Eskom PMV Phase 2: Phola

Activity 6: Air Quality Modelling

Activity 6.1: Phola Air Quality Modelling for year 1

Document by:

ARM
AIR RESOURCE MANAGEMENT

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EXECUTIVE SUMMARY

1. STUDY BACKGROUND & OBJECTIVE

Phase 2 of Eskom's Air Quality Offset (AQO) programme focuses on Phola. Approximately 6,700 households in Phola will receive Eskom's AQO interventions aimed at reducing emissions from residential fuel burning. Eskom has included eight targeted AQO work package activities for Phola. In accordance with the scope of work, for Activity 6: Air Quality Modelling, Air Resource Management (ARM) must develop and run appropriate dispersion model(s) to predict ambient PM, SO_2 and NOx levels in Phola. Further the model shall comply with DFFE's modelling framework and Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (Gazette No 37804, 2014). The focus of this study is on the baseline (year 1) air quality modelling for Phola

2. STUDY METHODOLOGY

Atmospheric dispersion models utilise mathematical equations that simulate the physics and chemistry that control the transport and transformation of pollutants in the atmosphere. They provide a means of estimating air pollutant concentrations and particle deposition in the ambient environment based on information on emissions and the prevailing meteorology.

All air quality modelling systems comprise of three major components: an emission inventory; a meteorological model and an air quality model. For this study a comprehensive emission inventory was created for Phola which included emissions for the following source categories: power generation; residential fuel burning; waste burning, biomass burning, vehicle emissions from both paved & unpaved roads and mining. The air quality impact of these emission sources is strongly influenced by meteorology which covers an array of atmospheric processes that determines the evolution of emissions, chemical species, aerosols and particulate matter. The integrated 3-dimensional mesoscale prognostic TAPM meteorological model was used to provide site-specific and representative meteorological data for the dispersion model. TAPM has been extensively verified both locally (DFFE, 2011; DFFE, 2014; Raghunandan et al, 2009) and internationally (Hurley et al., 2003) where the meteorological results show that TAPM performs well in a variety of regions (e.g., coastal, inland and generally complex terrain for sub-tropical to mid-latitude conditions). The output of the TAPM meteorological model was utilised an input into the dispersion modelling system.

In this study, the US-EPA approved Californian Puff (CALPUFF) dispersion modelling suite was used herein. The modelling approach for this activity is aligned to the prescribed requirements of the Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (Gazette No 37804, 2014).

The CALPUFF suite of models was used to predict the dispersion of the following pollutants: SO_2, SO_4, NO_X, HNO_3, NO_3, PM_{10}, $PM_{2.5}$ and TPM (to calculate particulate/dust deposition rates) using the MESOPUFF II Scheme chemical transformation method. The MESOPUFF II Scheme is a pseudo-first-order chemical reaction mechanism for conversion of SO_2 to SO_4 and total NO_X to NO_3. This baseline modelling study has taken a conservative approach (Scire, 2014) whereby the total concentrations of particulate matter (PM_{10} or $PM_{2.5}$) was computed as the sum of primary particulate matter concentrations (PM_{10} or $PM_{2.5}$) plus the contribution of concentrations from secondary particulate matter, including ammonium nitrate and ammonium sulphate. Results of the modelling were evaluated against the applicable National Ambient Air Quality Standard (NAAQS) for SO_2, NO_X as NO_2, PM_{10}, $PM_{2.5}$ and National Dustfall Standard for dustfall rates. Two modelling domains were utilised in the study. The primary modelling domain is referred to as the Greater Phola Airshed. This is a large coarse grid domain which caters for a range of emission source categories within a 40 km radius around Phola. The secondary modelling domain is referred to as the Phola Airshed. This is a smaller, finer grid domain within the primary grid, which is used to accurately capture the dispersion characteristics and ambient concentrations for Phola at a higher resolution.

3. STUDY RESULTS

In this study, the US-EPA approved Californian Puff (CALPUFF) modelling suite was used for this Level 3 tier modelling assessment. The dispersion of the pollutants were simulated for the prevailing meteorological conditions for the period 1 January 2021 to 31 December 2023. TAPM was used to model the hourly surface and upper air meteorology for the study area. In this study, the emission source categories include power generation, residential fuel burning, waste burning, biomass burning, vehicles travelling on paved roads, vehicles travelling on unpaved roads and mining. The emission inventory is presented in Table i.

Table i: Emission Inventory for the Phola Study

	Emission rate (tonnes/annum)				
Emission Source Category	**SO_2**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**TPM**
Power Generation	1 184 740.46	862 755.33	209 216.17	92 539.93	12 877.82
Residential Fuel Burning	5 622.18	2 581.32	7 324.15	6 813.56	
Waste Burning	38.73	196.50	1 911.99	1 904.43	
Biomass Burning	247.63	54.09	2 550.06	2 451.40	3 666.53
Vehicles – Paved Roads	133.57	8 991.08	183.00	183.00	
Vehicles – Unpaved Roads	0.17	46.61	2 461.17	246.81	8 631.59
Mining			10 068.07	2 683.46	32 642.47
All Sources	1 190 782.75	874 624.93	233 714.61	106 822.59	57 818.41

The results of the model simulations for the Phola modelling domains are as follows:

3.1 NAAQS Compliance

The model predicted concentrations were evaluated against the applicable NAAQS.

3.1.1 Greater Phola airshed

- Model predicted 1-hour, 24-hour and annual SO_2 ambient concentrations exceed the respective NAAQS within the Greater Phola airshed
- Model predicted 1-hour and annual NO_2 ambient concentrations exceed the respective NAAQS within the Greater Phola airshed
- Particulate matter (PM_{10} and $PM_{2.5}$) exceed both the 24-hour and annual NAAQS in the Greater Phola airshed

3.1.2 Phola airshed

- Model predicted 1-hour, 24-hour and annual SO_2 ambient concentrations exceed the respective NAAQS within the Phola airshed
- Model predicted 1-hour and annual NO_2 ambient concentrations exceed the respective NAAQS within the Phola airshed
- Particulate matter (PM_{10} and $PM_{2.5}$) exceed both the 24-hour and annual NAAQS in the Phola airshed

3.2 Source Contribution Analysis

As each emission source category was simulated independently in the dispersion model, ARM was able to differentiate the air quality impact of these individual source categories in relation to the cumulative modelled impact.

3.2.1 SO_2

As illustrated in Figure i, the source contribution analysis indicates that residential fuel burning and power generation are the main contributors to ambient SO_2 levels in the Phola Airshed. Ambient contributions from waste burning, biomass burning and vehicles on paved and unpaved roads are much smaller in comparison.

It is however noted that other large industries (petrochemical, metallurgical, etc.) were excluded from the modelling simulation due to data policy privacy issues. However, an analysis of the ambient air quality monitoring data indicates that SO_2 displays a typical industrial signature with increased SO_2 concentrations just around midday due to the break-up of an elevated inversion layer, in addition to the development of daytime convective conditions causing the plume to be brought down to ground level and relatively close to the point of release from tall stacks. This confirms the additional impact of other tall stack sources in the Phola airshed.

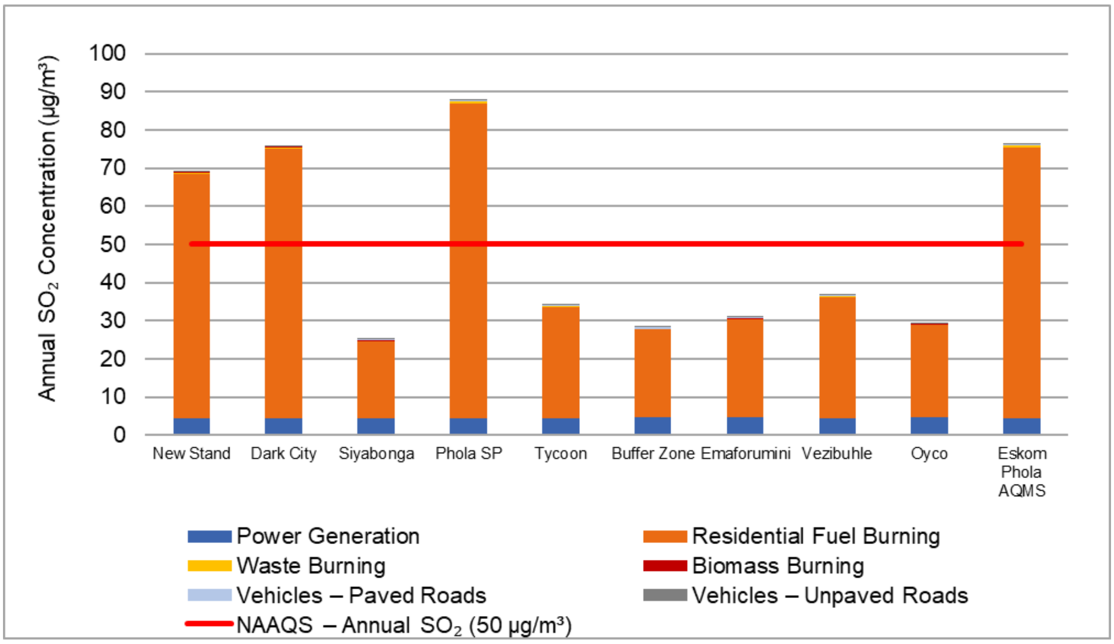

Figure i: Stacked bar graph representing model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the six emission source categories

3.2.2 NO_2

As illustrated in Figure ii, the source contribution analysis indicates that residential fuel burning and vehicles on paved roads are the main contributors to ambient NO_2 levels in the Phola Airshed. Ambient contributions from power generation, waste burning, biomass burning and vehicles on unpaved roads are much smaller in comparison. This is further supported by the analysis of the ambient data which clearly shows that elevated NO_2 levels are conditioned by both rush-hour traffic and the contribution of residential fuel burning in winter.

