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Part 2

Waterberg-Bojanala Priority Area Air Quality Management Plan: Threat Assessment

This report has been produced for the Department of Environmental Affairs by uMoya-NILU Consulting (Pty) Ltd. The authors are Mark Zunckel, Atham Raghunandan, Sarisha Perumal, Yegeshni Moodley and Benton Pillay.

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EXECUTIVE SUMMARY

The Minister of Water and Environmental affairs declared the Waterberg–Bojanala Priority Area (WBPA) on 15 June 2012 as the third National Priority Area (DEA, 2012a). The WBPA includes the Waterberg District Municipality (WDM) in the Limpopo Province and parts of the Bojanala Platinum District Municipality (BPDM) in the North West Province, and borders on Botswana. The WDM and Botswana have significant coal reserves that are largely unexploited with the Matimba Power Station and Morupule Power Station currently in operation. As a result, ambient air quality is relatively good. The National Development Plan 2030 (National Planning Commission, 2012), acknowledges that the lack of stable power to meet the energy demands is an impediment to economic growth in the region, proposing Strategic Infrastructure Projects (SIPs) to accelerated growth and development in the WDM. In addition, the Government of Botswana requires that the energy sector be augmented through the development of new coal-fired power plant generation capacity. The energy-based development initiatives in South Africa and Botswana pose a threat to the current state of ambient air quality in the region.

uMoya-NILU Consulting (Pty) Ltd was appointed to develop the Air Quality Management Plan (AQMP) for the WBPA. The characterisation of the baseline air quality conditions in the WBPA is the initial stage of the development of the AQMP and is documented in uMoya-NILU (2014a). Understanding these potential threats is fundamentally important to successfully implementing the WBPA AQMP.

For the Threat Assessment, feasible development scenarios concerning energy-based projects and mining are developed for the WDM and neighbouring Botswana for 2015, 2020, 2025 and 2030. For these, qualitative future emission inventories are developed and dispersion modelling is used to predict future ambient concentrations of SO_2, NO_2 and PM_{10} resulting from the emissions.

The development scenarios for the Threat Assessment initially considered the energy-based projects listed in the Regional Environmental and Social Assessment (RESA) feasibility study, were further refined to ensure agreement between the future scenarios and those developed for the World Bank-funded RESA study (Mott McDonald, 2014), which used information provided by the Department of Energy (DoE) and the Botswana Department of Energy, Department of Environmental Affairs, Eskom and the Botswana Power Corporation. Important exclusions from the scenario development and hence the Threat Assessment are the potential increase in emissions from the concomitant growth in urban settlements, motor vehicle traffic, the beneficiation industry and related secondary industry. The projects that are included in the 2015, 2020, 2025 and 2030 scenarios are listed in Table E-1.

Table E-1: Energy-based and mining projects for the Threat Assessment scenarios. New project in each scenario are shown in bold

2012 Baseline	2015	2020	2025	2030
Matimba Power Station Grootgeluk Coal Mine Morupule B Power Station Morupule Coal Mine	Matimba Power Station Grootgeluk Coal Mine Morupule B Power Station Morupule Coal Mine	Matimba Power Station Morupule B Power Station (Phase 1)	Matimba Power Station Morupule B Power Station (Phase 1)	Matimba Power Station Morupule B Power Station (Phase 1)
	Medupi Power Station **Grootgeluk Coal Mine expanded** **Morupule A Power Station (recommissioned) Morupule Coal Mine expanded**	Medupi Power Station (no FGD) Grootgeluk Coal Mine expanded Morupule A Power Station (recommissioned) Morupule Coal Mine expanded	Medupi Power Station (no FGD) Grootgeluk Coal Mine expanded Morupule A Power Station (recommissioned) Morupule Coal Mine expanded	Medupi Power Station (no FGD) Grootgeluk Coal Mine expanded Morupule A Power Station (recommissioned) Morupule Coal Mine expanded
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				Coal 3 Power Station **New Pulverised Fuel Power Station** **New CTL** **Mmamantswe Power Station** **Mmamantswe Coal Mine**

The proposed expansion of energy-based projects and mining in the WDM and neighbouring Botswana are recognised as a potential threat to ambient air quality in the region. Hence the declaration of the Waterberg-Bojanala Priority Area in June 2012. The potential increase in annual emissions from the current situation to 2030 for SO_2 of 370%, for NO_2 of 640% and for PM_{10} of 530% justifies the declaration of the priority area (Table E-2).

Table E-2: Cumulative emissions from energy-based sources and mining from the baseline to 2030 in tons per annum

Scenario	SO_2	NO_X	Particulates
Baseline	325 932	77 038	6 501
2015	825 995	172 002	15 508
2020	1 062 126	293 923	18 793
2025	620 620	264 722	18 146
2030	1 204 225	490 254	33 576

The threat to ambient air quality manifests in the associated increase in ambient concentrations of SO_2, NO_2 and PM_{10} and their potential impact on human health and the ecological environment. The increase in emissions from the base year (2012) to 2015 and from 2015 to 2020 results in a general increase in ambient concentrations on a regional scale. The largest increase occurs in the vicinity of the main sources near Lephalale and Palapye. Emissions from elevated power station stacks affect a large area, but dilution is effective and there is general compliance with the NAAQS, except close to the source areas where SO_2 and PM_{10} exceedances are predicted. Emissions from mines result in localised effects where exceedances of the NAAQS for PM_{10} are predicted.

In 2025 marked reductions in SO_2 and NO_2 emissions result when Flue Gas Desulphurisation (FGD) is implemented at Medupi. The resulting reduction in PM_{10} emissions is off-set by an increase in PM_{10} emissions from mining. The emission reductions result in regional decreases in predicted ambient concentrations and general compliance with NAAQS for SO_2 and NO_2. Ambient PM_{10} concentrations increase in 2025, particularly in a band extending westward from Lephalale to the Botswana border with exceedances of the NAAQS.

From the relatively low emissions base established in 2025 with the implementation of FGD, there is a significant increase in emissions to 2030. This results in a regional scale increase in ambient SO_2, NO_2 and PM_{10} concentrations. The largest increase in ambient concentration are in the vicinity of the main sources near Lephalale and extending westward towards Botswana. The elevated emissions from the new power stations and the coal-to-liquid plant affect a large area, but dilution is effective and there is general compliance with the NAAQS, except close to the source areas where SO_2 and PM_{10} exceedances are predicted. Emissions from mines result in localised effects where exceedances of the NAAQS for PM_{10} are predicted.

It should be borne in mind that the Threat Assessment excludes the contribution of emissions from the potential increase in residential fuel burning and motor vehicles. The outputs of the Threat Assessment modelling most likely indicate a best case scenario without these two contributing source types. In other words, the future scenarios are likely to be under-predicted. Emissions from residential fuel burning are released close to ground level and have a relatively localised effect, albeit a potentially significant effect on ambient concentrations. The effect of motor vehicle emissions is also limited and resulting ambient concentrations are generally much lower.

The Threat Assessment has however indicated a number of important points for air quality management in the region. These are:

- Development in the region will increase ambient concentrations of pollutants on a regional scale.
- The areas of greatest concern are where the NAAQS for SO_2 and PM_{10} are predicted to be exceeded, concentrated in the Lephalale area and extending towards Botswana.
- Tall stack emissions affect air quality on a more regional scale, but ground level concentrations are generally low compared to the NAAQS.
- Low level emissions from mining result in local scale effects, and ground level concentrations are relatively high compared to the NAAQS.
- FGD brings about significant reductions in SO_2 and NO_2 emissions and the resultant ambient concentrations when implemented in 2025.
- The magnitude of the predicted threat to ambient air quality can be mitigated through well designed air quality management interventions and the application of appropriate technologies and emission control measures.
- The likelihood of impacts on ambient air quality in the WDM from sources in Botswana is very low. Rather sources in the WDM are likely to affect ambient concentrations in Botswana considering the prevailing easterly wind and proximity of these sources to the Botswana border.

The current resources in all tiers of government responsible for AQM in the WBPA is not adequate to cope effectively with the imminent changes.

GLOSSARY OF TERMS AND DEFINITIONS

Term	Definition
Ambient air	Outdoor air in the troposphere, excluding work places. According to the National Environmental Management Act, (Act no.39 of 2004) **"ambient air"** excludes air regulated by the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993).
Averaging period	A period of time over which an average value is determined.
Compliance date	A date when compliance with the standard is required. This provides a transitional period that allows for activities to be undertaken to ensure a compliance date.
Exposure	An event that occurs when there is contact between a human and a contaminant of a specific concentration in the environment for an interval of time (Ott, 1995).
Frequency of exceedance	A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard.
Limit values	A numerical value associated with a unit of measurement and averaging period that forms the basis of the standard.
Isopleth	Line on a map showing equal concentration.
Respireable particulate matter	Particulate matter that is inhalable and generally less than 10 μm in diameter, i.e. PM_{10} and smaller.
Standard	A standard may have many components that define it as a "standard". These components may include some or all of the following; Limit values, averaging periods, frequency of exceedances, and compliance dates.
Threat Assessment	The threat posed by emissions from future development on ambient air quality.

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LIST OF ACRONYMS

$\mu g/m^3$	micrograms per cubic metre
μm	micrometres
ACGIH	American Conference of Government Industrial Hygienists
AEL	Atmospheric Emission Licence
AGL	Above ground level
AQA	National Environmental Management: Air Quality Act
AQM	Air Quality Management
AQMP	Air Quality Management Plan
AQO	Air Quality Officer
BPC	Botswana Power Corporation
BPDM	Bojanala Platinum District Municipality
DEA	Department of Environmental Affairs
DM	District Municipality
DoH	Department of Health
DoT	Department of Transport
EHP	Environmental Health Practitioner
EIP	Environmental Implementation Plan
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
g/kg	grams per kilogram
IDP	Integrated Development Plan
LED	Local Economic Development
LDEDET	Limpopo Dept. of Economic Development, Environment & Tourism
LM	Local municipality
MEC	Member of Executive Council
MHS	Municipal Health Services
MSRG	Multi-stakeholder Reference Group
MW	MegaWatt
NO	Nitrous oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
PM	Particulate matter
PM_{10}	Particulate matter of aerodynamic diameter less than 10 micrometres
$PM_{2.5}$	Particulate matter of aerodynamic diameter less than 2.5 micrometres
ppb	parts per billion
ppm	parts per million
PSC	Project Steering Committee
SAWS	South African Weather Service
SO_2	Sulphur dioxide
tpa	Tons per annum
TSP	Total suspended particulates
WBPA	Waterberg- Bojanala Priority Area
WDM	Waterberg District Municipality
WHO	World Health Organisation

1. INTRODUCTION

The Minister of Water and Environmental affairs declared the Waterberg–Bojanala Priority Area (WBPA) on 15 June 2012 as the third National Priority Area (DEA, 2012a). The WBPA includes the Waterberg District Municipality (WDM) in the Limpopo Province and parts of the Bojanala Platinum District Municipality (BPDM) in the North West Province, and borders on Botswana (Figure 1-1).

Figure 1-1: The WBPA showing District and Local Municipalities and the proximity to Botswana

The BPDM has abundant mineral reserves, particularly in the south between Rustenburg and Brits, where mining and mineral processing takes place. The WDM has significant coal reserves that are largely unexploited with the Matimba Power Station being currently in operation. The National Development Plan 2030 (National Planning Commission, 2012), which was adopted by Government in 2012, acknowledges that the lack of stable power to meet the energy demands is an impediment to economic growth in the region. Under the NDP-2030, 18 Strategic Infrastructure Projects (SIPs) address social and economic infrastructure imperatives across all nine provinces.

Botswana's energy demand has historically been supplied by energy generated by the Morupule A Power Station, and more recently by the new Morupule B Power Station which is currently at partial capacity. Botswana's electricity needs are augmented by imported energy from South Africa. The Government of Botswana therefore requires that the energy sector be augmented through the development of new coal-fired power plant generation capacity (Mott-MacDonald, 2014). Together with the Botswana Power Corporation (BPC), the Government has requested a World Bank partnership programme for the country's energy sector development, with an International Bank for Reconstruction and Development (IBRD) loan for the Morupule B Project while other energy projects are being considered.

uMoya-NILU Consulting (Pty) Ltd was appointed to develop the Air Quality Management Plan (AQMP) for the WBPA, as required by the National Environmental Management: Air Quality Act (Act No. 39 of 2004). The characterisation of the baseline air quality conditions in the WBPA is the initial stage of the development of the AQMP and is documented in uMoya-NILU (2014a).

The greatest potential threat to ambient air quality exists in the WDM through the planned expansion of energy-based projects and coal mining in the district and in Botswana. The planned development poses a threat to human and environmental health in the region and it poses challenges for air quality management in the region. Understanding these potential impacts is fundamentally important to the success of the AQMP. This is achieved through the *Threat Assessment* for the WDM which is the subject of this report.

The Threat Assessment report is structured in the following manner. A summary of the current state of air quality in the WDM is presented in Chapter 2 as a point of departure for the future cases, and includes discussion on emissions and ambient concentrations of sulphur dioxide (SO_2), oxides of nitrogen (NO_X) and respireable particulate matter (PM_{10}). Chapter 3 provides background information on the Strategic Development Projects. Plausible development scenarios are established and described in Chapter 4, focussing on the energy-based projects and coal mining. Estimated emissions resulting from these scenarios are presented in Chapter 5. The predicted ambient concentrations for each of the development scenarios and results are presented as isopleth maps in Chapter 6 where the predicted concentrations are compared with the National Ambient Air Quality Standards (NAAQS) and the deviation from the base case concentrations is illustrated. The nature of the threat to ambient air quality from future energy-based projects and mining in the region is assessed in Chapter 7. Chapter 8 links to the objectives of the WBPA AQMP (DEA, 2014b) where concluding remarks are made.

2. WDM AIR QUALITY BASELINE CHARACTERISATION

A comprehensive characterisation of the air quality baseline in the WBPA was compiled as the initial phase of the AQMP development (DEA, 2014a). A summary is presented in this chapter for the WDM to provide context to the Threat.

2.1 Emission sources

Total annual emissions of SO_2, NO_2 and PM_{10} from the main source sectors in the WDM are presented in Table 2-1. SO_2 results primarily from the combustion of fossil fuels by industry in the area, with 99.9% of total SO_2 emissions generated by the sector. Minimal SO_2 contributions result from motor vehicles and residential fuel burning. Total SO_2 emissions for the WDM are estimated at 353 750 tons per annum. For NO_X, the industrial contribution to the overall pollutant load is nearly 94%. Total WDM NO_X emissions are estimated at 61 633 tons per annum. For PM_{10}, mining contributes the greatest proportion of emissions, approximately 12 500 tons per annum, with 73% from industry and 22% from mining.

Table 2-1: Total emissions for WDM in tons per annum

	SO_2	NO_x	PM_{10}
Industry	353 638	57 839	9 217
Mining			2 816
Residential	3	15	121
Motor vehicles	109	3,686	150
Biomass		93	276
Total	**353 750**	**61 633**	**12 579**

2.2 Ambient air quality

Available ambient monitoring data at Mokopane, Thabazimbi, Lephalale and Marapong were used to describe the existing state of air quality in the WDM. Annual average SO_2 and NO_2 concentrations are well below the respective limit values of the national Ambient Air Quality Standards (NAAQS) of 50 $\mu g/m^3$ and 40 $\mu g/m^3$ respectively (Table 2-2). The annual average PM_{10} concentration at Marapong and Thabazimbi exceed the limit value of the NAAQS of 50 $\mu g/m^3$.

The following points are relevant for the 24-hour and 1-hour concentrations:

- Ambient SO_2 concentrations are low compared to the NAAQS despite the significant SO_2 emissions.
- The effects of domestic fuel burning on ambient SO_2 concentrations is evident in the monitoring data at Marapong and to some extent in Mokopane.
- Ambient NO_2 concentrations are low relative to the NAAQS.

- Ambient PM_{10} concentrations are relatively low compared to the current limit value of the NAAQS, but the effects of domestic fuel burning on ambient concentrations is evident at Marapong and to some extent in Mokopane.
- Ambient PM_{10} concentrations frequently exceed the 2015 limit value of the NAAQS at Marapong and Mokopane.

Table 2-2: Annual average ambient concentrations at monitoring stations in the WBPA

	Concentration ($\mu g/m^3$)		
Monitoring station	**SO_2**	**NO_2**	**PM_{10}**
Mokopane	0.92	3.69	28.9
Thabazimbi	4.85	5.54	51.0
Marapong	9.8	12.5	88.7
Lephalale	1.0	8.8	25.5

2.3 Capacity assessment

Issues that are identified in the baseline characterisation (DEA, 2014a) regarding air quality management capacity in the WDM are:

- Capacity at Provincial Government and in municipalities is currently not sufficient to carry out all AQM functions.
- Technical and management skills development requires greater focus to bolster AQM activity implementation.
- Co-operative governance through AQM tiers (National, Provincial, Local Government) is currently not optimal.
- The AEL functions are undertaken by the Limpopo Department of Economic Development, Environment & Tourism (LDEDET), rather than the WDM.
- Emission inventories are currently incomplete and the data are unreliable.
- The ambient air quality monitoring network is currently relatively sparse with a number of notable deficiencies.

