native distributional range and have arrived there predominately due to anthropogenic activity either deliberately or accidentally.
invasive species	species that may be introduced or native and spread and out-compete other species.
invertebrates	animals without a backbone or bony skeleton.
ion	an electrically charged atom, group, or molecule, formed as a result of loss or gain or one or more electrons.
isopleth	a line or curve of equal values; a line on a graph showing the occurrence or frequency of a phenomenon as a function of two variables.
keystone species	a species that has a critical role in maintaining the structure of an ecological community.
leachate	water that has percolated through a solid or semi-solid material (e.g., soil or mine waste) and leached out some of the constituent impurities.
lek/lekking	an aggregation of male animals gathered to engage in competitive displays, lekking, to entice visiting females.
LIDAR	Acronym for light detection and ranging. A remote-sensing technique that uses laser to measure distances to reflective surfaces.
macrofauna	small animal organisms found in the soil or on the sea floor, normally including fauna of greater than 0.5 mm size.
magnitude	a qualitative measure that considers the severity, size, scale, duration or extent of an impact.

marine pest	an exotic marine flora or fauna species carried by a vector (e.g., ballast water or hull biofouling) from a donor site to a recipient site, where it successfully establishes a self-reproducing population that is problematic ecologically and/or economically.
Metazoa	all multicellular animals.
metocean	(offshore and coastal engineering) a syllabic abbreviation of the words 'meteorology' and 'oceanography'. Metocean conditions include weather and climate, along with aspects of physical oceanography such as water level fluctuations, bathymetry, stratification, currents, salinity, etc. Metocean studies assess such conditions, often in relation to a project.
microclimate	the climate of a very small or restricted area, especially when this differs from the climate of the surrounding area.
microhabitat	a habitat which is of a small or limited extent and which differs in character from some surrounding, more extensive habitat.
micro-organism	a microscopic organism; includes viruses, bacteria, yeasts and fungi, and others.
micronekton	small (typically 20 to 100 mm) animal organisms that swim and move independently of water currents.
mitigation	action(s) taken to avoid or reduce the impact of an activity on the environment, cultural and/or socio-economic interests.
motile	moving or capable of moving spontaneously.
mud (drilling fluid)	any of a number of liquid fluids and mixtures of fluids and solids (as solid suspensions) used to drill boreholes into the earth. Synonymous with 'drilling fluid' in general usage. May be classified (for example) as water-based or non-water-based.
natural regeneration	The process by which vegetation returns from self-sown seeds or vegetative sources (i.e., without human intervention and towards a comparable vegetation type). Under commercial conditions this is usually preceded by rehabilitative actions which facilitate natural regeneration processes and maximize success, these may include actions such as stabilization of the substrate, recontouring and re-spreading of topsoil.
nearshore	refers to the waters from the highest astronomical tide to the 15-m depth contour. The habitat includes coral reefs and seagrass beds, beaches and intertidal habitats (e.g. mudflats).
nutrients	those constituents required by organisms for maintenance and growth.
offshore	refers to the areas of marine water that are seaward of the nearshore environment, and generally encompasses areas of deeper water beyond the 15-m depth contour.

omnivorous	being able to gain nutrition from more that one source/category (e.g., an organism capable of being both carnivorous and herbivorous).
onshore Project area	refers to any of the following Project aspects occurring onshore; PRL-15, the onshore part of the proposed export pipeline corridor, or the river transport corridor.
operations	a project phase that comprises the operation of a facility or installation, when the core business or purpose of that asset is realized.
operator	oil and gas: the owner of the right to drill or produce a well, or the entity contractually charged with drilling of a test well and production of subsequent wells. The company that serves as the overall manager and decision-maker of a drilling project. The company which organises the exploration and production programs in a permit on behalf of all the interest holders in the permit.
ordinance	military weapons, ammunition and associated equipment.
oxidation	the act or process of being oxidised; loss of electrons or increase in oxidation state by a molecule, atom or ion; particularly used to refer to the addition of oxygen to elements.
oxygen scavenger	a material in which one or more reactive compounds can combine with oxygen to reduce or remove oxygen.
ozone depleting substance	chemicals that destroy the earth’s ozone layer.
parameter	any constituent variable quality; a characteristic, feature or measurable factor forming one of a set that defines a system or sets the conditions of its operation.
patchiness	a condition in which organisms occur in aggregations.
pedological development	state of modification of parent rock or sediment, particularly the relative distinctness of soil horizons.
pelagic	of, relating to, or living in open oceans or seas; living at or near the surface of the ocean, far from land, especially relating to fish.
permeability (*k*)	(fluid mechanics and earth sciences) a measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it.
permit	oil and gas industry: an area of specified size within a sedimentary basin which is licenced or allocated to a company or companies by the government for the purpose of exploring for and producing oil and gas.
permanent threshold shift	the permanent reduction in hearing sensitivity caused by irreversible damage to the sensory hair cells of the ear.
pH	a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline.