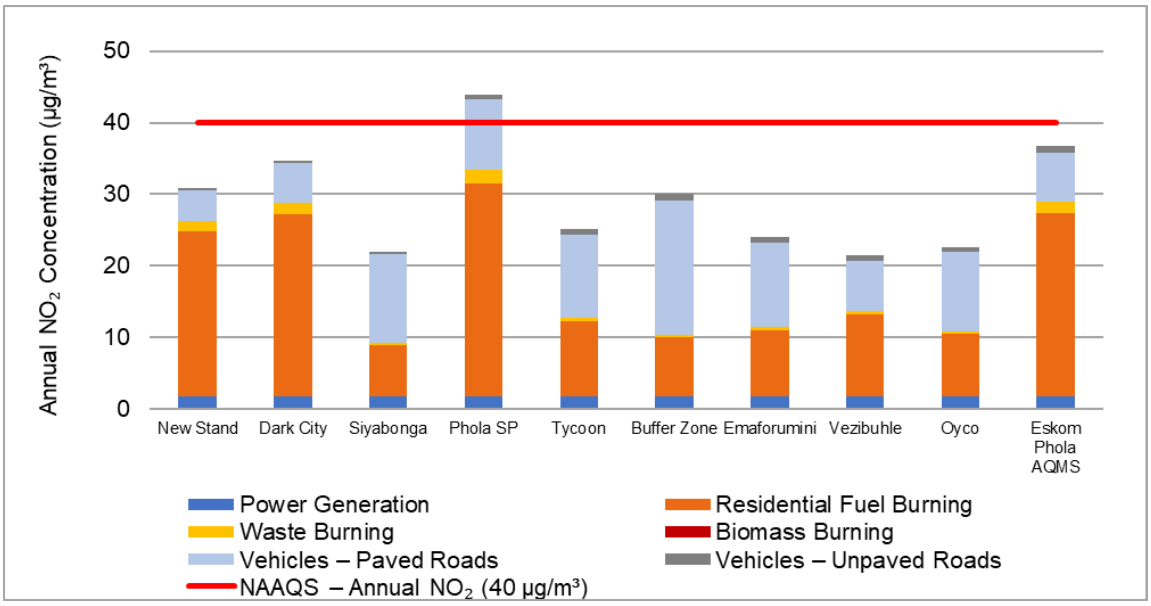

Figure ii: Stacked bar graph representing model predicted annual NO_2 ambient concentrations in µg/m^3 at discrete receptors for the six emission source categories

3.2.3 PM (PM_{10} and $PM_{2.5}$)

As illustrated in Figures iii & iv, the source contribution analysis indicates that residential fuel burning and vehicles on unpaved roads have the most significant air quality impact on ambient PM_{10} levels in the Phola Airshed while residential fuel burning have the most significant air quality impact on ambient $PM_{2.5}$ levels in the Phola Airshed.

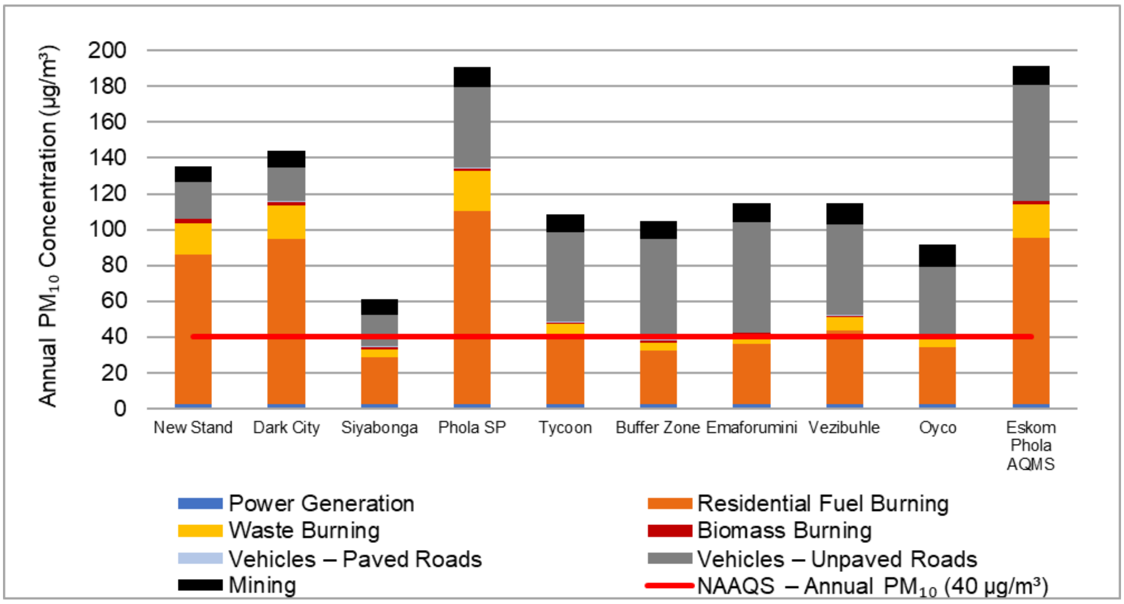

Figure iii: Stacked bar graph representing model predicted annual PM_{10} ambient concentrations in µg/m^3 at discrete receptors for the seven emission source categories

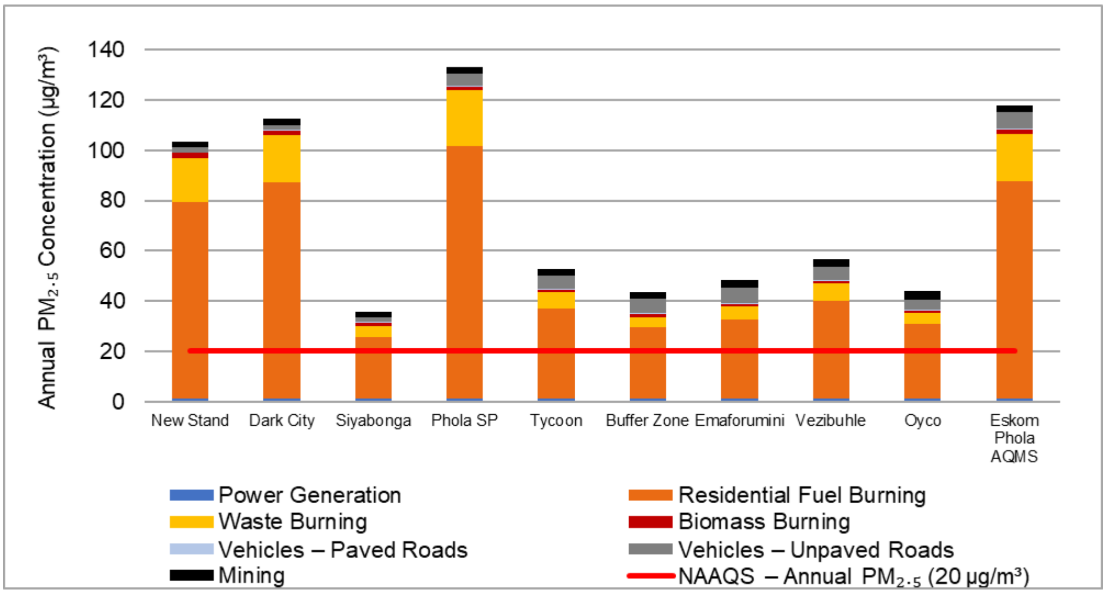

Figure iv: Stacked bar graph representing model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the seven emission source categories

3.3 Dustfall Rates

3.3.1 Greater Phola and Phola airshed

- The model predicted 24-hour dustfall rates are relatively high but below the National Dustfall Standard for both residential and non-residential areas, of 600 mg/m^2/day and 1 200 mg/m^2/day, respectively, throughout the Greater Phola and Phola modelling domains.

3.4 Air Quality Hotspots Identified In Phola

The health effects of airborne PM (PM_{10} & $PM_{2.5}$) have been extensively investigated (Dockery et al., 1993; Pope III et al., 2002; U.S. Environmental Protection Agency, 2004; Pope, 2007). PM has been strongly correlated to several adverse human health effects including exacerbation of chronic respiratory and cardiovascular diseases, decreased lung function. Thus, the prioritisation of air quality hotspots for Phola was ranked on the basis of PM air quality impacts from residential fuel burning emissions. This ensures that the areas that potentially pose the greatest risk to human health and the environment are prioritised in the roll-out of Eskom's AQO residential interventions in Phola. Subsequently a total of four air quality hotspots were identified in Phola (Figure v). It's noted that these hotspots are located at New Stand and Phola SP.

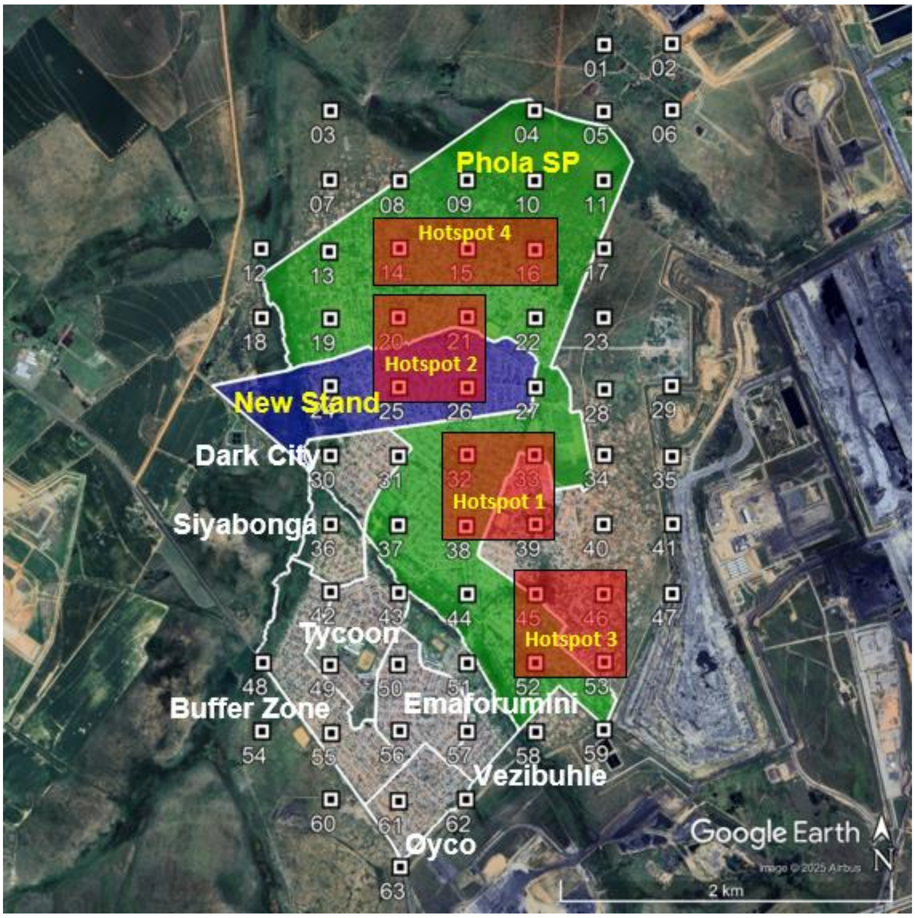

Figure v: Air quality hotspots identified for Phola

4. DISCUSSION

The model simulated results indicate that there are exceedances of the NAAQS for SO_2, NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) in the Phola airshed. An analysis of the source contribution analysis indicates that residential fuel burning and vehicles on unpaved roads have the most significant air quality impact on ambient PM_{10} levels in the Phola Airshed while residential fuel burning have the most significant air quality impact on ambient $PM_{2.5}$ levels in the Phola Airshed.