3. DEVELOPMENT INTENT IN THE WDM

The South African Government had adopted a National Infrastructure Plan that is intended to transform the economic landscape of South Africa, create a significant number of new jobs, strengthen the delivery of basic services to the people of South Africa, and support the integration of African economies. The Presidential Infrastructure Coordination Committee (PICC) was established following the Cabinet Lekgotla in July 2011. The State Owned Enterprise (SOE) Projects were clustered into 18 Strategic Infrastructure Projects (SIPs) covering transportation, telecommunication, energy, health and education and water and sanitation in all nine provinces. Each SIP comprises of a number of specific infrastructure components and programmes. Four SIPs are relevant to the WDM and these, with the proposed development in eastern Botswana, pose a threat to ambient air quality on a regional scale with negative implications for human health and the environment. An overview of the SIPs and the proposed development in Botswana is included in the following sections.

3.1 SIP 1: Unlocking the Northern Mineral Belt with Waterberg as the Catalyst

The PICC (2012) summarises SIP 1 as an investment in rail, water pipelines, energy generation and transmission infrastructure that will catalyse the unlocking of rich mineral resources in Limpopo resulting in thousands of direct jobs. Urban development in the Waterberg will be the first major post-apartheid new urban centre and will be a "green" development project. Mining includes coal, platinum and other minerals for local use and export, hence the rail capacity is being extended to Mpumalanga power stations and for export principally via Richards Bay and in future Maputo. The additional rail capacity will shift coal from road to rail in Mpumalanga with positive environmental and social benefits. Supportive logistics corridors will help to strengthen Mpumalanga's economic development.

The implications of SIP 1 for air quality lies in the potential increase in emissions associated with new power generation by coal-fired power stations, new coal mines and their associated emissions, and an increase in emissions associated with development and urbanisation, i.e. motor vehicles, domestic fuel burning, etc. With an increase in emissions there is the potential for baseline ambient concentrations to increase with an increase on a regional scale in the WDM with an increase in exposure and risk to human and environmental health.

3.2 SIP 8: Green energy in support of the South African economy

The PICC (2012) summarises SIP8 as sustainable green energy initiatives on a national scale through a diverse range of clean energy options as envisaged in the Integrated Resource Plan (IRP2010) and to support bio-fuel production facilities. The implications of SIP 8 for air quality lies in the potential increase in emissions on a local scale associated with the development and resulting urbanisation, i.e. motor vehicles, domestic fuel burning, etc. With an increase in emissions there is the potential for baseline ambient concentrations in parts of the WDM to increase with an increase in exposure and risk to human and environmental health.

3.3 SIP 9: Electricity generation to support socio-economic development

The PICC (2012) summarises SIP 9 as accelerating the construction of new electricity generation capacity in accordance with the Integrated Resource Plan for Electricity (DoE, 2011) to meet the needs of the economy and address historical imbalances. Further, the SIP intends to monitor the implementation of major projects such as new power stations, including Medupi, Kusile and Ingula.

Relevant to the WDM is the operation of the existing Matimba Power Station, and the construction and operation of the Medupi Power Station near Lephalale. Emissions of SO_2, NO_X and particulate matter from Medupi will add to the current baseline concentrations on a regional scale. In addition, with an increase in emissions associated with the development and the inevitable urbanisation, i.e. motor vehicles and domestic fuel burning, there is a potential for exceedances of health-based ambient air quality standards to occur and a risk to human and environmental health.

3.4 SIP 10: Electricity transmission and distribution for all

The PICC (2012) summarises SIP 10 as expanding the transmission and distribution network to address historical imbalances, provide access to electricity for all and support economic development. It aligns the 10-year transmission plan, the services backlog, the national broadband roll-out and the freight rail line development to leverage off regulatory approvals, supply chain and project development capacity.

SIP 10 relates to SIP 9 as the supporting transmission and distribution capacity for growing the generation capacity in the region. The implications of SIP 10 for air quality in the WDM lies in the potential increase in emissions on a local scale associated with development and resulting urbanisation, i.e. motor vehicles, domestic fuel burning, etc. With an increase in emissions there is the potential for baseline ambient concentrations in parts of the WDM to increase with an increase in exposure and risk to human and environmental health.

3.5 Regional energy development

Nine coal-based energy projects along the Botswana-South Africa border are the focus of a Regional Environmental and Social Assessment (RESA) commissioned by the World Bank, in conjunction with the Governments of South Africa and Botswana, to inform policy decisions required to meet rising electricity demand. The objectives of the RESA are described in the inception report (Mott MacDonald, 2014) which expands on the preliminary assessment (DEA, 2012b).

Coal-based energy projects are associated with emissions of SO_2, NO_X and particulate matter, amongst other pollutants. Individually, such projects may result in exceedances of health-based ambient air quality standards. The concentration of such projects regionally will result in a cumulative effect and an increase in ambient concentrations of pollutants. A preliminary analysis of the cumulative impacts associated with new coal-fired power plants is provided in the RESA, identifying potential air quality hot spots in Botswana and South Africa, cumulative impacts, and the potential for cross border exchange of air pollutants (DEA, 2012b).

4. DEVELOPMENT SCENARIOS

For the Threat Assessment, feasible development scenarios concerning energy-based projects and mining are developed for the WDM and neighbouring Botswana for 2015, 2020, 2025 and 2030. The objective is then to develop qualitative future emission inventories for each scenario to facilitate the prediction of future ambient concentrations of SO_2, NO_2 and PM_{10} resulting from these emissions.

The development scenarios for the Threat Assessment initially considered the energy-based projects listed in the RESA feasibility study (DEA, 2012b). They were updated in recognition of the revised coal investment plans for South Africa and Botswana. They were further refined to ensure agreement between the Threat Assessment scenarios and those developed for the World Bank-funded RESA study (Mott McDonald, 2014) which used information provided by the Department of Energy (DoE) and the Botswana Department of Energy. Mott McDonald (2014) also used information from the DEA, Eskom and the BPC to describe five future scenarios for the energy projects. Building on this information, development scenarios for 2015, 2020, 2025 and 2030 have been developed for the Threat Assessment.

Important exclusions from the scenario development and hence the Threat Assessment are the potential increase in emissions from the concomitant growth in urban settlements, motor vehicle traffic, the beneficiation industry and related secondary industry.

The projects that are included in the 2015, 2020, 2025 and 2030 scenarios are listed in Table 4-1 and their relative locations in the WDM and Botswana are illustrated in Figure 4-1.

Table 4-1: Energy-based and mining projects for the Threat Assessment scenarios

2012 Baseline	2015	2020	2025	2030
Matimba Power Station Grootgeluk Coal Mine Morupule B Power Station Morupule Coal Mine	Matimba Power Station Grootgeluk Coal Mine Morupule B Power Station Morupule Coal Mine	Matimba Power Station Morupule B Power Station (Phase 1)	Matimba Power Station Morupule B Power Station (Phase 1)	Matimba Power Station Morupule B Power Station (Phase 1)
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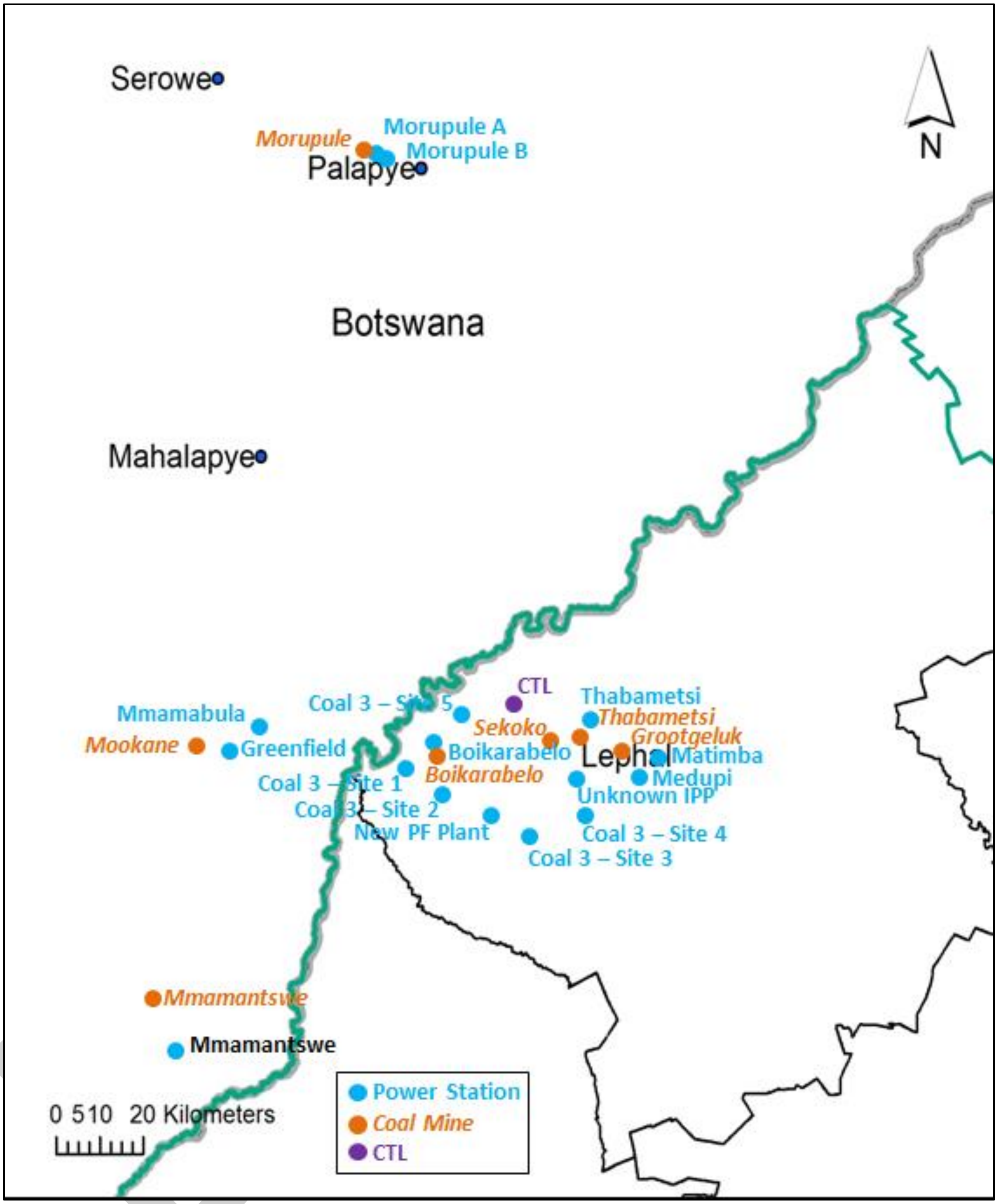

Figure 4-1: Relative locations of the proposed energy-based, mining and other projects in the WDM and Botswana, shown in blue, brown and purple, respectively

5. FUTURE EMISSIONS

Emissions data for the facilities in the 2012 baseline case have been adopted from the baseline characterisation of the WBPA (DEA, 2014a). For the future scenarios the following general rules have been applied:

i. For some proposed energy-based projects, emission information is available from air quality specialist reports for EIAs or from AIRs. In these cases the available data is used.
ii. For South African energy-based projects it is assumed that 2020 Minimum Emission Standards (DEA, 2013) are met, and these are applied to meet the worst case philosophy.
iii. For projects in Botswana it is assumed that power plants comply with the relevant International Finance Corporation emission standards (IFC, 1998).
iv. For mines, the SAMINDABA definitions of Size Class apply and the estimated emission rates determined in the WBPA baseline characterisation (DEA, 2014a) are used.

In developing the emissions for future scenarios it is necessary to make assumptions as primary data does not exist. The assumptions that are made for the South African energy-based project projects are:

- Matimba Power Station: It is assumed that Matimba will continue to be operational as currently for the entire Threat Assessment period, i.e. to 2030.
- Medupi Power Station: It is assumed that Medupi will be fully operational in 2015 (six units) without FGD in accordance with the 'worst case' philosophy. It is assumed FGD is installed by 2025.
- Small scale fluidised bed combustion (FBC) development (IPPs): The 2012 Ministerial Determinations for new coal generation indicates that by 2020, the DoE would seek to procure 1500 MW of base-load coal generation, increasing to 2500 MW of new coal generation by 2024. For the purposes of the RESA and the Threat Assessment, which both aim to assess a realistic but 'worst case' future in terms of coal-based energy development, the installed capacity of IPPs is assumed to be 2360 MW IPP, attributed to the following IPPs:
    - Boikarabelo power station (total 260 MW)
    - Thabametsi power station (total 1200 MW)
    - IPP 1 (total 300MW)
    - IPP 2 (total 600MW)
- Small scale fluidised bed combustion (FBC) development (Coal 3): The 2013 IRP update describes the Coal 3 project as a new set of fluidised bed combustion coal generation power plants with a total of capacity of 1000 to 1500 MW, based on discard coal. For purposes of the realistic but worst case future required in the RESA and the Threat Assessment, it is assumed that Coal 3 has the full capacity of 1500 MW and comes online between 2024 and 2034. Five sites have been selected in proximity to other emission sources to provide a worst case. Each site is assumed to have two circulating fluidised bed combustion (*CFBC*) units of 150 MW with a total of 300MW per site.

- New large-scale pulverised fuel (PF) station: The South African Coal Roadmap indicates that at least one new large-scale pulverised fuel power station will be required with the assumed commissioning date of 2027. The Coal Roadmap table indicates that future PF plants would have a generation capacity of approximately 4500 MW. The new PF plant is therefore assumed to have the same configuration as the Medupi Power Station, comprising 6 x 800MW units and the Medupi total installed generation capacity of 4800MW. The location of the new PF plant is assumed to be within the area considered for the original Coal 3 and Coal 4 projects.
- CTL Plant: Sasol's Mafutha project in the Waterberg was suspended in 2010. However, an 80 000 BPD coal-to-liquid plant in the Waterberg is consistent with the worst case assessment philosophy of the Threat Assessment. A hypothetical CTL plant is located at the proposed Mafutha site. It is assumed to be operational in the 2030 scenario.
- Coal mining: An increase in coal mining is necessary to support the energy-based projects in the region. A systematic increase in coal mining activity is therefore introduced by initially expanding existing collieries such as Grootgeluk and Morupule, then introducing known proposed collieries like Sekoko and Thabametsi in later scenarios, and finally adding collieries at the new power stations.

For the Botswana energy-based projects, the assumptions made by Mott MacDonald (2014) are carried into the Threat Assessment. These are paraphrased here:

- Morupule A: After being re-commissioned and returning to operation in 2016, available information indicates that this plant will continue to be operational up to 2025. With no information on decommissioning, the realistic worst case scenario of the RESA and the Threat Assessment assumes the plant continues to operate for the full period of the assessment. The plant's generating capacity will be restored to the design level of 116 MW.
- Mmamabula: Development of this plant is currently on hold but it is considered likely that this power station will be developed. The Mmamabula Energy Project EIA states that Phase 1 will comprise 4 x 150 MW units and Phase 2 will comprise 2 x 300 MW units. The RESA and Threat Assessment assume that Phase 1 and Phase 2 are fully operational by 2024.
- Mmamantswe: This plant is included in the final scenario of the RESA and the 2030 scenario of the Threat Assessment. The most likely configuration is for 3 x 350MW units and a total generation capacity of 1050 MW.
- Location of Greenfields IPP: Expressions of Interest have been submitted for the Greenfield development, but decisions have not been made or information released. For consistency with the RESA and with the focus on the worst case for the WBPA, these plants are included in the Threat Assessment. The locations are unknown, but to be consistent with the worst case approach of the RESA and the Threat Assessment they are assumed to be within the border region between the proposed Mmamabula plant and the village of Mookane.

Specific assumptions are made at a project level with respect to emission estimations, these are listed in Table 5-1.