photic zone	the depth zone in the ocean extending from the surface to that depth permitting photosynthesis.
phylogenetic	(biology) relating to the evolutionary development and diversification of a species or group of organisms, or of a particular feature of an organism.
phytoplankton	the plant component of plankton; plankton consisting of microscopic plants; the photosynthesising organisms residing in the plankton.
phytotoxic	poisonous to plants.
pipestring	a series of line pipe lengths welded together into a single length, prior to lowering the string into a trench or onto the seafloor
plankton	the mass of small and microscopic animal and plant organisms that float or drift in the sea or fresh water and are incapable of moving against water currents, especially at or near the surface; consisting chiefly of diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals.
population growth	increase in the number of individuals in a population.
potamodromous	fish that move and complete their lifecycle entirely within freshwater.
potential impact	the possible outcome resulting from the exposure of a receptor or value to an activity.
produced water	water produced from a wellbore that is not a treatment fluid; water produced as a byproduct along with the oil and gas, where water is present within the oil/gas reservoir with or underlying the hydrocarbons.
production	(oil and gas industry) 1. The phase that occurs after successful exploration and development and during which hydrocarbons are drained from an oil or gas field; an activity of the petroleum industry that deals with bringing well fluids to the surface and separating them and with storing, gauging, and otherwise preparing the product for transport. 2. the amount of oil or gas produced in a given period.
receptor	an entity (which may include individual/s or communities of flora or fauna, as well as individuals, households or communities of people) or a value of environmental or conservation significance, that is exposed to a stressor.
remediation	the action of remedying something, in particular of reversing or stopping environmental damage. Ecology: the restoration of an environment, land or water contaminated by pollutants, to a state suitable for other, beneficial uses.
reservoir	a place where fluid collects. Geology: a subsurface body of rock or formation having sufficient porosity and permeability to store and transmit fluids, such as hydrocarbons within the pore spaces between individual grains.

residual (impact)	those impacts that remain after the effective implementation of avoidance, mitigation and management measures, which are designed to reduce the magnitude or severity of the impact.
resilience	the capacity to recover from an impact.
restricted-range species	terrestrial species which have a total historical breeding range of less than 50,000 km^2.
riparian	relating to wetlands adjacent to rivers and streams.
sensitivity (of a receptor)	a qualitative measure of the susceptibility of a social receptor to change.
shoal	a place where a body of water is shallow; a sandbank or sandbar on the floor of a body of water, especially one which shows at low water.
silt	sediment with particles finer than sand and coarser than clay.
significant impact	an impact with a residual rating of Moderate or above.
sinkhole	a cavity in the ground, especially in a limestone formation, caused by water erosion and providing a route for surface water to disappear underground.
social receptor	the individuals, organizations, groups or resources that can be affected by Project activities.
soniferous	producing or conducting sound.
soil capacity	capacity of soil to support productive land use, e.g., horticulture.
soil structure	the arrangement of soil into aggregates and the pore spaces between them.
soil development status	state of soil evolution from parent geological material.
species richness	the number of different species represented in a sample, taxonomic group, ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions.
spectrum	a quantity expressed as a function of frequency, either as a narrowband spectrum (e.g., 1 Hz bands) or as aggregated bands (e.g., third-octave bands).
spring tide	the large rise and fall of the tide at or soon after the new or the full moon, when there is the greatest difference between high and low water; the phase of the tidal cycle when tidal range is at a maximum.
spirit/ritual site	a place used for ritual practices and/or that has spiritual significance.
substrate	an underlying substance or layer; the surface or material on or from which an organism lives, grows, or obtains its nourishment; e.g., the material comprising a seafloor (e.g., sand, mud, rock).