Although atmospheric dispersion models are indispensable in air quality assessment studies, their limitations should always be taken into account. In this study, the model predicted concentrations were compared with measured ambient data recorded at the Eskom Phola AQMS. The model validation exercise demonstrated that the model performance at the Eskom Phola AQMS is satisfactory, however it has under-predicted SO_2 and overpredicted NO_2, PM_{10} and $PM_{2.5}$.

The analysis of the ambient air quality monitoring data has indicated that both NO_2 and $PM_{2.5}$ are dominated by non-buoyant localised ground-level sources. NO_2 is conditioned by localised vehicle emissions whilst $PM_{2.5}$ is attributable to localised residential burning. To develop an emission inventory for the vehicles category, a number of assumptions had to be made based on best judgement. Furthermore, residential fuel burning and waste burning for the modelling was estimated based on energy use data at the sub place level for Phola using Statistics South Africa (Stats SA) 2016 Community Survey data. There is currently no finer resolution residential fuel burning or waste burning data for Phola. The model simulated results are therefore constrained by the granularity of this data. Thus, resulting in the model plausibly under-predicting herein.

5. CONCLUSION

In summary, this study has evaluated compliance with the applicable National Ambient Air Quality Standard (NAAQS) for SO_2, NO_X as NO_2, PM_{10}, $PM_{2.5}$ and National Dustfall Standard for dustfall rates. The study has demonstrated the exceedances of the NAAQS for SO_2, NO_2, PM_{10} and $PM_{2.5}$ at Phola and highlighted the contribution of residential fuel burning emission sources herein, as well as the important contribution made by unpaved roads to ambient PM_{10}. Hence there is an opportunity herein to reduce human exposure to harmful levels of particulate air pollution by reducing emissions from residential burning in Phola. Thus, supporting the roll-out of Eskom's PMV air quality offset intervention project in Phola.

ARM recommends that Eskom considers further investigating the potential PM_{10} air quality impact of unpaved roads in the Phola airshed. Addressing this issue may result in a greater overall improvement of general ambient air quality in the affected areas. Its noted that Eskom has piloted an ash polymer road at Kusile with good success. This could potentially be an affordable AQO intervention to stabilise the road and prevent dust. However the economic feasibility & viability of this potential AQO intervention will need to be tested by Eskom.

The prioritisation of air quality hotspots for Phola was ranked on the basis of PM air quality impacts. This ensures that the areas that potentially pose the greatest risk to human health and the environment are prioritised in the roll-out of Eskom's AQO program in Phola. Subsequently a total of four air quality hotspots were identified in Phola. Based on these study results, ARM recommends that Eskom considers the rollout of Eskom's AQO household intervention in Phola should prioritise the New Stand and Phola SP areas initially.

1. INTRODUCTION

1.1 Air Quality Offsets Guideline

An environmental offset is an action(s), designed to compensate for a negative environmental impact of resource use, a discharge, emission, or other activity. The Department of Environment, Forestry & Fisheries (DEFF) defines air emission offsets as an intervention, or interventions, specifically implemented to counterbalance the adverse and residual environmental impact of atmospheric emissions in order to deliver a net ambient air quality benefit within, but not limited to, the affected Airshed where ambient air quality standards are being or have the potential to be exceeded and whereby opportunities and need for offsetting exist (Notice 333 of 2016).

1.2 ESKOM'S Approach to Air Quality Offsets

DEFF's Air Quality Offset Guideline has shaped and informed Eskom's Air Quality Offsets Implementation Plan. This Plan has been based on a scientific process of feasibility studies, testing and demonstration, and on consultation with key stakeholders. Figure 1-1 illustrates the concept schedule for the phased implementation of Eskom's air quality offsets.

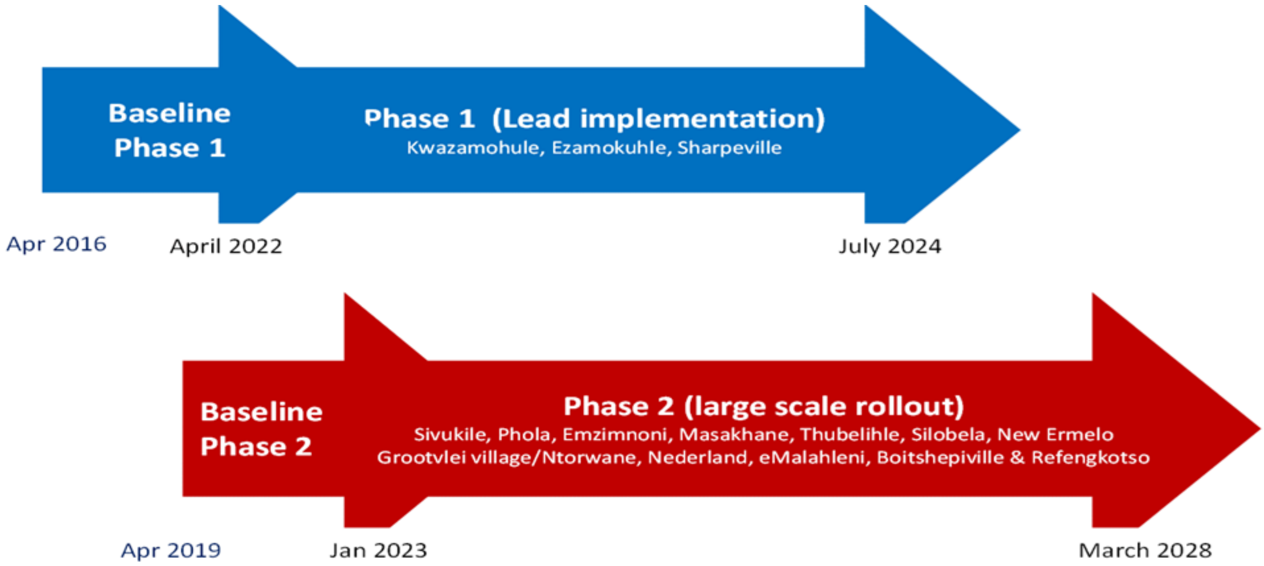

Figure 1-1: Concept Schedule for the implementation of Eskom's air quality offsets (Matimolane, 2023)

Eskom has adopted the phased approach (Figure 1-2) herein to increase the probability of success and to ensure that learnings from early phases are incorporated into the large-scale roll-out. (Matimolane, 2020).

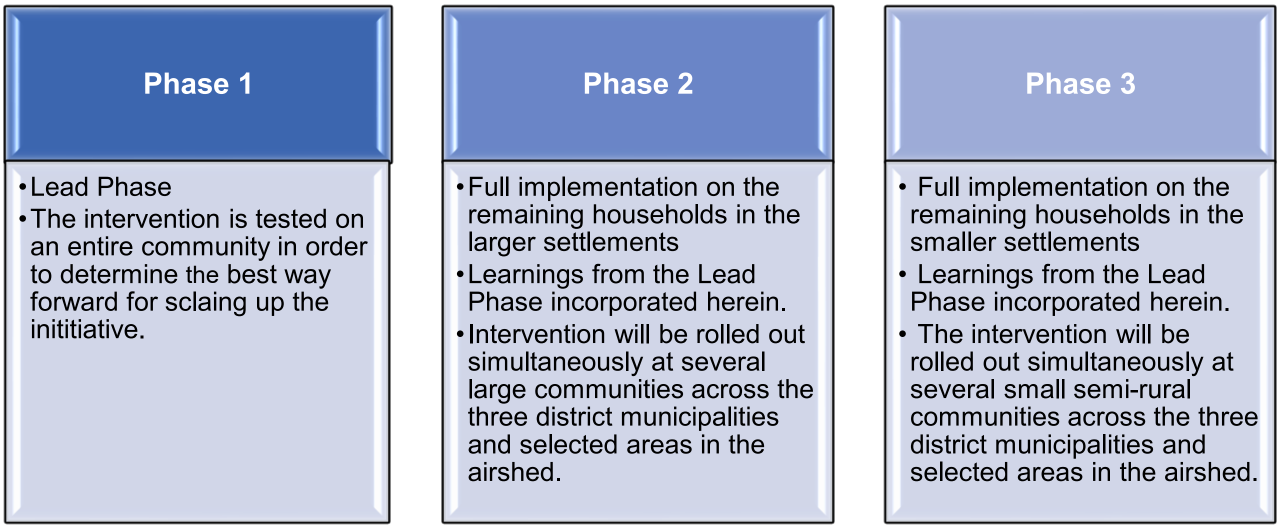

Figure 1-2: Eskom's Phased approach to the rollout of air quality offset interventions (Matimolane, 2020).