Table 5-1: Project specific assumptions with respect to emissions

Plant / Mine	Emission assumption
Matimba	Current stack and emissions data from the AIR for Eskom's postponement applications for Matimba Power Station (uMoya-NILU, 2013a)
Medupi	Stack and emission data from the AIR for Eskom's postponement applications for Medupi Power Station cumulative assessment (uMoya-NILU, 2013b)
Grootgeluk Colliery	The mine expands from a Size Class 4 to a Size Class 5 according to the SAMINDABA definitions
Morupule A	Current stack and emissions data from the air quality specialist study for the EIA for Morupule A Power Station (BPC, 2012).
Morupule Coal Mine	Morupule Coal Mine is a Size Class 2 mine
IPP: Thabametsi	Stack and emission data from the air quality specialist study for the EIA for Thabametsi Power Station (uMoya-NILU, 2013c)
Thabametsi Coal Mine	Thabametsi Coal Mine is a Size Class 2 Mine
Sekoko Coal Mine	Emission data from the air quality specialist study for the EIA for Sekoko Coal Mine are used (uMoya-NILU, 2013d)
IPP: Boikarabelo Phase 1	Minimum Emission apply
Boikarabelo Coal Mine	Boikarabelo Coal Mine is a size Class 2
IPP: Unknown IPP Phase 1	Minimum Emission apply
Morupule B (Phase 1)	IFC emission standards for new thermal power plants
Greenfields IPP	IFC emission standards for new thermal power plants
Mookane Coal Mine	Mookane Coal Mine is a size Class 2
Thabametsi Coal Mine expanded	Thabametsi Coal Mine expands to a Class 3 Mine
IPP: Boikarabelo Phase 2	Minimum Emission Standards apply
Boikarabelo Coal Mine expanded	Boikarabelo Coal Mine expands to a Size Class 3 Mine
IPP: Unknown IPP Phase 2	Minimum Emission Standards apply
Mmamabula (Phase 1)	IFC emission standards for new thermal power plants
Mmamabula (Phase 2)	IFC emission standards for new thermal power plants
Mookane Coal Mine expanded	Boikarabelo Coal Mine expands to a Class 3 Mine
Coal 3	Minimum Emission Standards apply
New Pulverised Fuel (PF) power station	Minimum Emission Standards apply
New CTL Plant	Minimum Emission Standards apply
Mmamantswe Power Station	IFC emission standards for new thermal power plants
Mmamantswe Coal Mine	Mmamantswe Coal Mine is a size Class 2

The details regarding source parameterisation and emission information that are used in the dispersion modelling are presented in Appendix 1. A summary of emissions for 2015, 2020, 2025 and 2030 are presented for comparison with the baseline in Table 5-2.

Table 5-2: Baseline and projected emissions rates in tons per annum for the respective energy-based and mining projects

Scenario	Facility	Emission Rate (tons per annum)		
		SO_2	NO_X	Particulates
Baseline	Matimba (6 units: 3990 MW)	309 262	67 592	4 904
	Morupule B (Phase 1) 4 units: 600 MW)	16 670	9 446	926
	Grootgeluk Coal Mine			537
	Morupule Coal Mine			134
	TOTAL	**325 932**	**77 038**	**6 501**
2015	Medupi (6 units: 4800 MW no FGD)	490 872	92 038	6 136
	Morupule A (4 units: 132 MW)	9 191	2 925	187
	Grootgeluk Coal Mine expanded			1 074
	Morupule Coal Mine expanded			268
	TOTAL	**500 063**	**94 964**	**7 665**
2020	IPP: Thabametsi (4 units: 1200 MW)	215 116	103 784	649
	IPP: Boikarabelo Phase 1 (3 units: 45 MW)	3 337	5 005	334
	IPP: Unknown IPP Phase 1 (2 units: 300 MW)	3 337	5 005	334
	Morupule B (Phase 2) (2 units: 300 MW)	8 335	4 723	463
	Greenfields IPP (2 units: 300 MW)	6 006	3 404	334
	Boikarabelo Coal Mine			134
	Thabametsi Coal Mine			134
	Sekoko Coal Mine			134
	Mookane Coal Mine			134
	TOTAL	**236 131**	**121 921**	**2 649**
2025	Medupi (6 units: total 4800 MW, now with FGD)	30 679	46 019	3 068
	IPP: Boikarabelo Phase 2 (1 unit: 215 MW)	6 674	10 011	667
	Mmamabula (Phase 1) (4 units: 600 MW)	12 013	6 807	667
	Boikarabelo Coal Mine expanded			268
	Thabametsi coal Mine expanded			268
	Mookane Coal Mine expanded			268
	TOTAL	**49 366**	**62 837**	**5 207**
2030	Coal 3 (10 units: 1500MW)	16 684	25 026	1 668
	New Pulverised Fuel (PF) power station (6 units: 4500 MW)	490 872	92 038	6 136
	Mmamantswe (3 units: 1050MW)	6 006	3 404	334
	New CTL (80000 bpd)	70 042	105 064	7 004
	Mmamantswe Coal Mine			134
	TOTAL	**583 605**	**225 532**	**15 276**

In Table 5-3 the cumulative emissions resulting from industry and mining are shown, i.e. 2015 = baseline + 2015, 2020 = baseline + 2015 + 2020, and so on. The decrease in emissions from 2020 to 2025 is a result of FGD implemented at Medupi. The cumulative emissions are depicted graphically in Figure 5-1 as a percentage of the baseline emission.

Table 5-3: Cumulative emission from energy-based sources and mining from the baseline to 2030 in tons per annum

Scenario	Energy-based projects			Mining
	SO_2	NO_X	Particulate	Particulate
Baseline	325 932	77 038	5 830	671
2015	825 995	172 002	14 166	1 342
2020	1 062 126	293 923	16 815	1 878
2025	620 620	264 722	15 886	2 280
2030	1 204 225	490 254	31 162	2 414

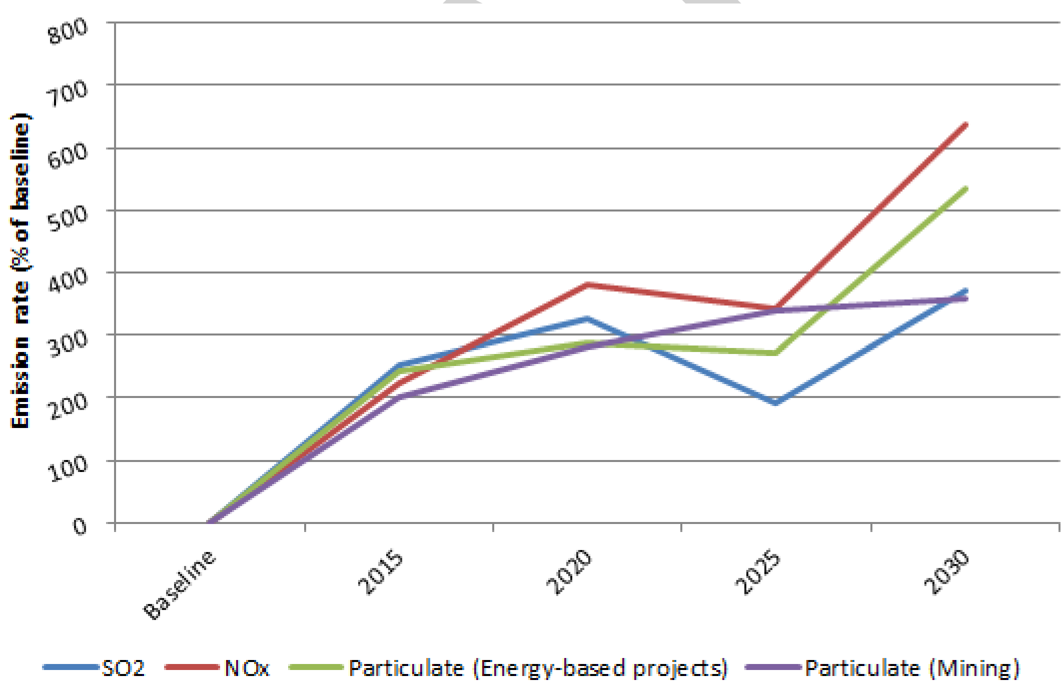

Figure 5-1: Change in emissions from 2015 to 2030 as a percentage of the baseline emission

6. PREDICTED AMBIENT AIR QUALITY

6.1 Methodology

The US-EPA-approved and DEA-recommended CALPUFF dispersion model was used to estimate ambient concentrations of SO_2, NO_2 and PM_{10} resulting from future energy-based projects and mining in the WDM and Botswana.

Modelling is done for a large domain covering the WDM and eastern parts of Botswana at a resolution of 3 km. Hourly meteorological data from SAWS monitoring stations were used with the diagnostic meteorological model TAPM to create hourly meteorological input files for 2010-2012. Emissions from energy-based projects were modelled as point sources and mines were modelled as area sources. A detailed description of the modelling approach is documented in the modelling plan of study (DEA, 2014).

The locations of energy-based projects and mines in the Threat Assessment uses good judgement and the best available information, including information contained in EIA documents, Atmospheric Impact Reports (AIR), the initial RESA (DEA, 2012b) and information in technical notes produced by Mott MacDonald. The relative siting of the energy-based plants and mines from the base year through to 2030 is shown in Figure 4-1.

In the section that follows, the dispersion model results are presented on maps of the region. Presented are the predicted annual average concentrations of SO_2, NO_2 and PM_{10} and the 99th percentile of the predicted 24-hour and 1-hour concentrations. These are compared with the limit value of the respective National Ambient Air Quality Standards (NAAQS) (Table 6-1). The frequency of exceedance of the limit value of the NAAQS is compared with the permitted tolerance values, i.e. 12 for three years of 24-hour concentrations and 264 for 3 years of hourly concentrations. The change in ambient concentrations from the base year (2012) to 2015, 2020, 2025 and 2030 respectively, are also mapped.

Table 6-1: National Ambient Air Quality Standards for SO_2, NO_2 and PM_{10} (DEA, 2009)

Pollutants	Averaging period	Limit value (µg/m^3)	Number of permissible exceedances per annum
SO_2	1-hour	350	88
	24-hour	125	4
	Calendar Year	50	0
NO_2	1-hour	200	88
	Calendar Year	40	0
PM_{10}	24-hour	75	4
	Calendar year	40	0

6.2 Baseline case

The baseline case predicts ambient SO_2, NO_2 and PM_{10} concentrations resulting from emissions from Matimba Power Station in the WDM and Morupule B Power Station in Botswana, as well as PM_{10} emissions from Grootgeluk and Morupule Coal Mines (Table 5-2).

6.3.1 Sulphur dioxide (SO_2)

The predicted ambient SO_2 concentrations for the baseline emissions are relatively low (Figure 6-1), with no predicted exceedance of the limit values of the NAAQS (Table 6-1). As may be expected, the highest predicted concentrations occur in the vicinity of the Matimba and Morupule power stations being the only sources of SO_2 in the modelling domain.

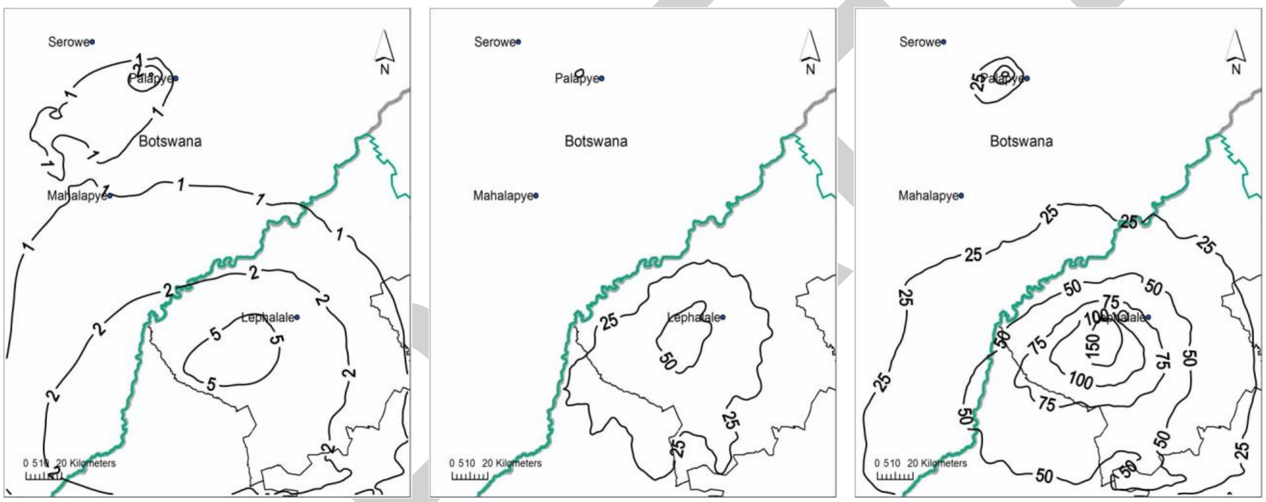

Figure 6-1: Predicted annual average SO_2 concentrations for the base case (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3

6.2.2 Nitrogen dioxide (NO_2)

The predicted ambient NO_2 concentrations for the baseline emissions are relatively low (Figure 6-2), with no predicted exceedance of the limit values of the NAAQS (Table 6-1). As may be expected, the highest predicted concentrations occur in the vicinity of the Matimba and Morupule power stations, the only sources of NO_2 in the modelling domain.

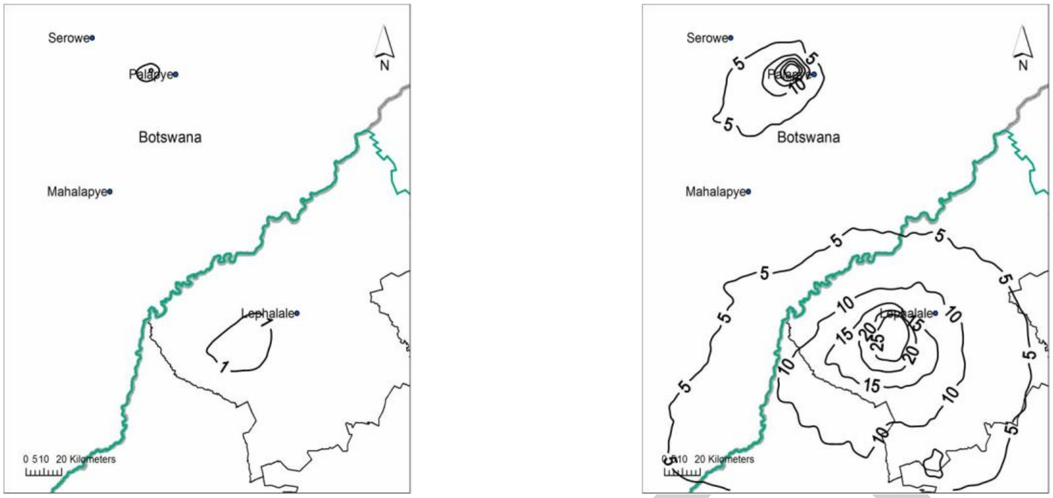

Figure 6-2: Predicted annual average NO_2 concentrations for the base case (left), and the 99th percentile of the predicted 1-hour concentration (right) in μg/m^3

6.2.3 Respireable particulate matter (PM_{10})

The predicted ambient PM_{10} concentrations for the baseline emissions are relatively low (Figure 6-3), except in the immediate vicinity of the two power stations and the coal mines where there are predicted exceedance of the limit values of the NAAQS (Table 6-1). Four exceedances of the 24-hour limit value are permitted annually. More than 12 exceedances are predicted in the 3-year modelling period in a small area west of Lephalale and west of Palapye.

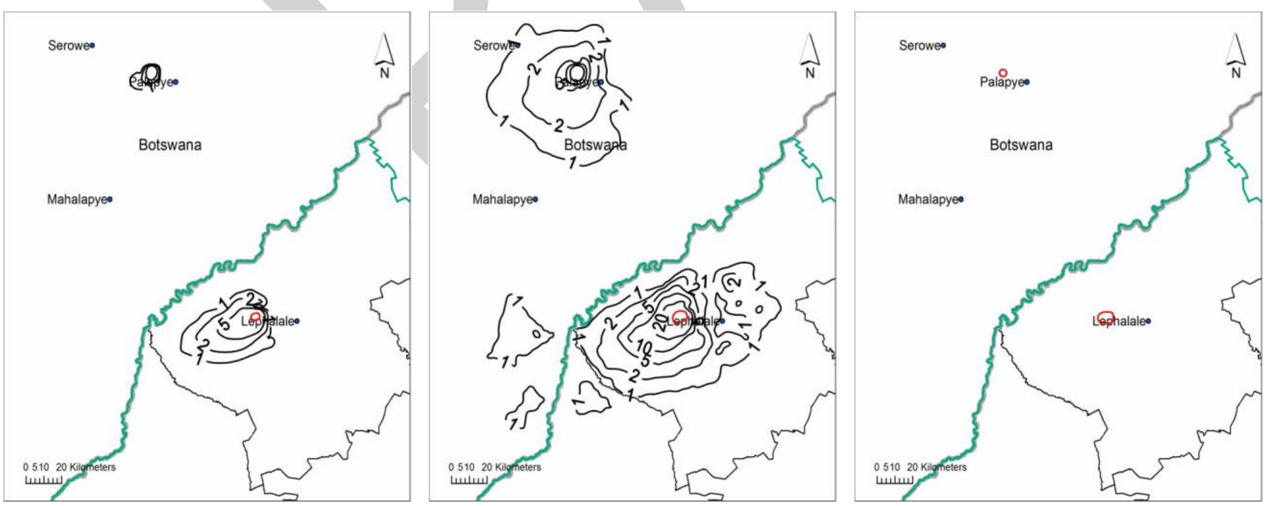

Figure 6-3: Predicted annual average PM_{10} concentrations for the base case (left), the 99th percentile of the predicted 24-hour concentration (middle) in μg/m^3 and the predicted frequency of exceedance of the 24-hour limit value (right)

6.3 Predicted ambient concentrations for 2015

In 2015 the Medupi Power Station and Morupule A Power Station add to the emission loading of the area. The Grootgeluk and Morupule Coal Mines expand in size, which result in an increase in emissions from the mining sector. The total SO_2 emission increases by 500 063 t/a, while the NO_X emission increases by almost 95 000 t/a and PM_{10} by more than 7 600 t/a.