suspended solids (SS)	small solid particles which remain in suspension in water as a colloid or due to the motion of the water. Used as one indicator of water quality.
tangible heritage	cultural heritage values that have a physical; presence and can be seen and/or touched (e.g., archaeological sites, landscape features and material items such as heirlooms).
taxa	plural of taxon.
taxon	a taxonomic group of any rank, such as species, family, or class.
temporary threshold shift	temporal and reversible elevation of the auditory threshold. A temporary reduction in hearing sensitivity caused by exposure to sound.
terrestrial	on or relating to dry land.
toxicity	the inherent potential or capacity of a material to cause adverse effects in a living organism; the degree to which a substance can damage an organism.
train	a series of parts; order. Gas processing: a production pathway and related infrastructure with its own process area.
tributary	a river or stream flowing into a larger river or lake.
tsunami	a large, often destructive sea wave or series of waves caused by an underwater earthquake, landslide, or volcanic eruption.
turbidity	a measure of the relative clarity of a liquid, particularly water, as a result of the amount of suspended particulate matter present, such as sediment particles, algae, plankton, microbes, and other substances. One indicator of water quality.
venting	provision of an outlet for air, gas or liquid.
volant	of an animal able to fly or glide.
volatile	(of a substance) easily evaporated at normal temperatures; passing off readily in the form of vapor.
vulnerability	the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made change.
well control	technologies and methods used to maintain pressure on open hydrocarbon formations (i.e., exposed to the wellbore) to prevent or direct the flow of formation fluids into the wellbore, to control pressures in a predictable manner, and to prevent blowout.
wellhead	the system of connections, spools, valves, gauges and assorted adapters installed at the exit from a production well that provide pressure control of the well.
zoonotic disease	a disease that can be transmitted from animals to people.

zooplankton	the mass of small and microscopic animal organisms that float or drift in the sea or fresh water and are incapable of moving against water currents.

TOTAL
TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 22: Study Team

TOTAL E&P PNG LIMITED

December 2019
(Report No. 01215B_23_v5)

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22. Study Team

A large multi-disciplinary team, with representatives from the proponent (Total E&P PNG Limited (TEP PNG)), lead environmental and social consultant (ERIAS Group Pty Ltd (ERIAS Group)), technical specialists and field support teams produced the Environmental Impact Statement (EIS) for the Papua LNG Project (the Project). Key team members from TEP PNG, ERIAS Group and specialists who contributed during EIS preparation are acknowledged in this chapter.

22.1 Total E&P PNG Limited

The TEP PNG management team and advisors that led and oversaw the EIS program of work, including participation in the environmental and social baseline studies (ESBS), are listed in Table 22.1.

Table 22.1 – TEP PNG Environmental Impact Statement Team

Name	Title/Role
Jeremy Roeygens	Permitting, Environmental, Social and National Content Director
Magali Pollard	Societal Manager
Bruno de Vals/ Christelle Jennet	Environmental Manager
Andy Hetra	Permitting and Environmental Coordinator
Kritoe Keleba	Societal Studies Coordinator
Hosea James	Community Relations Coordinator
Muse Opiang	Biodiversity Coordinator
Joyce Melepia	Community Investment Coordinator
Mericha Masta	GIS Specialist
Emmanuel Akike	GIS Officer
Armand Leblois	Community Affairs Coordinator
David Albert/Fabien Segura	Health, Safety and Environment Manager
Olivier Cudennec	Logistics Manager
Catherine Edet	Project Health, Safety, Environment and Quality Lead
Jason Frederick/Rachel Keown	Project Environment Advisor
Delphine Fauque/ Olivier Michel/Patrice Chevalier	Project Social Advisor
Dr Robert Jessop	EIS Advisor
Anthony Salvador	Land Access Advisor

22.2 Lead Consultant Team

ERIAS Group was commissioned as the lead environmental and social consultant to deliver the EIS for the Project. ERIAS Group provides specialist services in life-of-project environmental and social baseline, impact assessment and management. ERIAS Group's team of consultants have in-depth knowledge of extractive industries and infrastructure developments, particularly in Papua New Guinea.