Eskom's air quality offsets programme is designed to reduce human exposure to harmful levels of air pollution by reducing emissions from local sources, like domestic coal burning and waste burning. Thus, air quality offsets can improve ambient air quality in low-income communities in the vicinity of Eskom's power stations. Eskom's air quality offsets programme is designed to reduce human exposure to harmful levels of air pollution by reducing emissions from local sources, like domestic coal burning and waste burning. Thus, air quality offsets can improve ambient air quality in low-income communities in the vicinity of Eskom's power stations.

1.3 ESKOM'S PLANNING, MONITORING AND VERIFICATION (PMV) PROJECT

As part of phase 2 of the Eskom's air quality offset (AQO) programme, Phola is the main focus of Kendal Power Station's Air Quality Offset Intervention. Phola has an estimated population of 31, 885 (based on 2011 census). The estimated number of household earmarked to receive AQO intervention is 6700.

For Eskom's PMV Phase 2 Project, interventions to reduce household emissions from domestic coal/wood burning will be rolled out in Phola, located in the Mpumalanga Highveld. For formal dwellings the intervention will be a thermal insulation retrofit and an electricity starter pack and installation. Air Resource Management (ARM) (Pty) Ltd has been appointed by Eskom to support in the Planning monitoring and Verification (PMV) services of Air Quality Offset Phase 2 Project for a period of four (4) years at Phola in the Mpumalanga Province. The overall objective of Eskom's AQO Phola PMV study is to assist with the planning of the offset interventions to minimize implementation risk, increase practical and scientific knowledge, and develop and refine monitoring, reporting and verifications processes. To achieve this, Eskom has included eight targeted work package activities (Table 1) for Phola.

Table 1-1: Eskom Phola PMV Study

Activity no.	Description	Year 1	Year 2	Year 3	Year 4
1.	**Ethical clearance**	Initial report	Update report	Update report	Update report
2.	**Area intelligence**	Inception	Year 2 report (Less in-situ assessment & fuel survey)	Year 3 report (Less in-situ assessment & fuel survey)	Year 4 report
3.	**Household survey (baseline)**	Initial report			Year 4 report
4.	**Ambient Air Quality Monitoring**	Initial report	Year 2 report	Year 3 report	Year 4 report
5.	**Emission inventory**	Initial report	Year 2 report	Year 3 report	Year 4 report
6.	**Air quality modelling**	Initial report	Year 2 report	Year 3 report	Year 4 report
7.	**Project effectiveness review**	Initial report	Year 2 report	Year 3 report	Year 4 report
8.	**Database and Reporting**	Initial report	Year 2 report	Year 3 report	Year 4 report

1.4 Scope of Work

In accordance with the scope of work, for *Activity 6: Air Quality Modelling*, ARM must develop and run appropriate dispersion model(s) to predict ambient PM, SO_2 and NOx levels in Phola. Further the model shall comply with DFFE's modelling framework and Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (Gazette No 37804, 2014).. The focus of this study is on the baseline (year 1) air quality modelling for Phola (Figure 1-3).

Figure 1-3: Locality Map for Phola

1.5 STUDY OBJECTIVE

The main objective of this study is to use results of the dispersion modelling to inform Eskom's Air Quality Offsets Implementation Plan. This is done by firstly compiling a comprehensive emission inventory for a number of emission source categories which include power generation, residential fuel burning, waste burning, biomass burning, vehicles travelling on paved roads, vehicles travelling on unpaved roads and mining, and then assessing the contribution of each emission source to the ambient concentrations in the study area, with a strong focus on PM.

The second objective of this study is to assess the modelled ambient concentrations of SO_2, NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) against the respective National Ambient Air Quality Standards NAAQS (Table 1-2). Additionally an assessment of the modelled dustfall rates are evaluated against the National Dustfall Standard. The National Dust Control Regulations were published on 1 November 2013 (DEA, 2013b). It lists guidance on the requirements for monitoring dust fallout and provides limit values for acceptable dustfall rates for residential and non-residential areas (Table 1-3).

Table 1-2: NAAQS in μg/m^3 for SO_2, NO_2, PM_{10} (DEA, 2009) and $PM_{2.5}$ (DEA, 2012)

Pollutant	Averaging Period	Limit value (μg/m³)	Limit value (ppb)	Permitted frequency of exceedance	Compliance Date
Sulphur Dioxide (SO_2)	10 minutes	500	191	526	Immediate
	1 hour	350	134	88	Immediate
	24 hour	125	48	4	Immediate
	1 year	50	19	0	Immediate
Nitrogen Dioxide (NO_2)	1 hour	200	106	88	Immediate
	1 year	40	21	0	Immediate
Inhalable particulate matter less than 10 μm in diameter (PM_{10})	24 hour	75		4	Immediate
	1 year	40		0	Immediate
Inhalable particulate matter less than 2.5 μm in diameter ($PM_{2.5}$)	24 hour	40		4	Immediate
	24 hour	25		4	1 January 2030
	1 year	20		0	Immediate
	1 year	15		0	1 January 2030

Table 1-3: National limit values for dustfall rates in mg/m^2/day as a 30-day average (DEA, 2013b)

Area	Dustfall rate (D)	Permitted frequency of exceedance
Residential	D < 600	Two within a year, not in sequential months
Non-residential	600 < D < 1 200	Two within a year, not in sequential months

2. GENERAL DESCRIPTION OF AREA

2.1 LOCATION

The township of Phola lies approximately 4 km north of the town of Ogies within the Emalahleni Local Municipality, Nkangala District Municipality in the Mpumalanga Province, South Africa (Figure 1-3). According to the Census 2011 data, Phola has an area of 6.35 km^2 with a population of 31,885 (5,024.24 per km²) and has 8,913 households (1,404.46 per km²) (StatsSA, 2012).

2.2 TOPOGRAPHY AND LAND USE

2.2.1 TOPOGRAPHY

The Australian CSIRO Atmospheric Research Division, The Air Pollution Model (TAPM) was used to determine the topographical terrain map for the study area (Figure 2-1). The global terrain height and land use datasets are sourced from the US Geological Survey (USGS), Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC). The topography of the area is relatively flat with a generally uniform terrain.

2.2.2 LAND USE

For atmospheric dispersion modelling an understanding of the land use information is critical. Based on this information, appropriate chemical transformation mechanisms, dispersion coefficients, albedo, surface moisture and surface roughness are selected for the modelling assessment. The classification of a site as urban or rural is based on the Auer method specified in the United States Environmental Protection Agency (USEPA) guideline on air dispersion models (USEPA, 2005). The classification scheme is based on activities within a 3 km radius of the emitting source.

From the Auer's method, areas typically defined as rural include residences with grass lawns and trees, large estates, metropolitan parks and golf courses, agricultural areas, undeveloped land and water surfaces. An area is defined as urban if it has less than 35% vegetation coverage or the area falls into one of the land use types in Table 2-1.

A land cover map of the study area is presented in Figure 2-2. Based on the Auer's assessment method detailed above, the study area is classified as rural as the emitting sources are located throughout the modelling domain.

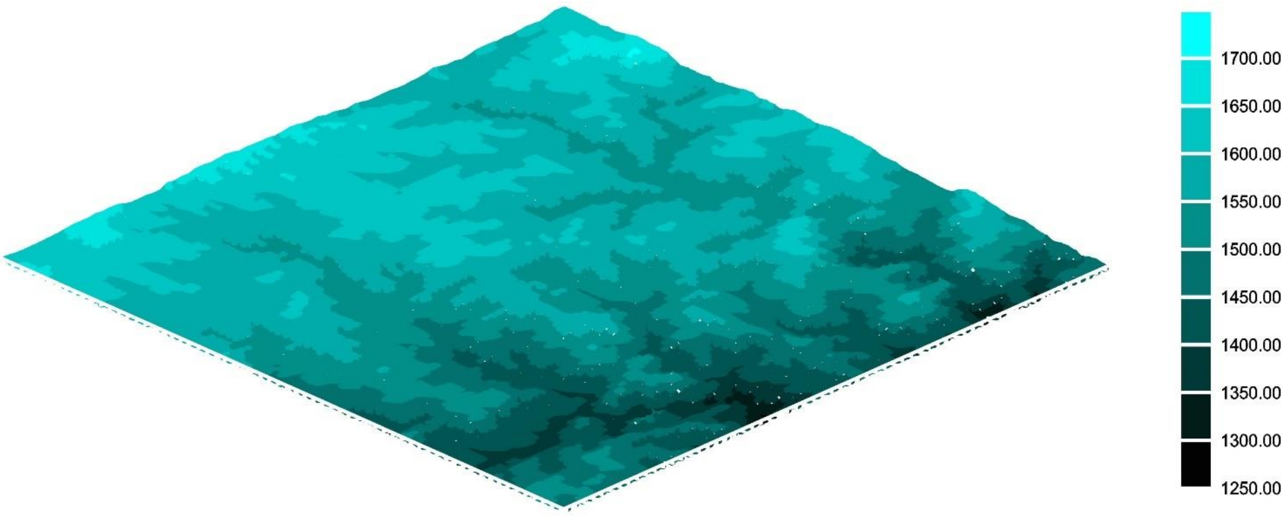

Figure 2-1: Topography of the Study Area

Table 2-1: Land types, use and structures and vegetation cover

Urban Land Use		
Type	**Land Use and Structures**	**Vegetation**
I1	Heavy industrial	Less than 5 %
I2	Light/moderate industrial	Less than 5 %
C1	Commercial	Less than 15 %
R2	Dense single / multi-family	Less than 30 %
R3	Multi-family, two-story	Less than 35 %