6.3.1 Sulphur dioxide (SO_2)

The predicted ambient SO_2 concentrations in 2015 increase dramatically with the addition of emissions from the new sources, particularly near Lephalale as a result of Medupi Power Station without FGD and near Palapye as a result of Morupule A Power Station (Figure 6-4). While the predicted annual concentrations are well below the NAAQS, the limit value of the 24-hour and 1-hour NAAQS (Table 6-1) are exceeded over a relatively large area southwest of Lephalale.

The frequency of exceedance of the 24-hour and 1-hour limit values is shown on Figure 6-5 for the 3-year modelling period. More than 12 exceedances of the 24-hour limit value occur over a relatively limited area southwest of Lephalale. More than 264 exceedances of the 1-hour limit value in the same area, albeit a somewhat smaller area.

The relative increase in predicted ambient SO_2 concentrations from the baseline case is shown in Figure 6-6. The predicted annual concentrations increase by 10% in the area of maximum predicted concentrations. The increase is more dramatic for the 24-hour and 1-hour concentrations. The predicted 24-hour concentrations increase by 80% in the area of maximum concentration southwest of Lephalale, with increase of 20% and more up to 100 km from the main source area. The predicted 1-hour concentrations increase by more than 200% to the southwest of Lephalale, and by more than 50% up to 100 km from the main source area.

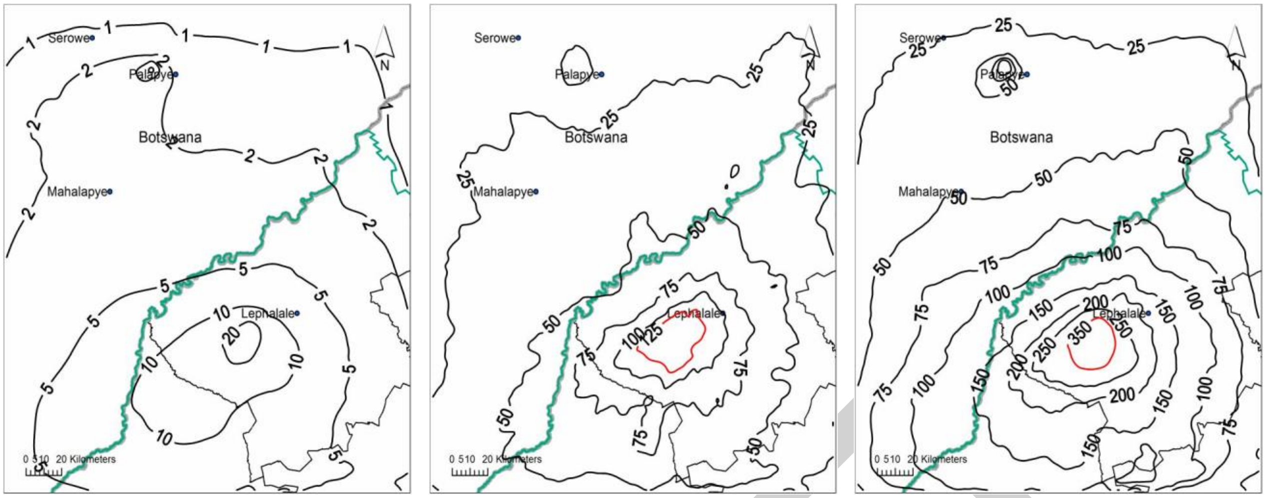

Figure 6-4: Predicted annual average SO_2 concentrations for 2015 (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3. The limit values of the NAAQS are shown by the red isopleths

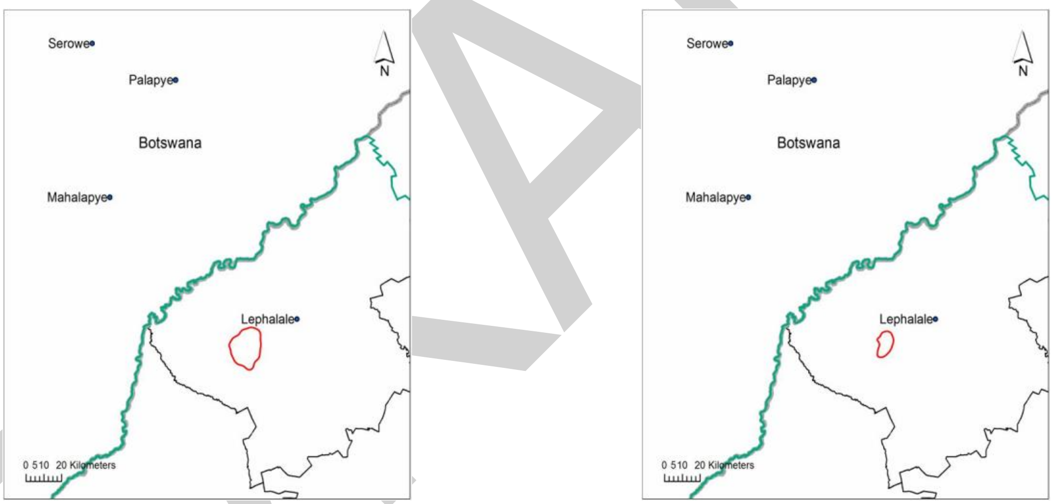

Figure 6-5: Predicted frequency of exceedance of the NAAQS limit value in 2015 for SO_2 for 24-hour (top) and 1-hour (bottom)

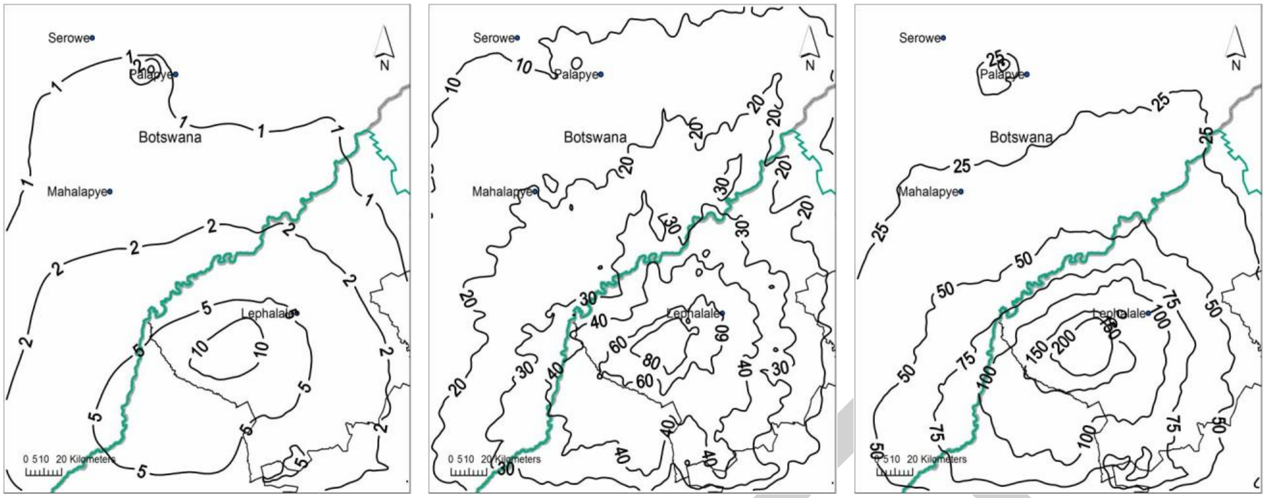

Figure 6-6: Difference in the predicted SO_2 concentrations in μg/m^3 in 2015 from the base case for annual concentrations (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right)

6.3.2 Nitrogen dioxide (NO_2)

The predicted ambient NO_2 concentrations in 2015 increase with the increase in emissions (Figure 6-7). The maximum concentrations are predicted to occur to the southwest of Lephalale and west of Palapye. The predicted annual concentrations are well below the NAAQS. Similarly the 99th percentile of the predicted 1-hour concentrations are below the limit value of the 1-hour NAAQS (Table 6-1).

The relative increase in predicted ambient NO_2 concentrations from the baseline case is shown in Figure 6-8. The predicted annual concentrations increase by just 2% in the area of maximum predicted concentrations. The predicted 1-hour concentrations increase by up to 30% in the area of maximum predicted concentrations to the southwest of Lephalale.

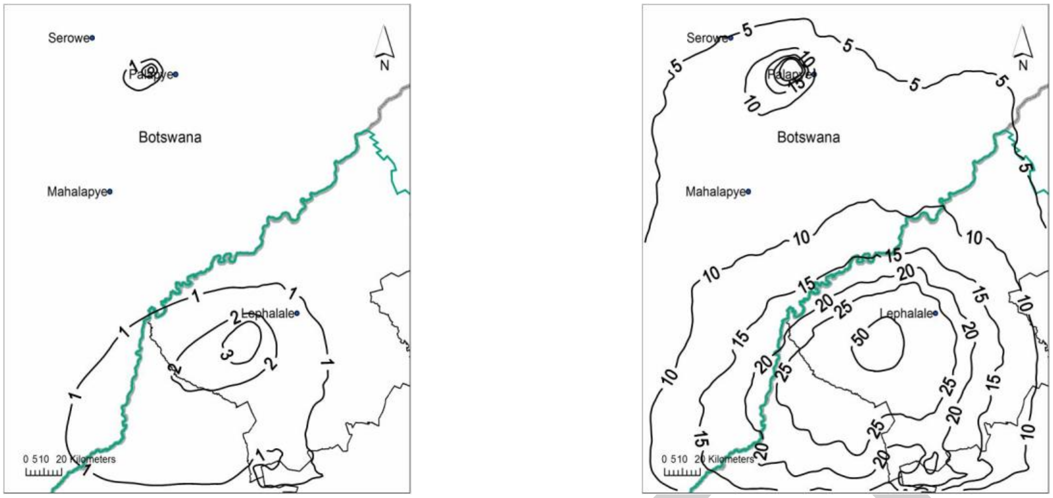

Figure 6-7: Predicted annual average NO_2 concentrations for 2015 (left) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m³

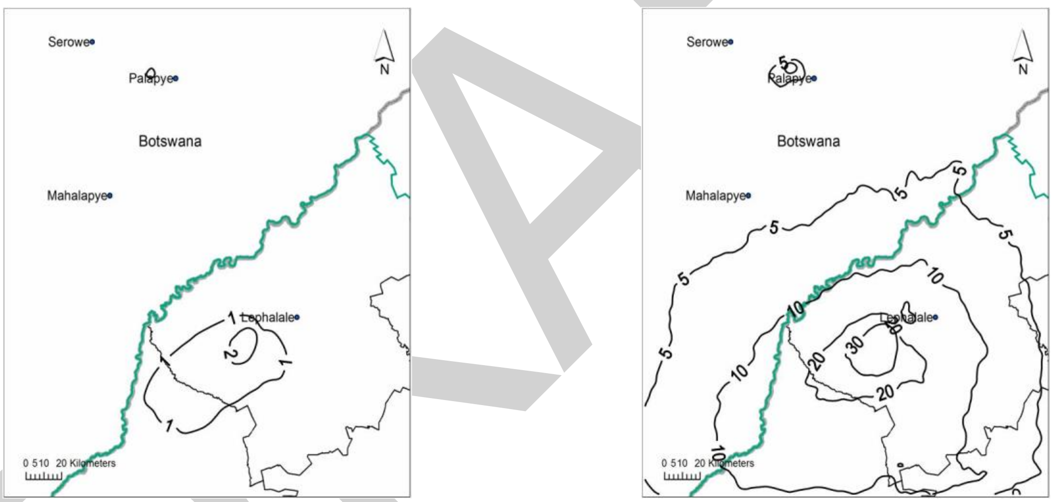

Figure 6-8: Percentage difference in the predicted NO_2 concentrations in 2015 from the base case for annual concentrations (top) and the 99th percentile of the predicted 1-hour concentration (bottom).

6.3.3 Respireable particulate matter (PM_{10})

The predicted ambient PM_{10} concentrations in 2015 increase with the addition of the power station emissions and as a result of expansion of the Grootgeluk and Morupule coal mines (Figure 6-9). The maximum concentrations are predicted to occur to the southwest of Lephalale and west of Palapye. The predicted annual concentration are generally below the limit value of the NAAQS except in a small area west of Lephalale, coinciding with the Grootgeluk Colliery. Similarly the 99th percentile of the predicted 24-hour concentrations are below the limit value of the NAAQS other than the small area west of Lephalale.

The relative increase in predicted ambient PM_{10} concentrations from the baseline case is shown in Figure 6-10. The predicted annual concentrations increase by just 5% in the area of predicted maximum concentrations near Grootegeluk Colliery. The predicted 24-hour concentrations increase by up to 20% in the same area and by 10% west of Palapye.

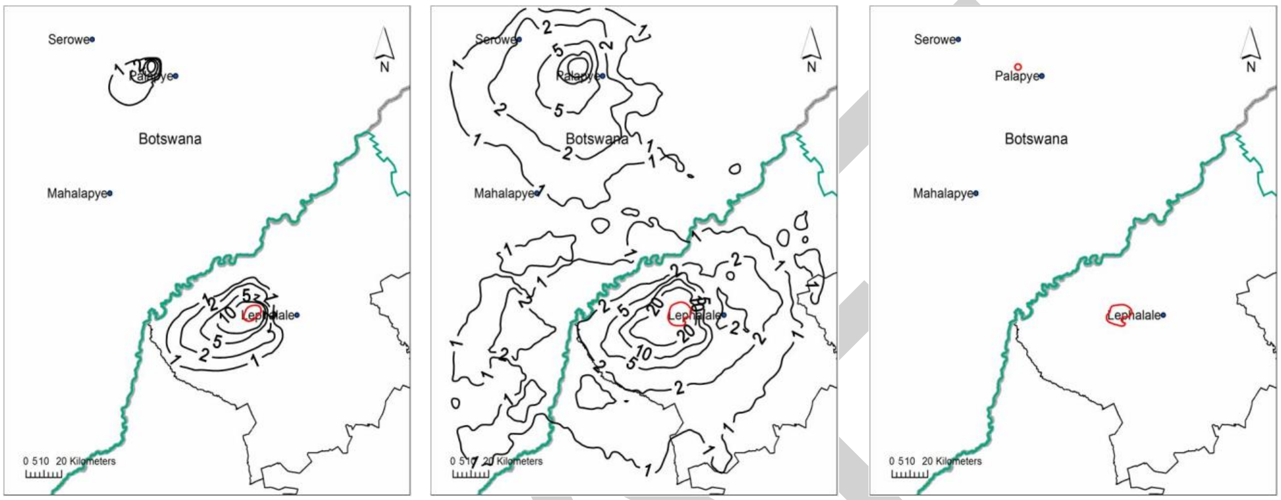

Figure 6-9: Predicted annual average PM_{10} concentrations for 2015 (left) and the 99th percentile of the predicted 24-hour concentration (middle) in µg/m^3 showing the limit values of the NAAQS, and the predicted frequency of exceedance of the 24-hour limit value of the NAAQS (right)

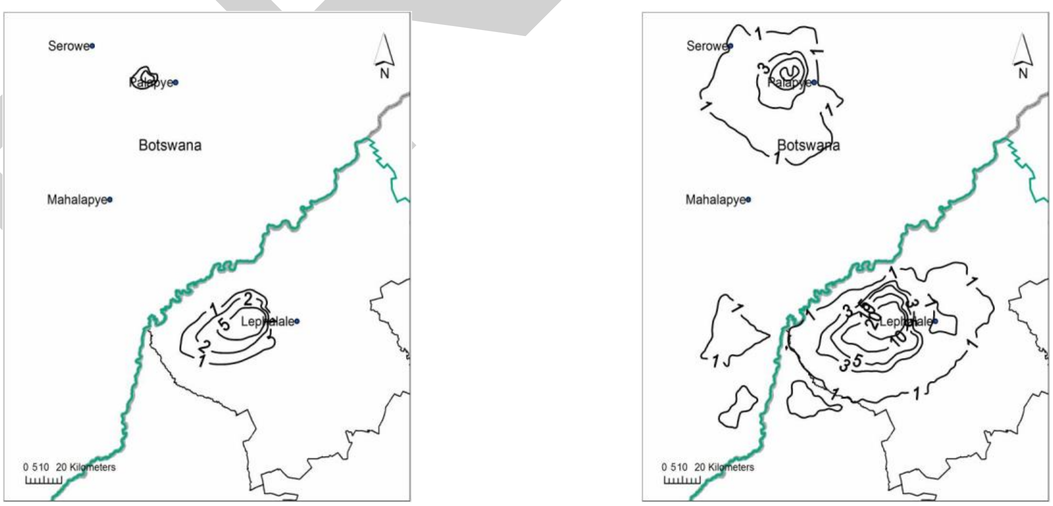

Figure 6-10: Difference in the predicted PM_{10} concentrations in 2015 from the base case for annual concentrations (left) and the 99th percentile of the predicted 24-hour concentration (right)

6.4 Predicted ambient concentrations for 2020

In 2020 the Thabametsi Power Station becomes operational with three new IPP power stations (Boikarabelo, Unknown IPP and Greenfields), supported by four new coal mines. Total SO_2 emissions increase from 2015 by 236 131 t/a, NO_X by nearly 122 000 t/a and PM_{10} by 2 649 t/a.