The EIS team comprises environmental and social impact assessment lead practitioners and consultants, and specialists who executed technical investigations to support the baseline studies. Table 22.2 identifies key personnel who contributed to the preparation of the EIS.

Table 22.2 – ERIAS Group Environmental Impact Statement Team

Name	Project Title/Role
Management Team and Discipline Leads	
Carmel Coyne	Project Director* Senior Technical Advisor#
Luci David	Project Director# Project Manager – EIS Project Manager – Amenity
Andrew Pym	Project Manager – Terrestrial Biodiversity ESBS Field Logistics Manager
Clark Monahan	Project Manager – Freshwater and Marine Project Manager – Geology, Terrain, Soils and Groundwater
Andrea Lucas/Danielle Martin/Angela Reeman	Project Manager – Social and Cultural Heritage
Michael Jones	Health, Safety, Security and Environment Manager
Technical Support	
Brett Perry/Kobus Meulenbroeks	Papua New Guinea In-country Manager, ESBS execution
Inneke Nathan/Erica Odell	Terrestrial biodiversity support
Kate Munro/Joanna Cundy/Melanie Brown	Social and ecosystem services support
Michelle Clark	Amenity support
Scott Breschkin/Harry Hughes	Marine and freshwater support
James Tanner/Mitchell Goodin/Kate Sinai /Geordie Brock/Michael Wright/Julia Barnes/Liz Jacobsen	General support
Grant Dickins/Mipela Geosolutions	Geographic information systems services
Cambrium Group/Gareth Lewis Design	Drafting services
Contract Support	
David Browne	Contract Manager
Casey Mortlock	Contract management support

Note: Discipline leads and technical support staff contributed to the production of the EIS through authorship, drafting, editing and reviewing. * Until 7 June 2019. # From 7 June 2019.

22.3 Technical Specialists and Field Support

Technical specialists engaged by ERIAS Group to undertake baseline and modeling studies (Volumes 2 and 3), and to support the impact assessments are provided in Tables 22.3, 22.4 and 22.5. In particular, the baseline studies included PNG specialist consultants with technical expertise particularly in the fields of terrestrial biodiversity, resource use, and cultural heritage. The names of the PNG consultants and technical specialists are indicated by an asterisk (*).

Table 22.3 – Environmental Specialist Team

Name	Specialty	Role	Organization
Nicholas Bukowski	Engineering	Engineering interface support (Paris)	SLR Consulting Australia Pty Ltd
Nathan Redfern/ Sandy Lonergan	Health, safety and environment (HSE) specialist	HSE procedures and reporting	SLR Consulting Australia Pty Ltd
Mark Caslin	Geology, terrain and soils	Land and amenity supervisor	SLR Consulting Australia Pty Ltd
Rod Masters/ Clayton Richards/ Chris Armit/Murray Fraser/Cameron Traill	Geology, terrain and soils	Technical specialist	SLR Consulting Australia Pty Ltd
Derwin Lyons/John Leyland	Groundwater	Technical specialist	SLR Consulting Australia Pty Ltd
Dr Darren Richardson/Jeremy Visser/Lyn Leger	Freshwater and marine studies	Freshwater and marine studies lead	BMT Eastern Australia Pty Ltd
Ben Caddis/ Eoghain O'Hanlon	Hydrology, meteorology and sediment processes	Technical specialist	BMT Eastern Australia Pty Ltd
Brad Grant	Freshwater, estuarine and marine water and sediment quality	Technical specialist	BMT Eastern Australia Pty Ltd
Dr Conor Jones /Brad Hiles/Daniel Moran	Freshwater, estuarine and marine biodiversity	Technical specialist	BMT Eastern Australia Pty Ltd
Dr Ian Teakle/Dr Paul Guard/Daniel Machado	Seabed and coastal geomorphology, physical oceanography	Technical specialist	BMT Eastern Australia Pty Ltd
Dr David Balloch	Aquatic biodiversity, underwater noise, river traffic and transport	Technical specialist	EnviroGulf Consulting
Dr Adrian Flynn	Marine fisheries	Technical specialist	Fathom Pacific
Ninkama Yoba*	Aquatic ecology	Technical specialist	Ninkama Yoba and Associates
Dr Iain Woxvold	Avifauna, terrestrial biodiversity	Terrestrial biodiversity lead, technical specialist	Iain Woxvold Consulting Pty Ltd
Dr Ken Aplin	Mammals (volant and non-volant)	Technical specialist	Ken Aplin Fauna Studies Pty Ltd
Dr Kyle Armstrong	Mammals (volant)	Technical specialist	Specialist Zoological
Stephen Richards	Herpetofauna and odonates	Technical specialist	--
Fanie Venter	Vegetation/flora	Technical specialist	Fanie Venter Botanical and Environmental Consultant Pty Ltd
Dr Howard Rogers	Deforestation and vegetation regeneration	Technical specialist	Booyong Forest Science PNG Pty Ltd