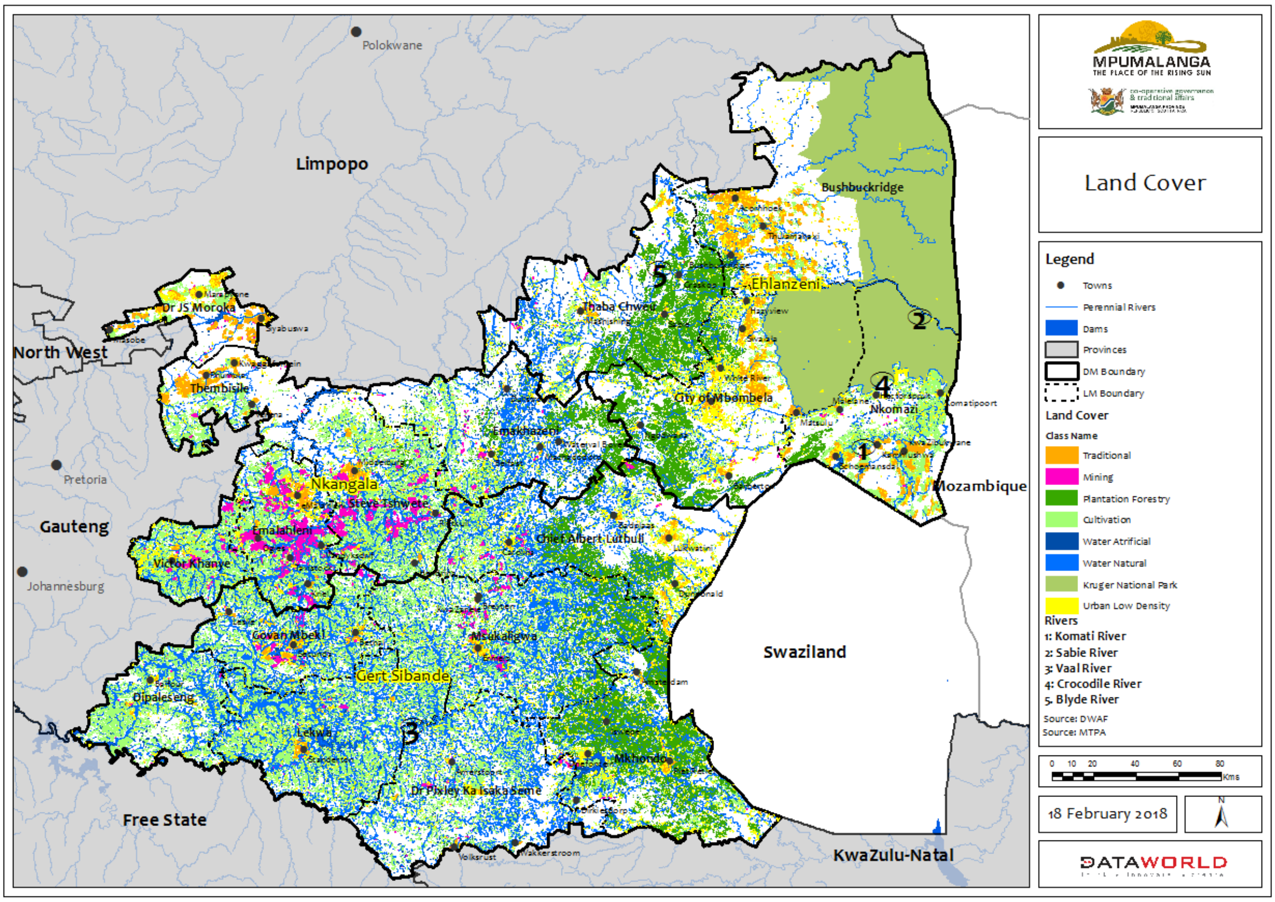

Figure 2-2: Land cover for Mpumalanga (Source: Mpumalanga Spatial Development Framework, 2019)

2.3 Climate and Meteorology

The Highveld experiences a temperate climate with dry winters according to the Köppen Climate Classification system (Köppen, 1884). The winters are mild and dry, but cold at night. Rainfall occurs in summer. The rain is largely due to the development of low-pressure troughs over the central plateau in summer whilst the dry winters are due to the dominant subtropical high-pressure system. The temperate temperatures are attributed to the relatively high altitude (DEFF, 2010).

2.3.1 Rainfall and Temperature

The mean monthly rainfall totals recorded at the Eskom Phola Air Quality Monitoring Station (AQMS) for the period 2021 to 2023 is presented in Figure 2-3. It is noted that rainfall occurs predominantly from September to May, with the maximum in November. The region received a mean annual rainfall of ~455 mm for the period 2021 to 2023. Average temperatures for the area are mild throughout the year with slightly cooler temperatures in winter. The long-term average (2021-2023) maximum temperature is 31.7°C in summer and 25.9°C in winter, with extreme maxima of 33.9°C in summer and 25.9°C in winter. The long-term minimum, maximum and mean temperatures observed at the Eskom Phola AQMS station is presented in Figure 2-3.

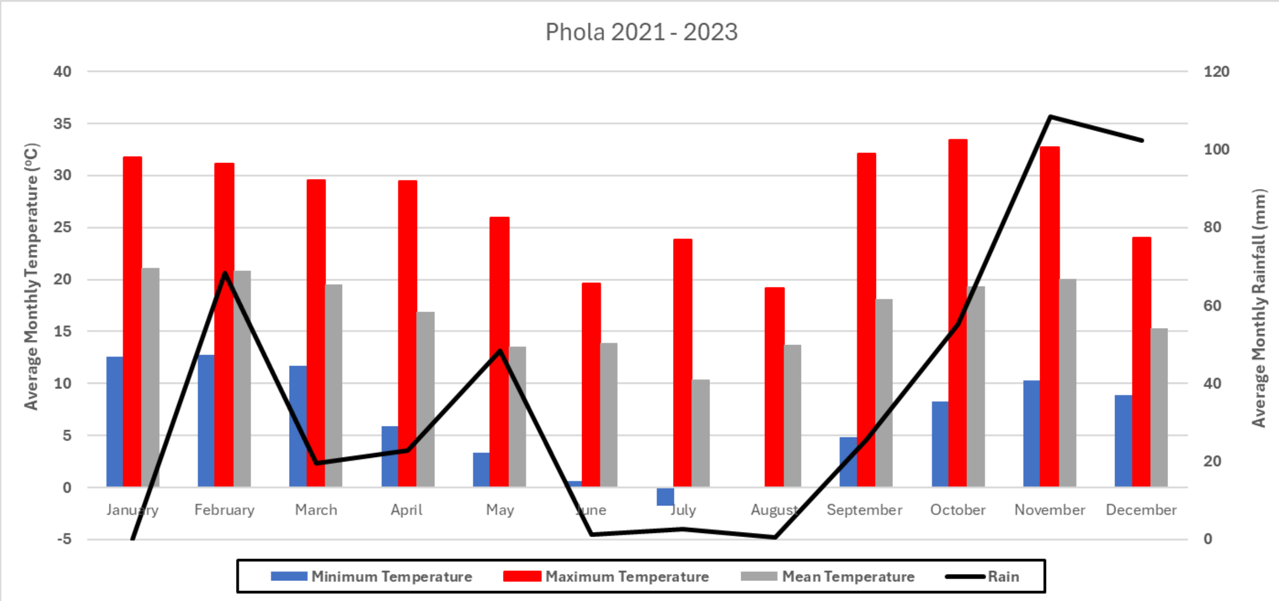

Figure 2-3: Average monthly maximum, minimum and mean temperatures and average monthly rainfall recorded at the Eskom Phola AQMS

2.3.2 Surface and Near-Surface Winds

Air quality is strongly influenced by meteorology. Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere (Seaman, 2000). The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. The horizontal dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and rate of pollutant dilution. The wind rose is a useful way of showing how wind speed and wind direction conditions vary by year.

Wind Direction

At the Eskom Phola AQMS, the average wind speed for the period 2021-2023 was recorded at 2.2 m/s with calm condition at 0% (Figure 2-4). Calm condition means that wind speed is recorded at 0 m/s (Carlaw, 2015). The predominant wind directions were northerly (~18% frequency of occurrence) followed by north easterly and southerly (~ 15% frequency of occurrence) with maximum wind speed of 5-8 meters/second in the northerly direction.

The wind speed and direction data for the period 2021-2023 also demonstrates a seasonal signal at the Eskom Phola AQMS (Figure 2-5). For the spring and summer months, the average wind speed was recorded at ~2.5 m/s, with predominant wind directions of northerly winds (~ 20% frequency of occurrence for the period) followed by both a south easterly and easterly wind (~15% frequency of occurrence for the period). For the autumn and winter winds, the average wind speed was recorded between ~ 1.9 m/s with the predominant wind direction of a southeasterly wind (~15% frequency of occurrence for the period) followed by a southerly wind (~10% frequency of occurrence for the period).

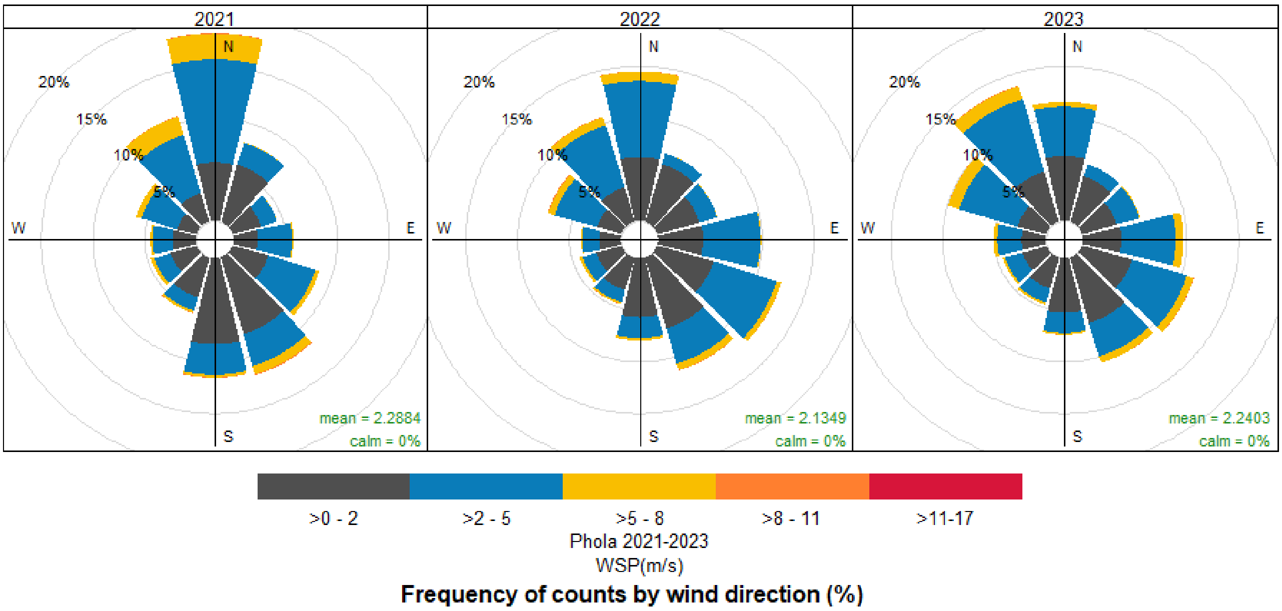

Figure 2-4: Annual wind rose for the Eskom Phola AQMS for the period 2021 to 2023