6.4.1 Sulphur dioxide (SO_2)

The predicted ambient SO_2 concentrations in 2020 increase somewhat from 2015 with the expansion and addition of the smaller IPP power plants, with a notable increase in the area of maximum predicted concentration in the vicinity of Lephalale and near Papapye (Figure 6-11). The predicted annual concentrations remain well below the NAAQS. However, the limit value of the 24-hour and 1-hour NAAQS (Table 6-1) are exceeded over a relatively large area west of Lephalale.

The frequency of exceedance on the 24-hour and 1-hour limit values is shown on Figure 6-12 for the 3-year modelling period. More than 12 exceedances of the 24-hour limit value occur over a relatively large area west and southwest of Lephalale. More than 264 exceedances of the 1-hour limit value in the same area, albeit somewhat smaller.

The relative increase in predicted ambient SO_2 concentrations in 2020 from the baseline case is shown in Figure 6-13. The predicted annual concentrations increase by 20% in the area of maximum predicted concentrations. The increase is more dramatic for the 24-hour and 1-hour concentrations. The predicted 24-hour concentrations increase by more than 80% in the area of maximum concentration west and southwest of Lephalale, with an increase of 40% and more up to 100 km from the main source area. The predicted 1-hour concentrations increase by more than 200% to the west and southwest of Lephalale, and by more than 75% up to 100 km from the main source area.

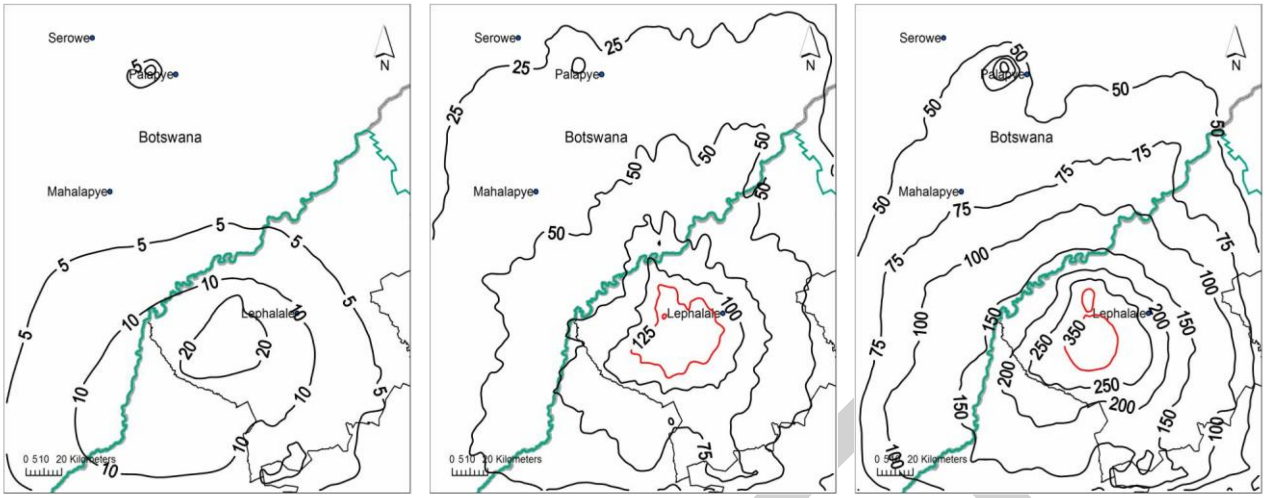

Figure 6-11: Predicted annual average SO_2 concentrations for 2020 (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3. The limit values of the NAAQS are shown by the red isopleths

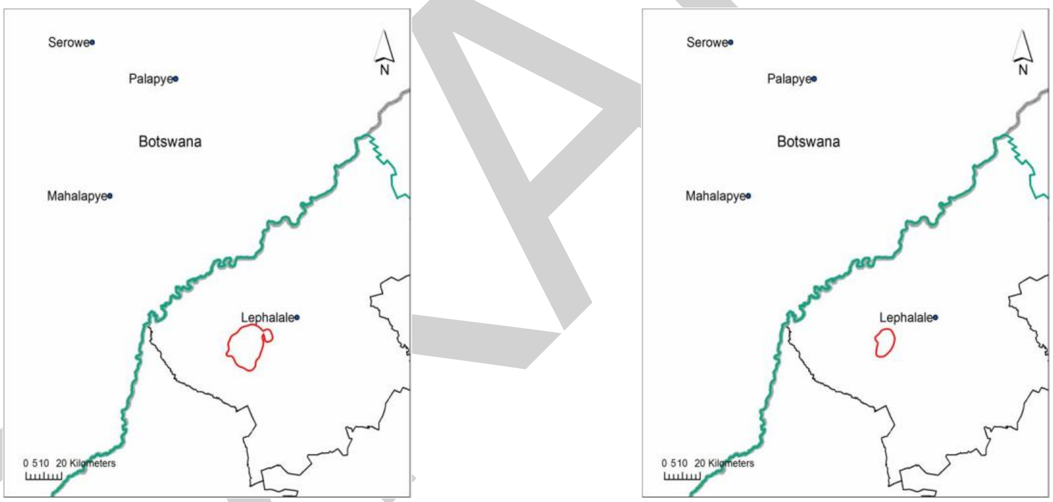

Figure 6-12: Predicted frequency of exceedance of the NAAQS limit value in 2020 for SO_2 for 24-hour (left) and 1-hour (right)

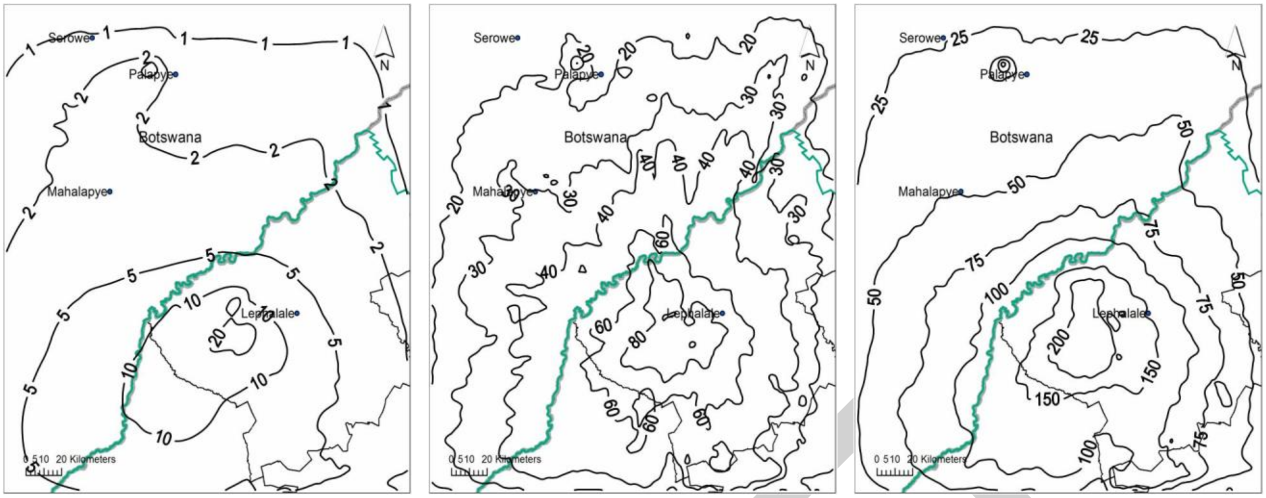

Figure 6-13: Difference in the predicted SO_2 concentrations in 2020 from the base case for annual concentrations (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right)

6.4.2 Nitrogen dioxide (NO_2)

The predicted ambient NO_2 concentrations in 2020 increase with the addition power generation capacity (Figure 6-14). The maximum concentrations are predicted to occur to the southwest of Lephalale and west of Palapye. The predicted annual concentrations remain well below the NAAQS (Table 6-1). Similarly the 99th percentile of the predicted 1-hour concentrations remains below the limit value of the 1-hour NAAQS (Table 6-1).

The relative increase in predicted ambient NO_2 concentrations in 2020 from the baseline case is shown in Figure 6-15. The predicted annual concentrations increase by just 5% in the area of maximum predicted concentrations. The predicted 1-hour concentrations increase by up to 60% in the area of maximum predicted concentrations to the west and southwest of Lephalale, and by more than 20% west of Palapye.

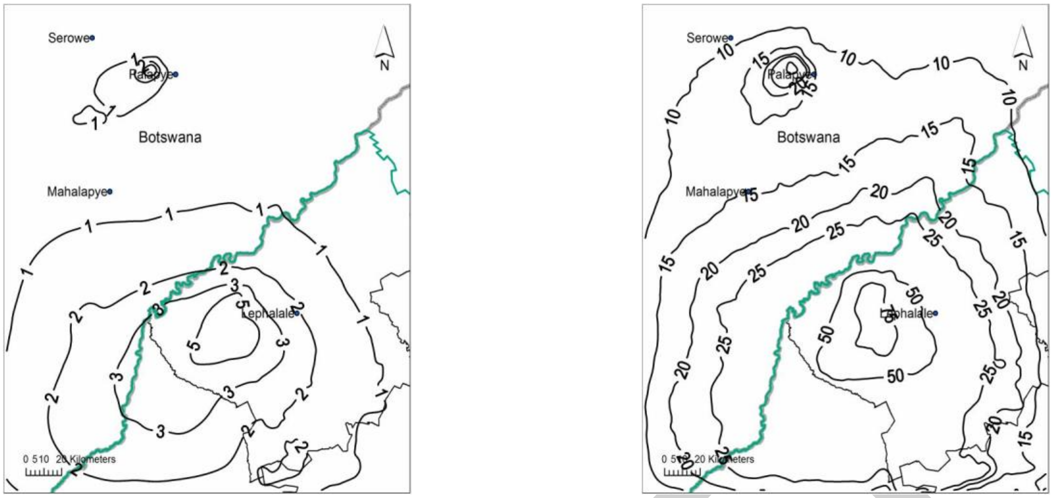

Figure 6-14: Predicted annual average NO_2 concentrations for 2020 (left) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m³

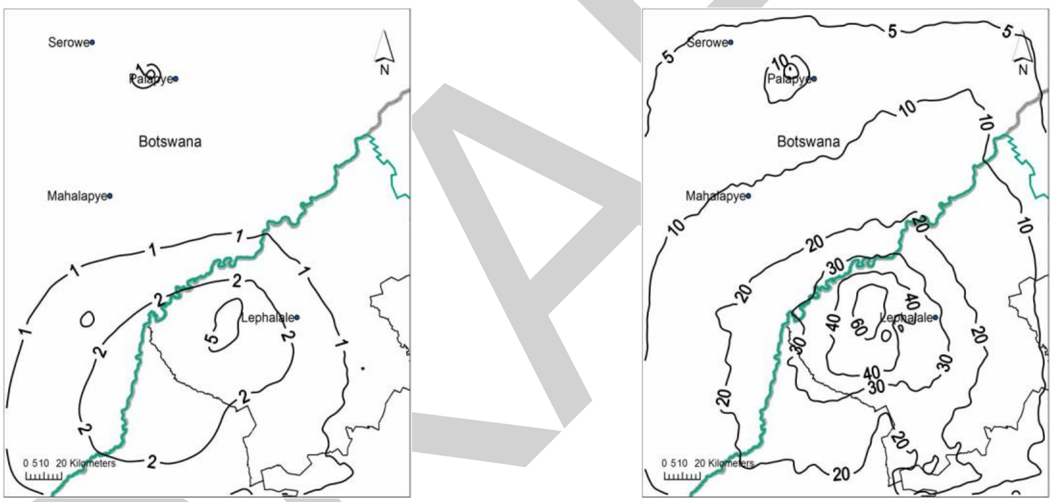

Figure 6-15: Percentage difference in the predicted NO_2 concentrations in 2020 from the base case for annual concentrations (left) and the 99th percentile of the predicted 1-hour concentration (right)

6.4.3 Respireable particulate matter (PM_{10})

The predicted ambient PM_{10} concentrations in 2020 increase with the addition of the generation capacity and four new coal mines in the WDM and Botswana (Figure 6-16). The maximum concentrations are predicted to occur west of Lephalale extending into Botswana and west of Palapye. The predicted annual concentration are generally below the limit value of the NAAQS except in a small area west of Lephalale, coinciding with the Grootgeluk Colliery and the mines at Boikarabelo and Mookane. Similarly the 99th percentile of the predicted 24-hour concentrations are below the limit value of the NAAQS other than the three small areas west of Lephalale. In these areas the limit value is exceeded on more than 12 occasions in the 3-year modelling period.

The relative increase in predicted ambient PM_{10} concentrations in 2020 from the baseline case is shown in Figure 6-17. The predicted annual concentrations increase by just 5% in the area of maximum predicted concentrations west of Lephalale and towards Botswana. The predicted 24-hour concentrations increase by up to 20% west of Lephalale and by 10% further west into Botswana.

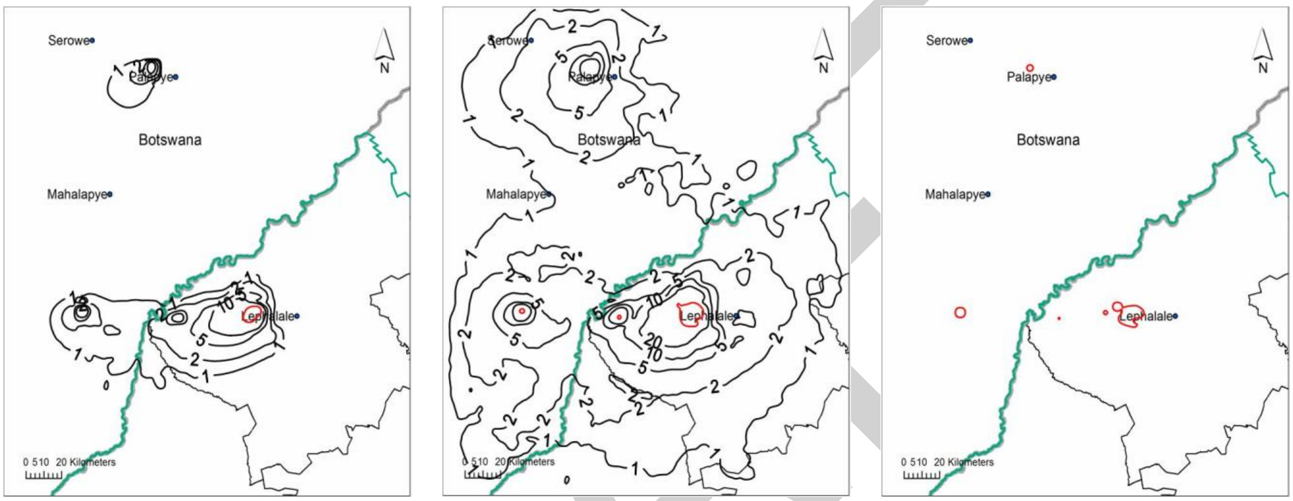

Figure 6-16: Predicted annual average PM_{10} concentrations for 2020 (left) and the 99th percentile of the predicted 24-hour concentration (middle) in µg/m^3, the limit value of the NAAQS is shown by the red isopleth, and the frequency of exceedance of limit value of the 24-hour NAAQS (right)

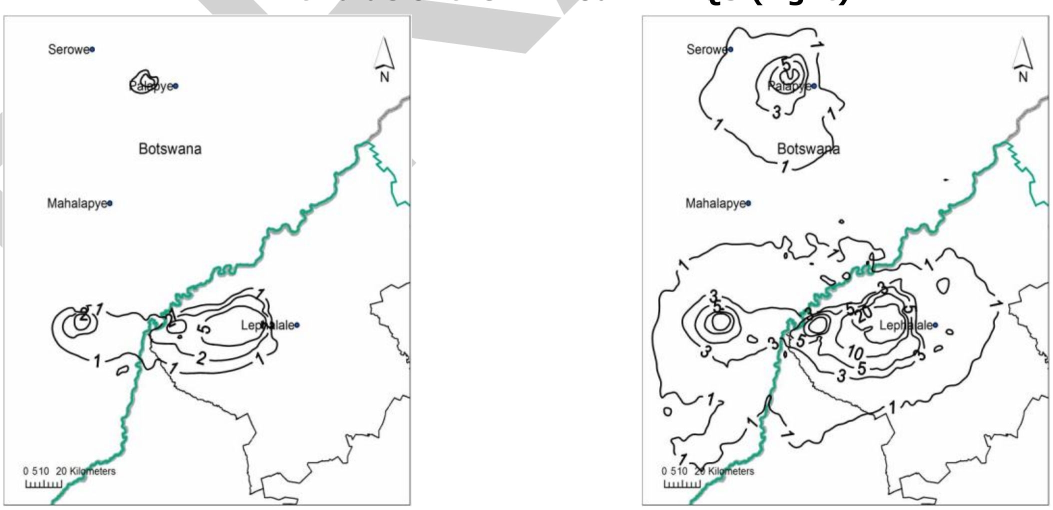

Figure 6-17: Percentage difference in the predicted PM_{10} concentrations in 2020 from the base case for annual concentrations (top) and the 99th percentile of the predicted 24-hour concentration (bottom).