Table 22.3 – Environmental Specialist Team (cont'd)

Name	Specialty	Role	Organization
Technical Field Specialists			
Junior Novera*	Non-volant mammals/bats	Discipline scientist	Papua New Guinea Institute of Biological Research
Peter Amick*	Bats	Discipline scientist	The New Guinea Binatang Research Center
Chris Dahl*/Elizah Nagombi*/Pagi Toko*	Herpetology/odonates	Discipline scientist	The New Guinea Binatang Research Center
Fufuse Bewang*/ Benjamin Kelimbua*	Vegetation, weeds and forestry/resource use	Discipline scientist	Booyong Forest Science PNG Pty Ltd
Amos Ona*	Ecosystem services/vegetation, weeds and forestry	Discipline scientist	Booyong Forest Science PNG Pty Ltd
Harry Hughes/ Kobus Meulenbroeks/ Scott Breschkin	Marine studies	Marine scientist	ERIAS Group Pty Ltd

Table 22.4 – Amenity Specialist Team

Name	Specialty	Role	Company
Kirsten Lawrence/ Fardausur Rahaman	Air quality	Technical specialist	SLR Consulting Australia Pty Ltd
Gustaf Reutersward/ Ima Fricker/David Woodcock	Noise	Technical specialist	SLR Consulting Australia Pty Ltd
Peter McGown/ Nathan Thompson/ Kris Oettinger	Visual	Technical specialist	SLR Consulting Australia Pty Ltd
Danielle O'Toole/ Lono Tyson	Waste	Technical specialist	SLR Consulting Australia Pty Ltd

Table 22.5 – Social and Cultural Specialist Team

Name	Specialty	Role	Company
Mike Finlayson	Socio-economics	Technical specialist	SIA & Development
Lisa Richie	Community health	Technical specialist	Engaging Development
Marci Balge/Gary Krieger	Community health	Technical specialist	Newfields Environment and Engineering, LLC
Dr Sue Phuanukoonnon	Community health	Technical specialist	--
Danielle Martin	Socio-economics	Technical specialist	DMConsulting
Dr Nick Bainton	Human Rights and In-migration	Technical specialist	Centre for Social Responsibility in Mining (The University of Queensland)

Table 22.5 – Social and Cultural Specialist Team (cont'd)

Name	Specialty	Role	Company
Dr Howard Rogers	Land and natural resource use, ecosystem services	Technical specialist	Booyong Forest Science PNG Pty Ltd
Dr Ken Aplin	Land and natural resource use, ecosystem services	Technical specialist	Ken Aplin Fauna Studies Pty Ltd
Junior Novera*	Land and natural resource use, ecosystem services	Discipline scientist	Papua New Guinea Institute of Biological Research
Dr Robert Skelly	Anthropology and cultural heritage	Technical specialist	In collaboration with the Social Research Institute
David Kombako*	Anthropology and cultural heritage	Technical specialist	--
John Sepe*	Anthropology and cultural heritage	Technical specialist	Social Research Institute
Dr Chris Ballard	Cultural heritage	Technical specialist	Australian National University (ANU) Enterprises
Dr John Muke*	Cultural heritage	Technical specialist	--
Robert Barclay	Social and ESHIA advisory	Technical specialist	--
Field Support Team			
Yvonne Hani*	Social studies	Team lead	The University of Papua New Guinea
Sally Jerome*	Social studies	Team lead	--
Claire Gangai*/ Charles Wakinau*/ Auvita Kilori*/Joyleen Noki*/Gerard Gowae*/Alex Nava*/ Levana Vanua*/Elai Soutai*	Social studies	Enumerator	The University of Papua New Guinea