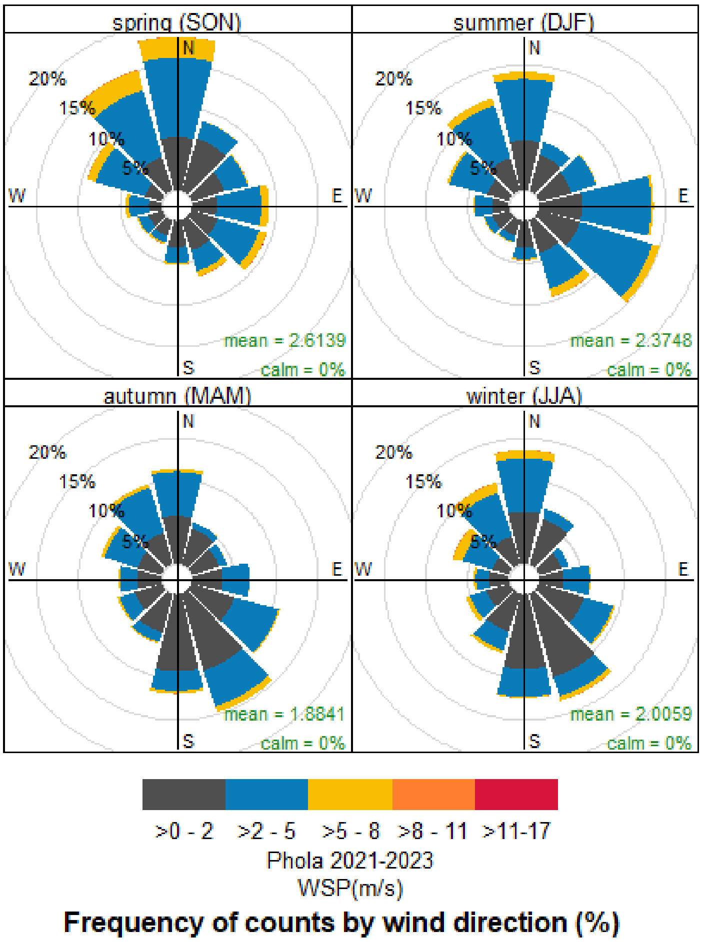

Figure 2-5: Seasonal wind rose for the Eskom Phola AQMS for the period 2021 to 2023

WIND SPEED

Wind drives the atmospheric transport and strongly affects vertical mixing and thus the ventilation of the urban air (Grundstrom et al., 2015). Stagnant atmospheric conditions with calm, clear weather often leads to stable atmospheric stratification which then leads to poor air quality (Delaney and Dowding, 1998; Janhall et al., 2006; Olofson et al., 2009). Low wind speeds leads to restricted air ventilation and may cause ambient air quality to deteriorate particularly when pollutants are emitted near ground level (Jones et al., 2010). In contrast, high wind speeds are associated with increased dispersion and mixing of atmospheric pollutants which may result in low ambient pollution concentrations.

Monthly wind speed averages for the Eskom Phola AQMS is presented in Figure 2-6. For the period January to May, the wind speed pattern shows a general decrease in values with low averages recorded until July. This is associated with less mixing and dispersion of pollutants which may result in elevated ambient concentrations particularly during winter (Liebenberg, 1999). Conversely, there is an increase in wind speeds from August to November. This is associated with increased dispersion and mixing of atmospheric pollutants which may result in lower ambient pollution concentrations in the spring and summer months.

Diurnal wind speed averages for the Eskom Phola AQMS is presented in Figure 2-7. Lower wind speeds are logged from 19h00 to 05h00. This is associated with elevated atmospheric pollution concentrations due to less mixing and dispersion. The wind speeds then increase from 06h00 to 15h00. This is associated with lower pollution concentrations influenced by an increase in the mixing and dispersion of atmospheric pollutants (Liebenberg, 1999).

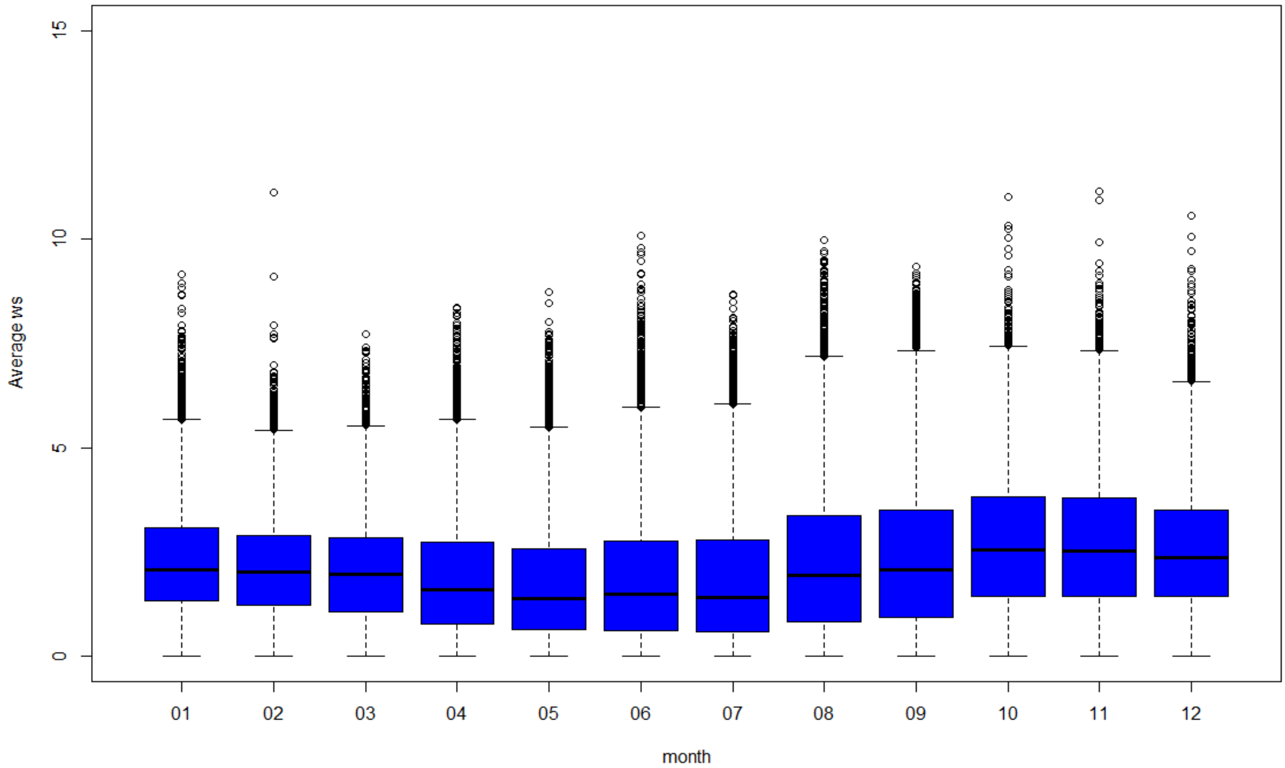

Figure 2-6: Monthly wind speed averages for the Eskom Phola AQMS (box and whisker plot indicates interquartile range, diamond indicate outliers and bars indicate the min and max value)

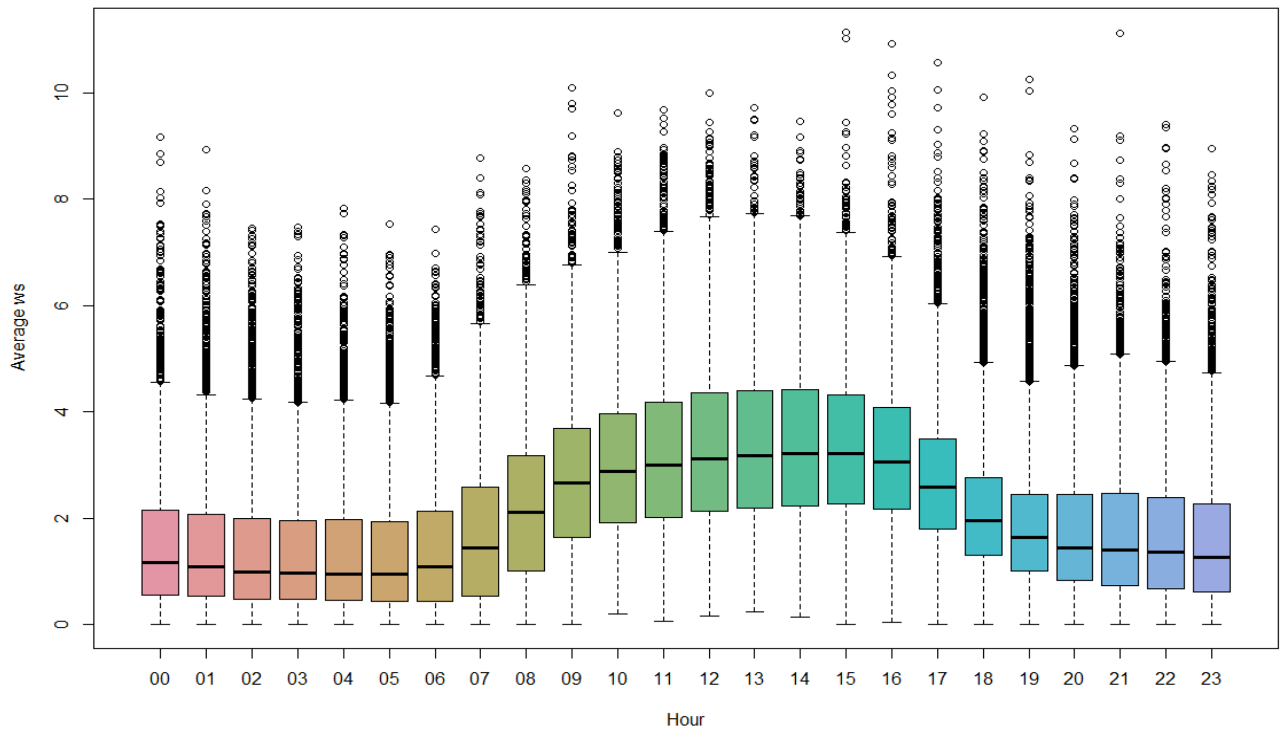

Figure 2-7: Diurnal wind speed averages for the Eskom Phola AQMS (box and whisker plot indicates interquartile range, diamond indicate outliers and the bars indicate the min and max value)