6.5 Predicted ambient concentrations for 2025

New generation capacity in 2025 is brought by expansions at the Boikarabelo and Unknown IPP Power Stations, and commissioning of Phase 1 and 2 at the Mmamabula Power Station. The 2025 case also includes the expansion of three coal mines. The total SO_2 and NO_2 emissions decreases substantially as FGD is operational at the Medupi Power Station (Table 5-2), but PM_{10} emission increase by a further 5 207 t/a.

6.5.1 Sulphur dioxide (SO_2)

The predicted ambient SO_2 concentrations in 2025 exhibit a marked decrease from 2020 despite the expansion of the Boikarabelo and Unknown IPP Power Stations, and commissioning of the Mmamabula Power Station. The decrease is attributed to a reduction on SO_2 emissions with the implementation of FGD at Medupi. The predicted annual concentrations remain well below the NAAQS (Figure 6-18). The limit value of the 24-hour and 1-hour NAAQS (Table 6-1) are exceeded over a small area west of Lephalale. The exceedances are predicted to occur on fewer occasions than permitted by the NAAQS, i.e. there is general compliance with the NAAQS for SO_2.

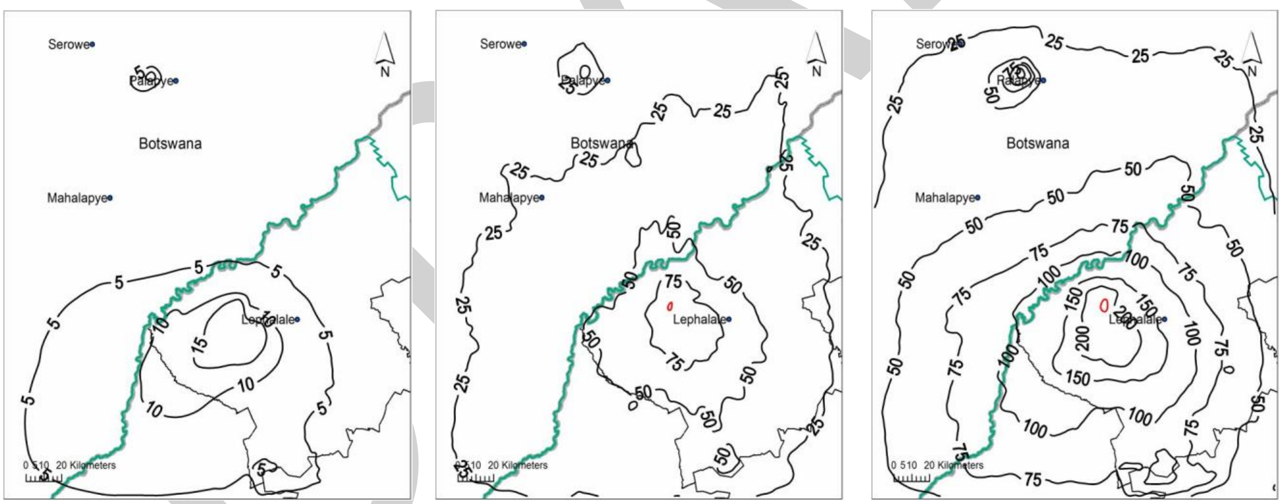

Figure 6-18: Predicted annual average SO_2 concentrations for 2025 (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3. The limit values of the NAAQS is shown by the red isopleths

The relative increase in predicted ambient SO_2 concentrations in 2025 from the baseline case are shown in Figure 6-19. The predicted annual concentrations increase by 10% in the area of maximum predicted concentrations southwest of Lephalale. The increase is more exaggerated for the predicted 24-hour and 1-hour concentrations. The predicted 24-hour concentrations increase by more than 40% in the area of maximum concentration west of Lephalale, with increase of 15% up to 100 km from the main source area. The predicted 1-hour concentrations increase by more than 100% to the west of Lephalale, and by more than 25% up to 100 km from the main source area.

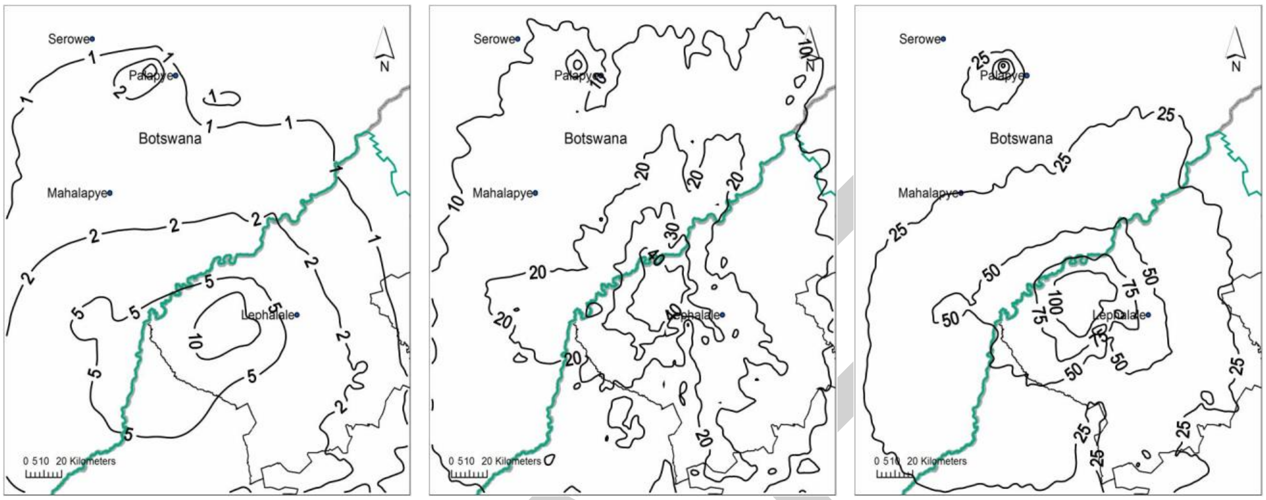

Figure 6-19: Percentage difference in the predicted SO_2 concentrations in 2025 from the base case for annual concentrations (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right)

6.4.2 Nitrogen dioxide (NO_2)

The predicted ambient NO_2 concentrations in 2025 exhibit a marked decrease from 2020 despite the expansion of the Boikarabelo and Unknown IPP Power Stations, and commissioning of the Mmamabula Power Station; as a result of the reduction on NO_X emissions from Medupi Power Station. The predicted annual concentrations remain well below the NAAQS (Figure 6-20). The limit value of the 1-hour NAAQS (Table 6-1) is exceeded over a small area west of Lephalale, but on fewer occasions than permitted by the NAAQS, i.e. there is general compliance with the NAAQS.

The relative increase in predicted ambient NO_2 concentrations in 2025 from the baseline case is shown in Figure 6-21. The predicted annual concentrations increase by 5% in the area of maximum predicted concentrations southwest of Lephalale. The increase is more exaggerated for the predicted 1-hour concentrations. The predicted 1-hour concentrations increase by more than 80% to the west of Lephalale, and by more than 20% up to 100 km from the main source area.

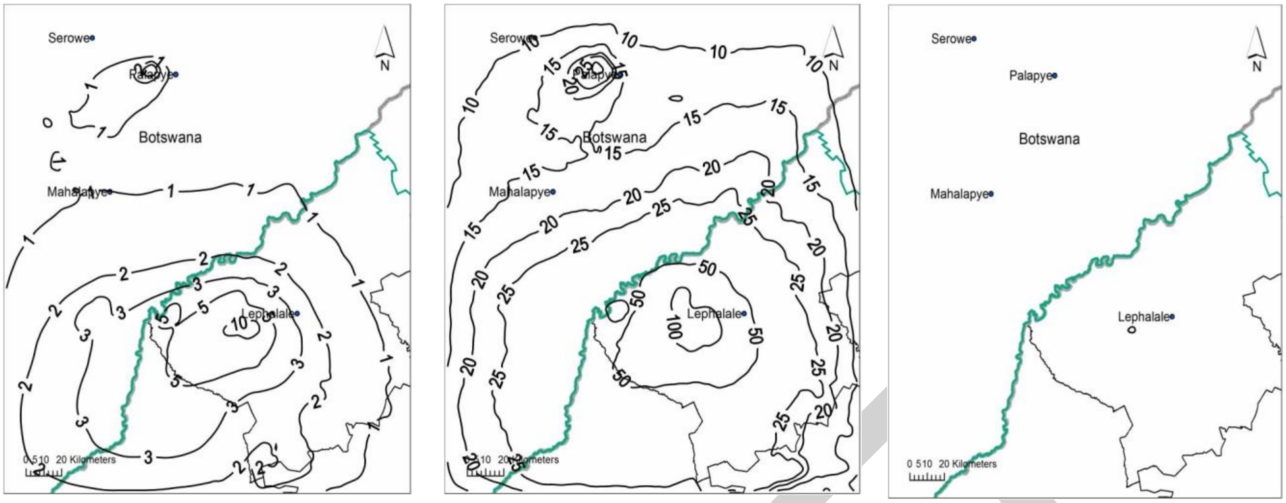

Figure 6-20: Predicted annual average NO_2 concentrations for 2025 (left) and the 99th percentile of the predicted 1-hour concentration (middle) in µg/m^3. The limit values of the NAAQS is shown by the red isopleths. The predicted frequency of exceedance is shown (right)

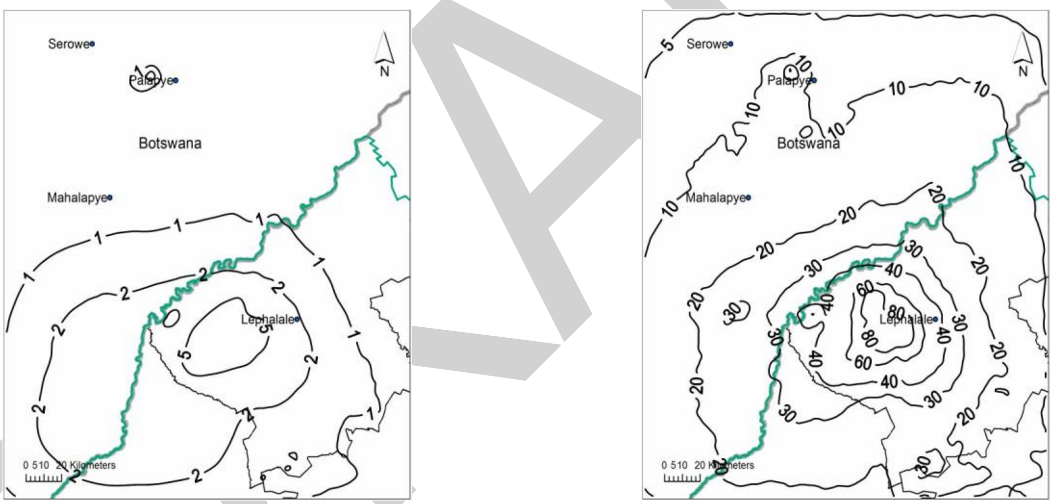

Figure 6-21: Percentage difference in the predicted NO_2 concentrations in 2025 from the base case for annual concentrations (top) and the 99th percentile of the predicted 1-hour concentration (bottom).

6.4.3 Respireable particulate matter (PM_{10})

The predicted ambient PM_{10} concentrations in 2025 increase with the addition of the generation capacity despite the FGD at Medupi and as a result of the expansion at three coal mines in the WDM and Botswana (Figure 6-22). The maximum concentrations are predicted to occur west of Lephalale extending into Botswana and also west of Palapye. The predicted annual concentration are generally below the limit value of the NAAQS other than small areas west of Lephalale, coinciding with the coal mines at Thabametsi, Boikarabelo and Mookane. The 99th percentile of the predicted 24-hour concentrations are also below the limit value of the NAAQS other than the three small areas west of Lephalale. In these areas the limit value is exceeded on more than 12 occasions in the 3-year modelling period (Figure 6-22).

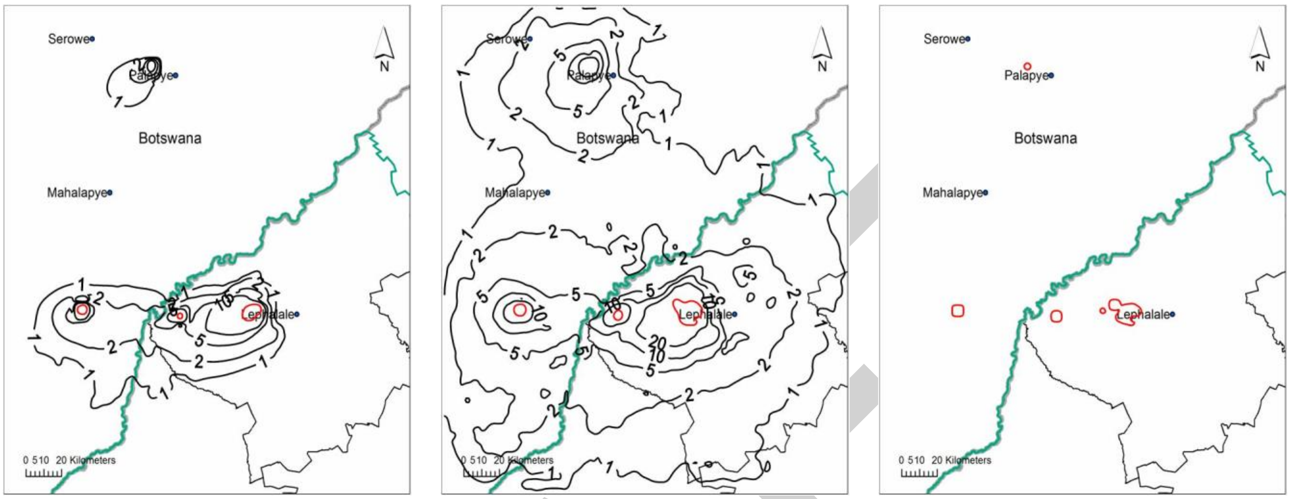

Figure 6-22: Predicted annual average PM_{10} concentrations for 2025 (left) and the 99th percentile of the predicted 24-hour concentration (middle) in µg/m^3. The limit value of the NAAQS is shown by the red isopleth. The predicted frequency of exceedance is shown (right)

The relative increase in predicted ambient PM_{10} concentrations in 2025 from the baseline case is shown in Figure 6-23. The predicted annual concentrations increase by just 5% in the area of maximum predicted concentrations west of Lephalale and into Botswana. The predicted 24-hour concentrations increase by up to 20% west of Lephalale and by 10% further west into Botswana.

Figure 6-23: Difference in the predicted PM_{10} concentrations in 2025 from the base case for annual concentrations (left) and the 99th percentile of the predicted 24-hour concentration (right).

6.6 Predicted ambient concentrations for 2030

The 2030 scenario sees a significant increase in all emission with SO_2 emission increasing by 583 605 t/a, NO_2 by 225 532 t/a and PM_{10} by 15 276 t/a (Table 5-2). The increase is attributed to further expansion of the generation capacity by more than 7 000 MW and the operation of a new coal-to-liquid refinery.

6.6.1 Sulphur dioxide (SO_2)

The predicted ambient SO_2 concentrations in 2030 increase somewhat from 2025 (Figure 6-24). The predicted annual concentrations however remain well below the NAAQS. The limit value of the 24-hour and 1-hour NAAQS (Table 6-1) are exceeded over a relatively large area southwest and also northwest of Lephalale.

The frequency of exceedance on the 24-hour and 1-hour limit values is shown on Figure 6-25 for the 3-year modelling period. More than 12 exceedances of the 24-hour limit value occur over a relatively large area southwest of Lephalale and also to the northwest. More than 264 exceedances of the 1-hour limit value in the same area, albeit somewhat smaller. There is non-compliance with the NAAQS in these areas.

The relative increase in predicted ambient SO_2 concentrations in 2020 from the baseline case is shown in Figure 6-26. The predicted annual concentrations increase by 20% in the area of maximum predicted concentrations. The increase is more dramatic for the 24-hour and 1-hour concentrations. The predicted 24-hour concentrations increase by more than 100% in the area of maximum concentration west and southwest of Lephalale, with increases of between 60% and 40% and more up to 100 km from the main source area. The predicted 1-hour concentrations increase by more than 200% to the west and southwest of Lephalale, and between 100% and 75% up to 100 km from the main source area.