2.3.3 Dispersion Potential

The extent to which synoptic systems and weather disturbances impact on the dispersion potential of the atmosphere depends on the height and persistence of elevated temperature inversions. Elevated inversions reduce the height at which pollutants are able to mix, and consequently results in the accumulation of pollutants between the surface and the base of the inversion layers. These inversions therefore play a key role in the recirculation of pollutants as well as controlling long-range transport.

The southern African subcontinent is under the influence of a semi-permanent sub-tropical anticyclone. They are dominant in mid-winter with a frequency of occurrence of 80% as opposed to 20% in summer (Garstang et al., 1996). These high-pressure systems are associated with large-scale subsidence inversions which has a considerable influence on the accumulation of trace gases and aerosols in the troposphere (Garstang et al., 1996; Swap and Tyson, 1999). The presence of subsidence induced semi-permanent absolutely-stable layers at altitudes of approximately 700 hPa (~3 km), 500 hPa (~5 km) and 300 hPa (~7 km) (Figure 2-8), were identified over southern Africa by Cosijn and Tyson (1996) and Freiman and Tyson (2000). The horizontal and vertical transport of aerosols between the surface and the tropopause is controlled by these stable layers (Garstang et al, 1996). The lower level elevated subsidence inversion is significant in that it represents a persistent cap impeding the upward mixing of air pollutants (DEFF, 2007).

Convective activity hinders the formation of inversions. Whilst cyclonic disturbances are usually associated with the dissipation of inversions, pre-frontal conditions tend to lower the base of the elevated inversion, thus reducing the mixing depth. After the passage of a cold front, there is a gradual increase in the mixing depth (Scott and Diab, 2000).

For Phola, the dispersion potential is anticipated to be better during the day due to higher daytime temperatures and a higher frequency of moderate wind speeds. In addition, summer months will have a better dispersion potential than the winter months due to a higher frequency of stronger winds, higher rainfall, stronger thermal mixing, weaker and less persistent night-time temperature inversions.

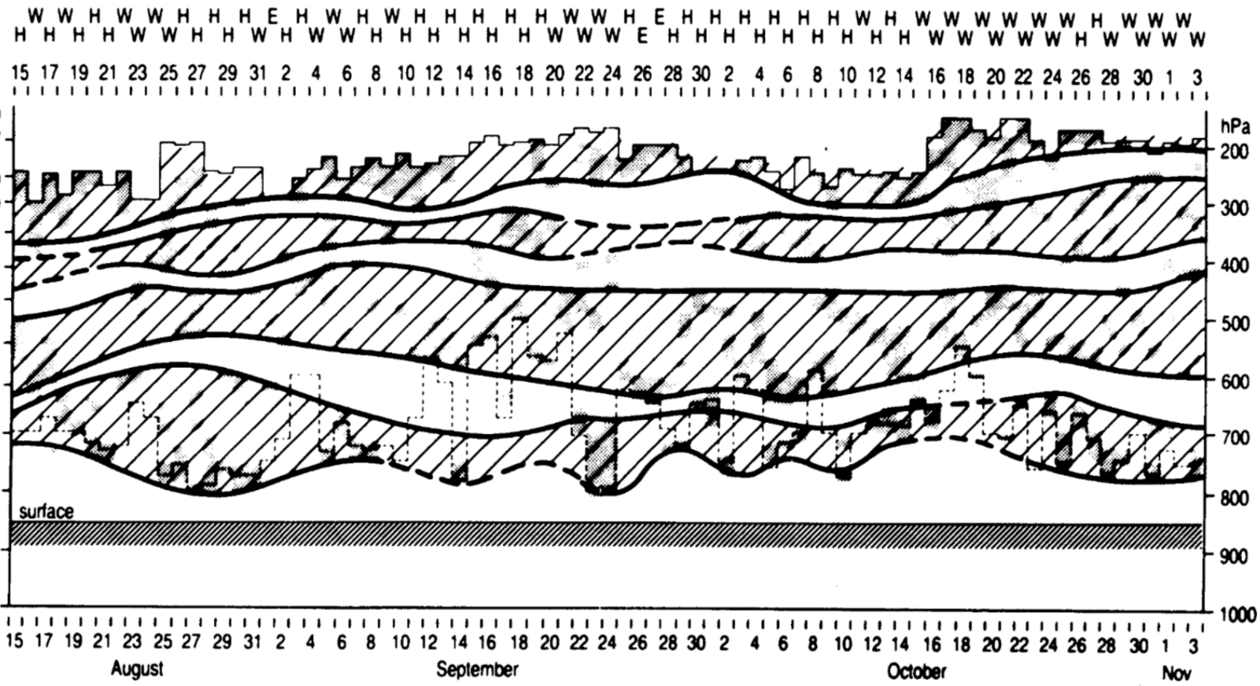

Figure 2-8: Daily variation of absolutely stable layers over Pretoria (southern Africa) during SAFARI-92. Stippled boxes indicate the height and depth of stable layers. Envelopes of continuous and discontinuous stable layers are indicated by cross-hatched regions enclosed by solid and dashed lines respectively. Light dashed lines depict the height of the 1200UT mixing depth. Circulation class for each day is shown by H (continental high), W (westerly disturbance) and E (easterly disturbance) (Source: Garstang et al., 1996: p 23724)

2.4 Ambient Air Quality Monitoring Analysis

The Openair air quality model was used to statistically analyse the semi-empirical mathematical relationships between air pollutant concentration and meteorological factors for the Eskom Phola AQMS for the period 1 January 2021 to 31 December 2023.

2.4.1 Trend analysis plot

The trend analysis (mean with 95% confidence interval) of ambient pollutant concentrations measured at the Eskom Phola AQMS show the variation of these pollutants over daily, weekly and annual cycles for the period 2021-2023.

Mean pollutant concentrations for the Eskom Phola AQMS for the hourly mean during weekdays, a single day, monthly and daily mean for the period 2021-2023 is presented in Figure 2-9 for SO_2 and NO_2; and in Figure 2-10 for particulate matter (PM_{10}).

SO_2 displays a typical industrial signature with increased SO_2 concentrations just around midday due to the break-up of an elevated inversion layer, in addition to the development of daytime convective conditions causing the plume to be brought down to ground level and relatively close to the point of release from tall stacks. The elevated SO_2 levels in winter (June, July and August) indicates the contribution of residential fuel burning at the Eskom Phola AQMS. It is also evident that there is a pronounced peak (compared to the midday values), that occurs at 18h00 in winter (peaking in the months of May and July) which indicates the impact of residential fuel burning.

The variability of NO_2 clearly shows that it is highly influenced by vehicle emissions. Daily and weekly variation corresponds to the cyclical nature of traffic volumes with marked peaks in concentration on weekdays around the early-morning and late-afternoon rush-hour. NO_2 concentrations plotted by time-of-day shows a clear rise in concentrations corresponding to the peak of the morning rush-hour at around 06h00 and a second less marked rise with the evening rush-hour, peaking at around 19h00. The elevated NO_2 levels in winter (June, July and August) indicates the contribution of residential fuel burning at the Eskom Phola AQMS.

The particulate matter morning peak occurs at 06h00 while the evening peak occurs at 18h00. This is a typical profile for residential fuel burning. The morning peak reduces towards midday as the inversion layer rises and improves the mixing height of the planetary boundary layer. Monthly variation of particulate matter shows elevated concentrations during early winter months to early spring (May to September) due to the greater contribution from residential fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall.