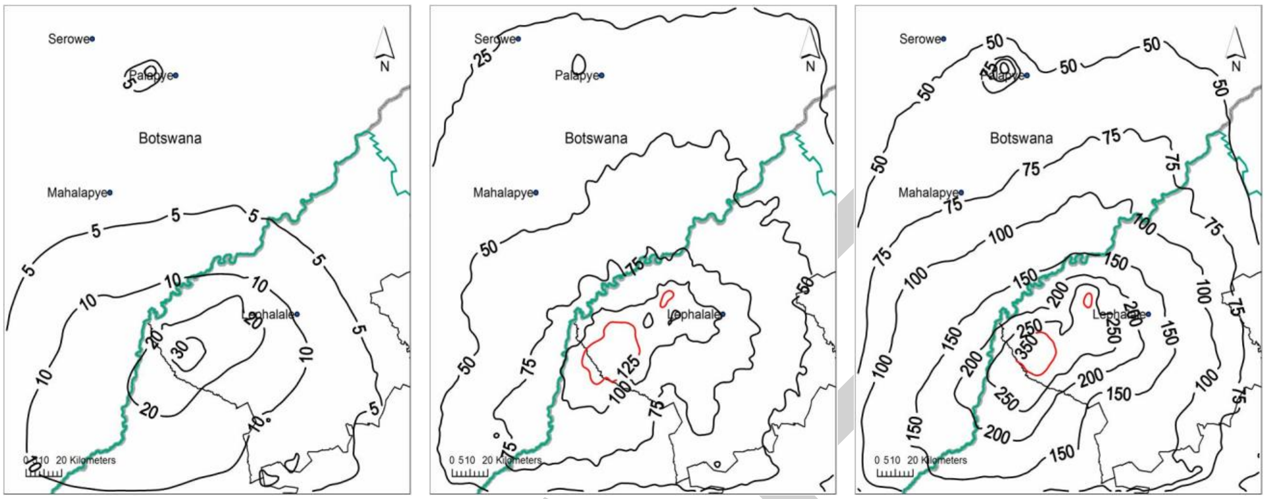

Figure 6-24: Predicted annual average SO_2 concentrations for 2030 (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3. The limit values of the NAAQS is shown by the red isopleths

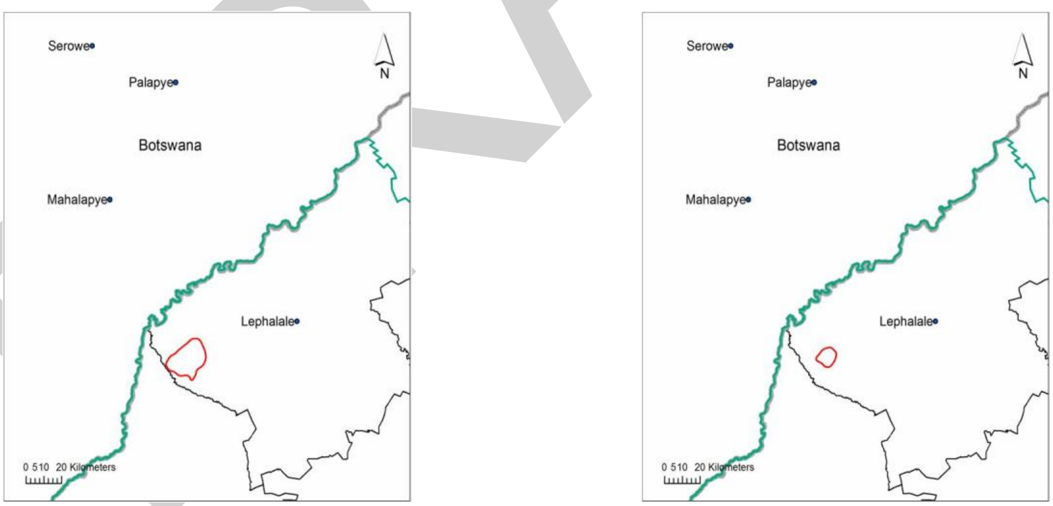

Figure 6-25: Predicted frequency of exceedance of the NAAQS limit value in 2030 for SO_2 for 24-hour (top) and 1-hour (bottom)

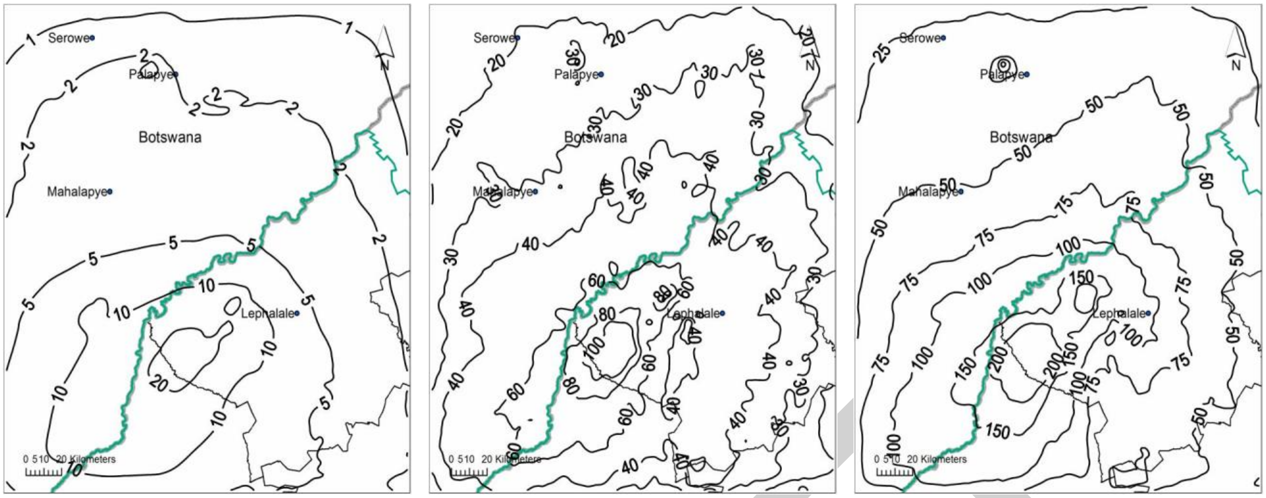

Figure 6-26: Percentage difference in the predicted SO_2 concentrations in 2030 from the base case for annual concentrations (left), the 99th percentile of the predicted 24-hour concentration (middle) and the 99th percentile of the predicted 1-hour concentration (right)

6.4.2 Nitrogen dioxide (NO_2)

The predicted ambient NO_2 concentrations in 2030 exhibit an increase in 2025, but despite substantial increase in emission, the predicted annual concentrations remain well below the NAAQS (Figure 6-27). The limit value of the 1-hour NAAQS (Table 6-1) is exceeded over a small area west of Lephalale, but on fewer occasions than permitted by the NAAQS, i.e. there is general compliance with the NAAQS.

The relative increase in predicted ambient NO_2 concentrations in 2030 from the baseline case is shown in Figure 6-28. The predicted annual concentrations increase by just more than 10% in the area of maximum predicted concentrations southwest of Lephalale. The increase is more exaggerated for the predicted 1-hour concentrations. The predicted 1-hour concentrations increase by more than 80% to the west of Lephalale, and by more than 40% up to 100 km from the main source area.

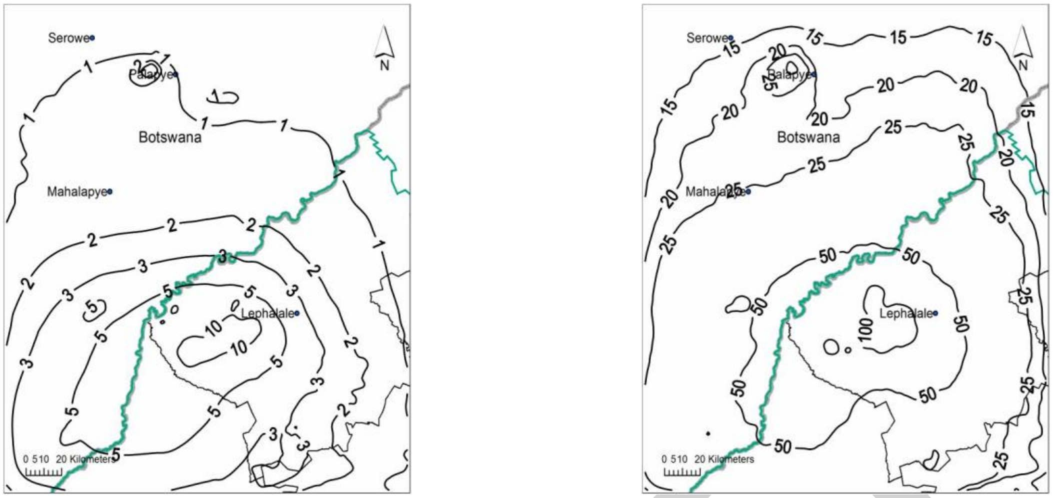

Figure 6-27: Predicted annual average NO_2 concentrations for 2030 (left) and the 99th percentile of the predicted 1-hour concentration (right) in µg/m^3. The limit values of the NAAQS is shown by the red isopleths

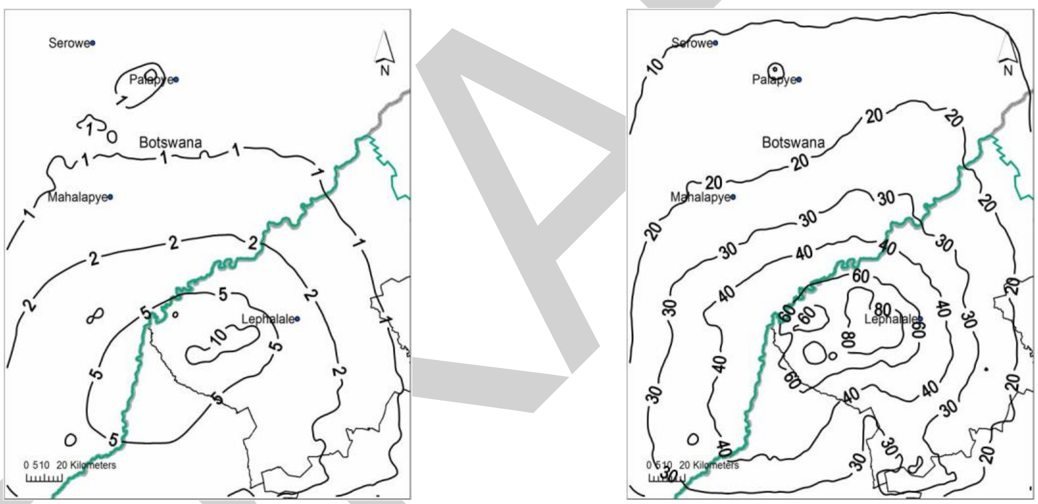

Figure 6-28: Percentage difference in the predicted NO_2 concentrations in 2030 from the base case for annual concentrations (left) and the 99th percentile of the predicted 1-hour concentration (right)

6.4.3 Respireable particulate matter (PM_{10})

The predicted ambient PM_{10} concentrations in 2030 increase with the addition of the generation capacity in the WDM and Botswana (Figure 6-29). The maximum concentrations are predicted to occur west of Lephalale extending into Botswana and also just west of Palapye. The predicted annual concentration are generally below the limit value of the NAAQS other than in the areas of maximum predicted concentrations. The 99th percentile of the predicted 24-hour concentrations are also below the limit value of the NAAQS other than the three small areas west of Lephalale. In these areas the limit value is exceeded on more than 12 occasions in the 3-year modelling period (Figure 6-29) indicating areas of non-compliance with the NAAQS.

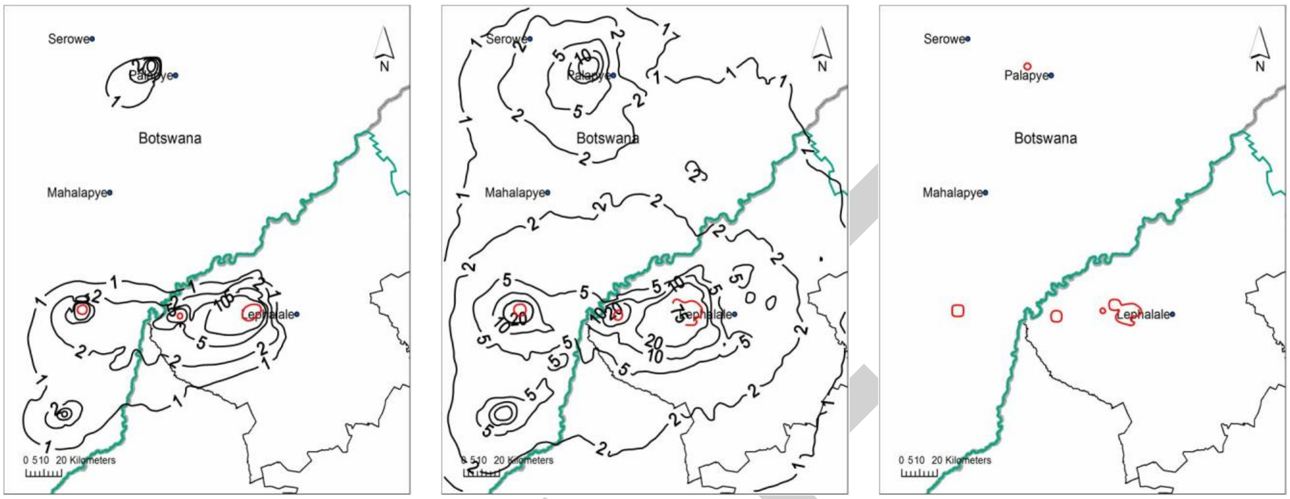

Figure 6-29: Predicted annual average PM_{10} concentrations for 2030 (left) and the 99th percentile of the predicted 24-hour concentration (middle) in µg/m^3. The limit value of the NAAQS is shown by the red isopleth and the predicted frequency of exceedance of the NAAQS limit value in 2030 for PM_{10} for 24-hour (right)

The relative increase in predicted ambient PM_{10} concentrations in 2030 from the baseline case is shown in Figure 6-30. The predicted annual concentrations increase by just 5% in the area of maximum predicted concentrations west of Lephalale and into Botswana. The predicted 24-hour concentrations increase by up to 20% west of Lephalale and by 10% further west into Botswana.

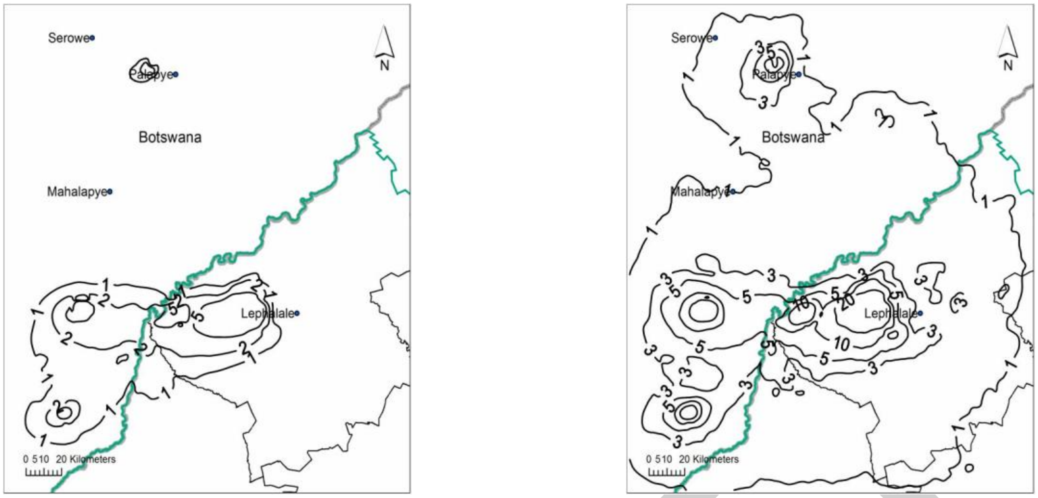

Figure 6-30: Percentage difference in the predicted PM_{10} concentrations in 2030 from the base case for annual concentrations (left) and the 99th percentile of the predicted 24-hour concentration (right)

7. SUMMARY AND CONCLUSION

The proposed expansion of energy-based projects and mining in the WDM and neighbouring Botswana are recognised as a potential threat to ambient air quality in the region. Hence the declaration of the Waterberg-Bojanala Priority Area in June 2012. The potential increase in annual emissions from the current situation to 2030 for SO_2 of 370%, for NO_2 of 640% and for PM_{10} of 530% shown in Figure 5.1 justifies the declaration of the priority area.

The threat to ambient air quality manifests in the associated increase in ambient concentrations of SO_2, NO_2 and PM_{10} and their potential impact on human health and the ecological environment. The increase in emissions from the base year (2012) to 2015 and from 2015 to 2020 results in a general increase in ambient concentrations on a regional scale. The largest increase occurs in the vicinity of the main sources near Lephalale and Palapye. Emissions from elevated power station stacks affect a large area, but dilution is effective and there is general compliance with the NAAQS, except close to the source areas where SO_2 and PM_{10} exceedances are predicted. Emissions from mines result in localised effects where exceedances of the NAAQS for PM_{10} are predicted. The potential increase in ambient concentrations in 2015 and 2020 in summarised in Table 7-1.

In 2025 marked reductions in SO_2 and NO_2 emissions result when FGD is implemented at Medupi. The resulting reduction in PM_{10} emissions is off-set by an increase in PM_{10} emissions from mining. The emission reductions result in regional decreases in predicted ambient concentrations and general compliance with NAAQS for SO_2 and NO_2. Ambient PM_{10} concentrations increase in 2025, particularly in a band extending westward from Lephalale to the Botswana border with exceedances of the NAAQS.

Table 7-1: Summary of the threat to ambient air quality in the WDM

Scenario	SO_2	NO_2	PM_{10}
2015	• Increase in emission of more than 500 000 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS • Non-compliance with 24-hour and 1-hour NAAQS in a small area southwest of Lephalale	• Increase in emission of 94 964 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS	• Increase in emission of more than 7 600 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • Non-compliance with annual NAAQS in an isolated area west of Lephalale • General compliance with 24-hour NAAQS • Non-compliance with 24-hour NAAQS in a small area west of Lephalale
2020	• Further increase in emission of 236 131 t/a • Further regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS • Non-compliance with 24-hour NAAQS in a large area including Lephalale • Non-compliance with 1-hour NAAQS in a smaller area west and southwest of Lephalale	• Further increase in emission of 121 921 t/a • Further regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS	• Further increase in emissions of 3 185 t/a • Further regional scale increase in ambient concentrations • General compliance with annual NAAQS • Non-compliance with annual NAAQS in an isolated area west of Lephalale • General compliance with 24-hour NAAQS • Non-compliance with 24-hour NAAQS in a small but increased area west of Lephalale
2025	• Decrease in emissions of more than 440 000 t/a • Marked decrease in ambient concentrations on a regional	• Decrease in emissions of more than 29 000 t/a • Notable decrease in ambient concentrations on a regional scale	• Decrease in emissions of more than 500 t/a • Small decrease in ambient concentrations on a regional scale

Scenario	SO_2	NO_2	PM_{10}
	scale • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS • Non-compliance with 24-hour NAAQS in an isolated area west of Lephalale • Non-compliance with 1-hour NAAQS in a smaller isolated area west of Lephalale	• General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS	• General compliance with annual NAAQS • Non-compliance with annual NAAQS in an isolated area west of Lephalale • General compliance with 24-hour NAAQS • Non-compliance with 24-hour NAAQS in a small but increased area west of Lephalale and near the Botswana border
2030	• Increase in emission of more than 530 000 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS • Non-compliance with 24-hour and 1-hour NAAQS in a small area southwest of Lephalale	• Increase in emission of more than 220 000 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • General compliance with 24-hour and 1-hour NAAQS	• Increase in emission of more than 15 000 t/a • Regional scale increase in ambient concentrations • General compliance with annual NAAQS • Non-compliance with annual NAAQS in an isolated area west of Lephalale • General compliance with 24-hour NAAQS • Non-compliance with 24-hour NAAQS in a small but increased area west of Lephalale and near the Botswana border

From the relatively low emissions base established in 2025 with the implementation of FGD, there is a significant increase in emissions to 2030. This results in a regional scale increase in ambient SO_2, NO_2 and PM_{10} concentrations. The largest increase in ambient concentration are in the vicinity of the main sources near Lephalale and extending westward towards Botswana. The elevated emissions from the new power stations and the CTL plant affect a large area, but dilution is effective and there is general compliance with the NAAQS, except close to the source areas where SO_2 and PM_{10} exceedances are predicted. Emissions from mines result in localised effects where exceedances of the NAAQS for PM_{10} are predicted. The potential increase in ambient concentrations from 2025 to 2030 in summarised in Table 7-1.

It should be borne in mind that the Threat Assessment excludes the contribution of emissions from the potential increase in residential fuel burning and motor vehicles. The outputs of the Threat Assessment modelling most likely indicate a best case scenario without these two contributing source types. In other words, the future scenarios are likely to be under-predicted. Emissions from residential fuel burning are released close to ground level and have a relatively localised effect, albeit a potentially significant effect on ambient concentrations. The effect of motor vehicle emissions is also limited and resulting ambient concentrations are generally much lower.

Despite this limitation, the Threat Assessment has indicated a number of important points for air quality management in the region. These are:

- Development in the region will increase ambient concentrations of pollutants on a regional scale.
- The areas of greatest concern are where the NAAQS for SO_2 and PM_{10} are predicted to be exceeded, concentrated in the Lephalale area and extending towards Botswana.
- Tall stack emissions affect air quality on a more regional scale, but ground level concentrations are generally low compared to the NAAQS.
- Low level emissions from mining result in local scale effects, and ground level concentrations are relatively high compared to the NAAQS.
- FGD brings about significant reductions in SO_2 and NO_2 concentrations when implemented in 2025.
- The magnitude of the predicted threat to ambient air quality can be mitigated through well designed air quality management interventions and the application of appropriate technologies and emission control measures.
- The likelihood of impacts on ambient air quality in the WDM from sources in Botswana is very low. Rather sources in the WDM are likely to affect ambient concentrations in Botswana considering the prevailing easterly wind and proximity of these sources to the Botswana border.
- The current resources in all tiers of government responsible for AQM in the WBPA is not adequate to cope effectively with the imminent changes.

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APPENDIX 1: EMISSIONS PARAMETERISATION USED IN THE CALPUFF DISPERSION MODELLING

Table A1-1: Emissions Inventory – location and base elevation of power stations

	Facility	Source name	Location		
			UTMx (km)	UTMy (km)	Base elevation (m)
Baseline	Matimba Power Station (6 units: 3990 MW)	Stack 1	562.333	7382.183	870
		Stack 2	562.278	7382.430	870
	Morupule B Power Station - Phase I (4 units: 600 MW)	Stack 1	504.904	7509.375	945
		Stack 2	504.904	7509.250	945
2015	Medupi Power Station (6 units: 4800 MW, no FGD)	Stack 1	557.140	7378.399	897
		Stack 2	557.308	7378.108	897
	Morupule A Power Station (4 units: 132 MW)	Stack 1	503.778	7509.710	953
		Stack 2	503.865	7509.758	953
2020	IPP: Thabametsi Power Station (4 units: 1200 MW)	Stack 1	549.778	7391.089	937
		Stack 2	549.836	7391.005	937
		Stack 3	549.890	7390.923	937
		Stack 4	549.946	7390.839	937
	IPP: Boikarabelo Power Station - Phase I (3 units: 45 MW)	Stack 1	515.500	7385.481	871
	IPP: Unknown IPP Power Station - Phase I (2 units: 300 MW)	Stack 1	545.100	7377.725	933
	Morupule B Power Station - Phase II (2 units: 300 MW)	Stack 1	504.904	7509.500	945
	Greenfields IPP Power Station (2 units: 300 MW)	Stack 1	472.000	7384.263	929
2025	Medupi Power Station (6 units: 4800 MW, with FGD)	Stack 1	557.140	7378.399	897
		Stack 2	557.308	7378.108	897
	IPP: Boikarabelo Power Station - Phase 2 (1 unit: 215 MW)	Stack 1	515.700	7385.481	871
	IPP: Unknown IPP Power Station - Phase 2 (4 units: 600 MW)	Stack 1	545.300	7377.725	933
	Mmamabula Power Station - Phase 1 (4 units: 600 MW)	Stack 1	478.200	7388.701	914
	Mmamabula Power Station - Phase 2 (2 units: 600 MW)	Stack 1	478.400	7388.701	914
2030	Coal 3 Power Station - Site 1 (2 units: 300MW)	Stack 1	509.2500	7379.875	870
	Coal 3 Power Station - Site 2 (2 units: 300MW)	Stack 1	516.9000	7374.784	906
	Coal 3 Power Station - Site 3 (2 units: 300MW)	Stack 1	534.7000	7365.586	981
	Coal 3 Power Station - Site 4 (2 units: 300MW)	Stack 1	547.4000	7370.367	923
	Coal 3 Power Station - Site 5 (2 units: 300MW)	Stack 1	520.6500	7391.397	852
	Pulverised Fuel Power Station (6 units: 4500MW)	Stack 1	527.1200	7370.297	966
		Stack 2	527.3200	7370.297	966
	Mmamantswe (3 units: 1050MW)	Stack 1	461.7000	7322.146	932
	CTL	Stack 1	533.9400	7393.160	865
		Stack 2	534.1400	7393.160	865

Table A1-2: Emissions Inventory – stack parameters for power stations

	Facility	Source name	Stack Height (m)	Stack Temp (degree)	Stack Temp (k)	Stack Diameter (m)	Stack Area (m^2)	Stack Velocity (m/sec)	Average pressure (hPa)	Stack Flowrate (Am^3/s)	Stack Flowrate (Nm^3/s)
Baseline	Matimba Power Station (6 units: 3990 MW)	Stack 1	250	132	405	12.82	129.08	27.9	920	3601	2205
		Stack 2	250	132	405	12.82	129.08	27.9	920	3601	2205
	Morupule B Power Station - Phase I (4 units: 600 MW)	Stack 1	150	130	403	5.2	21.24	21.1	980	448	294
		Stack 2	150	130	403	5.2	21.24	21.1	980	448	294
2015	Medupi Power Station (6 units: 4800 MW, no FGD)	Stack 1	220	140	413	15.4	186.26	17.4	920	3241	1946
		Stack 2	220	140	413	15.4	186.26	17.4	920	3241	1946
	Morupule A Power Station (4 units: 132 MW)	Stack 1	150	127	400	2	3.14	18	no data	no data	no data
		Stack 2	150	127	400	2	3.14	18	no data	no data	no data
2020	IPP: Thabametsi Power Station (4 units: 1200 MW)	Stack 1	150	145.6	418.6	11.5	103.87	18.29	no data	no data	no data
		Stack 2	150	145.6	418.6	11.5	103.87	18.29	no data	no data	no data
		Stack 3	150	145.6	418.6	11.5	103.87	18.29	no data	no data	no data
		Stack 4	150	145.6	418.6	11.5	103.87	18.29	no data	no data	no data
	IPP: Boikarabelo Power Station - Phase I (3 units: 45 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	IPP: Unknown IPP Power Station - Phase I (2 units: 300 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Morupule B Power Station - Phase II (2 units: 300 MW)	Stack 1	150	130	403	5.2	21.24	21.1	980	448	294
	Greenfields IPP Power Station (2 units: 300 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
2025	Medupi Power Station (6 units: 4800 MW, with FGD)	Stack 1	220	50	323	15.4	186.26	17.4	920	3241	1946
		Stack 2	220	50	323	15.4	186.26	17.4	920	3241	1946
	IPP: Boikarabelo Power Station - Phase 2 (1 unit: 215 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	IPP: Unknown IPP Power Station - Phase 2 (4 units: 600 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Mmamabula Power Station - Phase 1 (4 units: 600 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Mmamabula Power Station - Phase 2 (2 units: 600 MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
2030	Coal 3 Power Station - Site 1 (2 units: 300MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Coal 3 Power Station - Site 2 (2 units: 300MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Coal 3 Power Station - Site 3 (2 units: 300MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Coal 3 Power Station - Site 4 (2 units: 300MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Coal 3 Power Station - Site 5 (2 units: 300MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	Pulverised Fuel Power Station (6 units: 4500MW)	Stack 1	220	140	413	15.4	186.26	17.4	920	3241	1946
		Stack 2	220	140	413	15.4	186.26	17.4	920	3241	1946
	Mmamantswe (3 units: 1050MW)	Stack 1	100	140	413	5.3	22.06	15	980	331	212
	CTL	Stack 1	250	160	433	13	132.73	20	980	2655	1619
		Stack 2	250	160	433	13	132.73	20	980	2655	1619

Table A1-3: Emissions Inventory – emission concentration and emission rates for energy-based projects

	Facility	Source name	SO_2 Emission Concentration (mg/Nm^3)	SO_2 Emission Rate (ton/annum)	NOx Emission Concentration (mg/Nm^3)	NOx Emission Rate (ton/annum)	Particulate Emission Concentration (mg/Nm^3)	Particulate Emission Rate (ton/annum)
Baseline	Matimba Power Station (6 units: 3990 MW)	Stack 1	2224	154631	486	33796	35	2452
		Stack 2	2224	154631	486	33796	35	2452
	Morupule B Power Station - Phase I (4 units: 600 MW)	Stack 1	900	8335	510	4723	50	463
		Stack 2	900	8335	510	4723	50	463
2015	Medupi Power Station (6 units: 4800 MW, no FGD)	Stack 1	4000	245436	750	46019	50	3068
		Stack 2	4000	245436	750	46019	50	3068
	Morupule A Power Station (4 units: 132 MW)	Stack 1	no data	4595	no data	1463	no data	94
		Stack 2	no data	4595	no data	1463	no data	94
2020	IPP: Thabametsi Power Station (4 units: 1200 MW)	Stack 1	no data	53779	no data	25946	no data	162
		Stack 2	no data	53779	no data	25946	no data	162
		Stack 3	no data	53779	no data	25946	no data	162
		Stack 4	no data	53779	no data	25946	no data	162
	IPP: Boikarabelo Power Station - Phase I (3 units: 45 MW)	Stack 1	500	3337	750	5005	50	334
	IPP: Unknown IPP Power Station - Phase I (2 units: 300 MW)	Stack 1	500	3337	750	5005	50	334
	Morupule B Power Station - Phase II (2 units: 300 MW)	Stack 1	900	8335	510	4723	50	463
	Greenfields IPP Power Station (2 units: 300 MW)	Stack 1	900	6006	510	3404	50	334
2025	Medupi Power Station (6 units: 4800 MW, with FGD)	Stack 1	500	30679	750	46019	50	3068
		Stack 2	500	30679	750	46019	50	3068
	IPP: Boikarabelo Power Station - Phase 2 (1 unit: 215 MW)	Stack 1	500	3337	750	5005	50	334
	IPP: Unknown IPP Power Station - Phase 2 (4 units: 600 MW)	Stack 1	500	3337	750	5005	50	334
	Mmamabula Power Station - Phase 1 (4 units: 600 MW)	Stack 1	900	6006	510	3404	50	334
	Mmamabula Power Station - Phase 2 (2 units: 600 MW)	Stack 1	900	6006	510	3404	50	334
2030	Coal 3 Power Station - Site 1 (2 units: 300MW)	Stack 1	500	3337	750	5005	50	334
	Coal 3 Power Station - Site 2 (2 units: 300MW)	Stack 1	500	3337	750	5005	50	334
	Coal 3 Power Station - Site 3 (2 units: 300MW)	Stack 1	500	3337	750	5005	50	334
	Coal 3 Power Station - Site 4 (2 units: 300MW)	Stack 1	500	3337	750	5005	50	334
	Coal 3 Power Station - Site 5 (2 units: 300MW)	Stack 1	500	3337	750	5005	50	334
	Pulverised Fuel Power Station (6 units: 4500MW)	Stack 1	4000	245436	750	46019	50	3068
		Stack 2	4000	245436	750	46019	50	3068
	Mmamantswe (3 units: 1050MW)	Stack 1	900	6006	510	3404	50	334
	CTL	Stack 1	500	25531	750	38297	50	2553
		Stack 2	500	25531	750	38297	50	2553

Table A1-4: Emissions Inventory – extent and emission rates for coal mines

		top left		top right		bot left		bot right			
	Area Name	UTMx (km)	UTMy (km)	UTMx (km)	UTMy (km)	UTMx (km)	UTMy (km)	UTMx (km)	UTMy (km)	Area (m2)	PM10 (t/a)
Baseline	Grootgeluk Coal Mine (Class 4)	554.686	7384.744	557.686	7384.744	554.686	7381.744	557.686	7381.744	9000000	537
	Morupule Coal Mine (Class 2)	502.055	7510.592	503.055	7510.592	502.055	7509.592	503.055	7509.592	1000000	134
2015	Grootgeluk Coal Mine (expanded to Class 5)	554.186	7385.244	558.186	7385.244	554.186	7381.244	558.186	7381.244	16000000	1074
	Morupule Coal Mine (expanded to Class 3)	501.555	7511.092	503.555	7511.092	501.555	7509.092	503.555	7509.092	4000000	268
2020	Boikarabelo Coal Mine (Class 2)	516.833	7382.921	517.833	7382.921	516.833	7381.921	517.833	7381.921	1000000	134
	Thabametsi Coal Mine (Class 2)	546.947	7387.196	547.947	7387.196	546.947	7386.196	547.947	7386.196	1000000	134
	Sekoko Coal Mine (Class 2)	540.951	7386.194	541.951	7386.194	540.951	7385.194	541.951	7385.194	1000000	134
	Mookane Coal Mine (Class 2)	466.416	7385.065	467.416	7385.065	466.416	7384.065	467.416	7384.065	1000000	134
2025	Boikarabelo Coal Mine (expanded to Class 3)	516.333	7383.421	518.333	7383.421	516.333	7381.421	518.333	7381.421	4000000	268
	Thabametsi coal Mine (expanded to Class 3)	546.447	7387.696	548.447	7387.696	546.447	7385.696	548.447	7385.696	4000000	268
	Mookane Coal Mine (expanded to Class 3)	465.916	7385.565	467.916	7385.565	465.916	7383.565	467.916	7383.565	4000000	268
2030	Mmamantswe Coal Mine (Class 2)	457.286	7332.100	458.286	7332.100	457.286	7331.100	458.286	7331.100	1000000	134