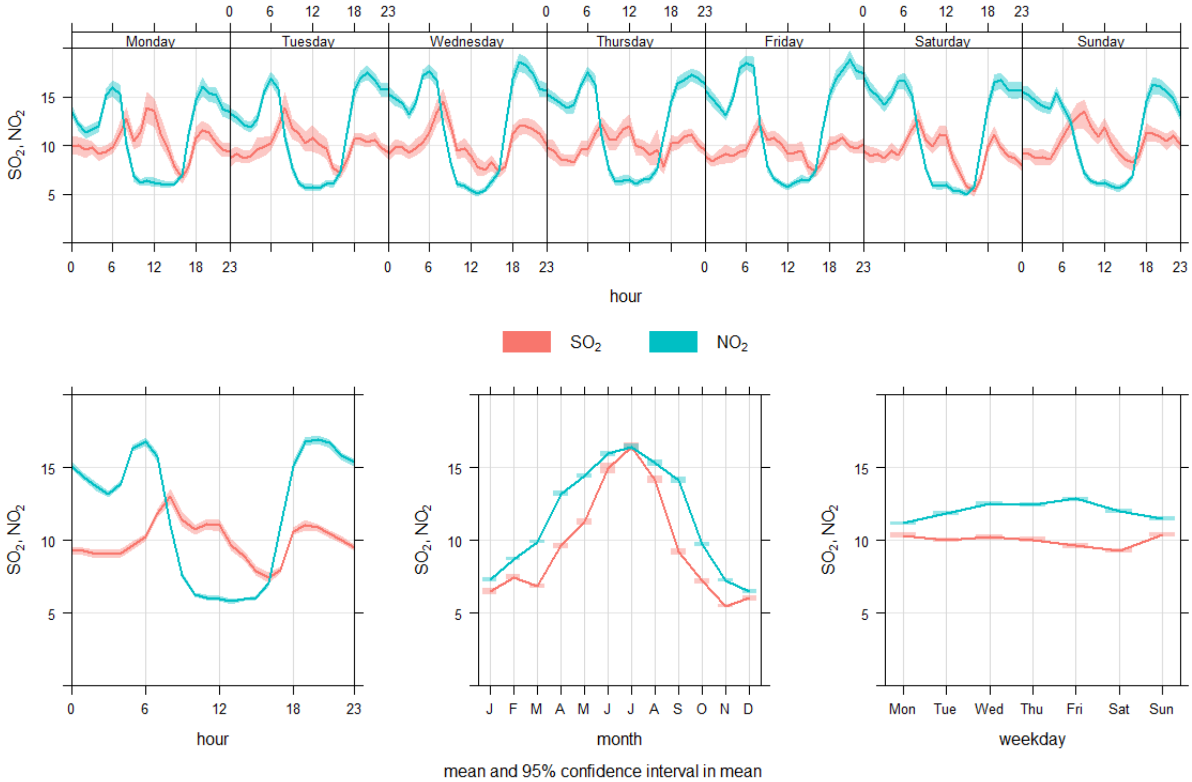

Figure 2-9: Mean pollutant concentrations in ppb for the Eskom Phola AQMS for the hourly mean during weekdays, a single day, monthly and daily mean for the period 2021-2023 for SO_2 and NO_2

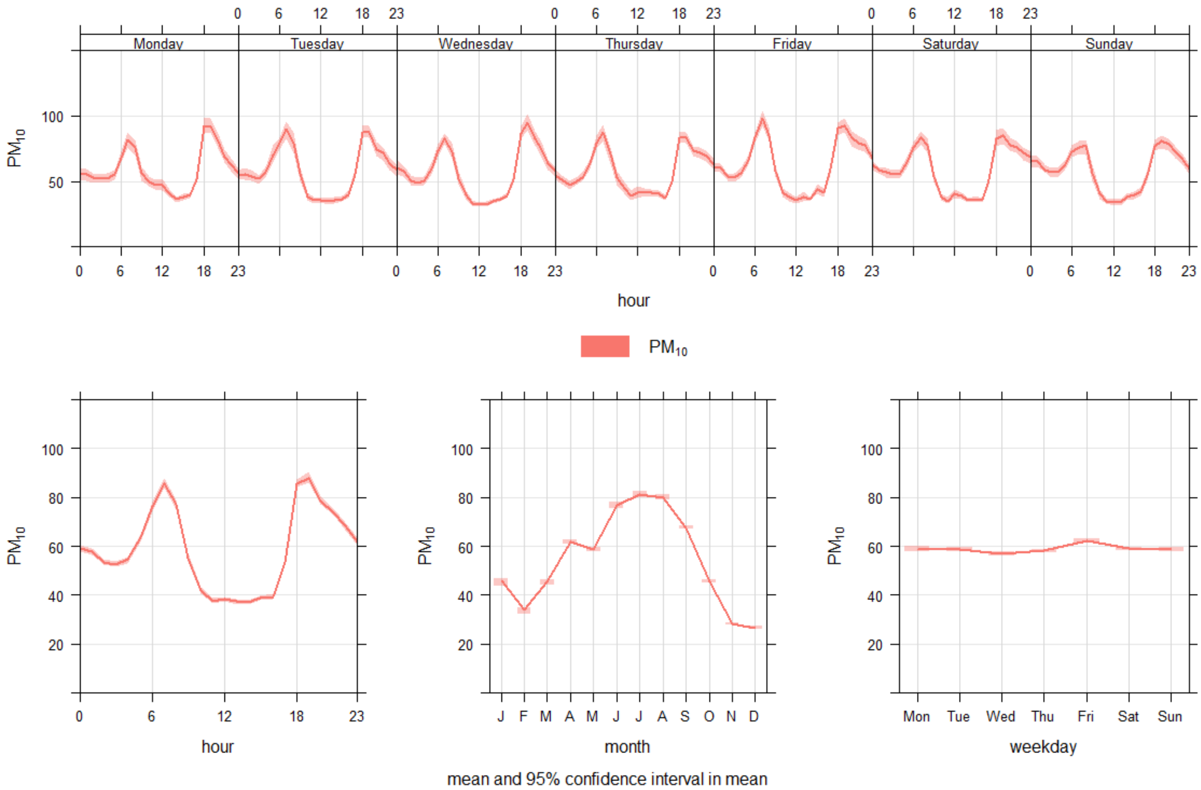

Figure 2-10: Mean pollutant concentrations in µg/m³ for the Eskom Phola AQMS for the hourly mean during weekdays, a single day, monthly and daily mean for the period 2021-2023 for PM_{10}

2.4.2 Time series analysis

A summary of ambient data measured at the Eskom Phola AQMS for the period 2021-2023 is presented in Table 2-2. Exceedances of the NAAQS is shown in red text

Table 2-2: Summary of ambient air quality measurements at the Eskom Phola AQMS

Station	Year	Maximum Measured Pollutant Measurement			
		SO_2 (ppb)		NO_2 (ppb)	PM_{10} (µg/m^3)
		Hourly	Daily	Hourly	Daily
	NAAQS	**134**	**48**	**106**	**75**
Eskom Phola AQMS	2021	136	42.6	72.8	42.6
	2022	235	50.1	64.6	138
	2023	186	52.4	65.2	178

Time-series graphs for measured concentrations at the Eskom Phola AQMS for the period 2021 to 2023 is presented in Figure 2-11 and Figure 2-12 for hourly and daily SO_2 concentrations respectively, in Figure 2-13 for hourly NO_2 concentrations, and in Figure 2-14 for daily $PM_{2.5}$ concentrations.

The hourly 99th percentiles for SO_2 were above the limit value of 134 ppb on numerous occasions during the 2021 to 2023 period. These exceedances occur in the months of May, June, July and August just around the evening. Additionally, the hourly SO_2 polar plot for the Eskom Phola AQMS (Figure 2-15) further shows a typical local residential fuel burning signature with increased SO_2 concentrations in the evening. It is evident that daily SO_2 concentrations exceeded the NAAQS limit value of 48 ppb on two occasions during the entire period.

Hourly NO_2 concentrations clearly indicate that there were no recorded exceedances of the NAAQS standard of 106 ppb.

The NAAQS for the daily PM_{10} limit (75 µg/m^3) was exceeded on numerous occasions mainly in the winter months, with morning peak concentrations occurring at 06h00 and evening peaks occurring at 18h00, which is a typical profile for residential fuel burning.

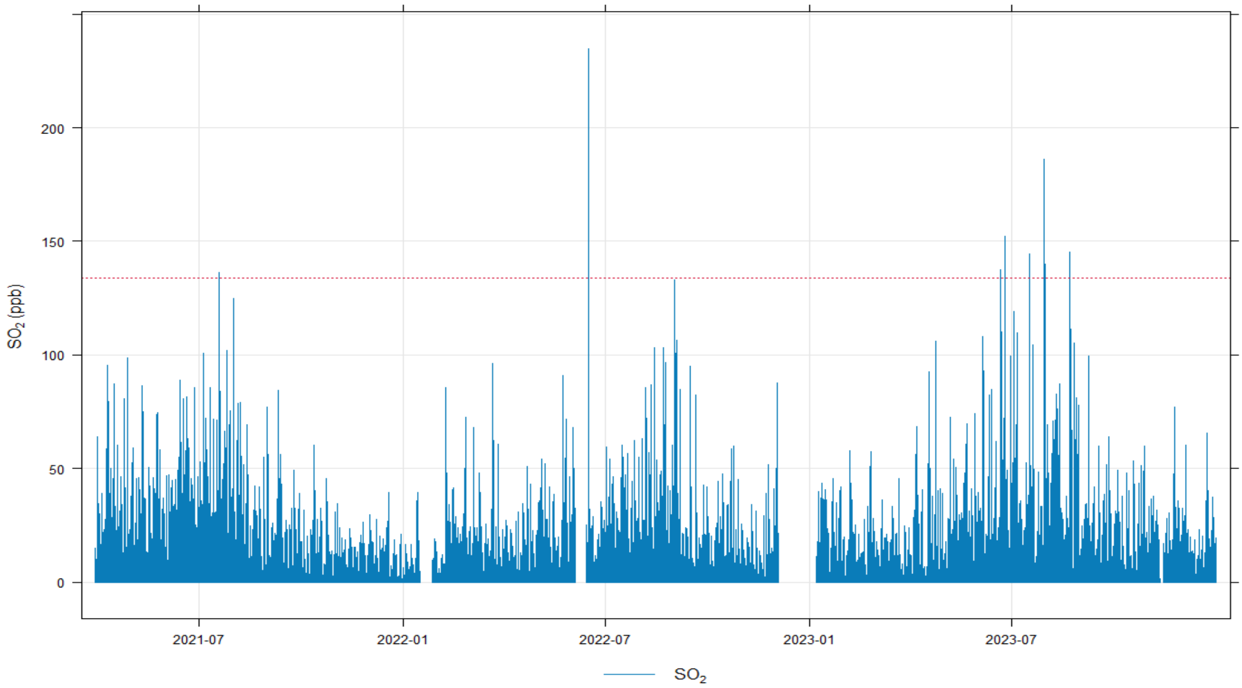

Figure 2-11: Time series for hourly SO_2 ground level concentrations measured at the Eskom Phola AQMS (2021-2023)

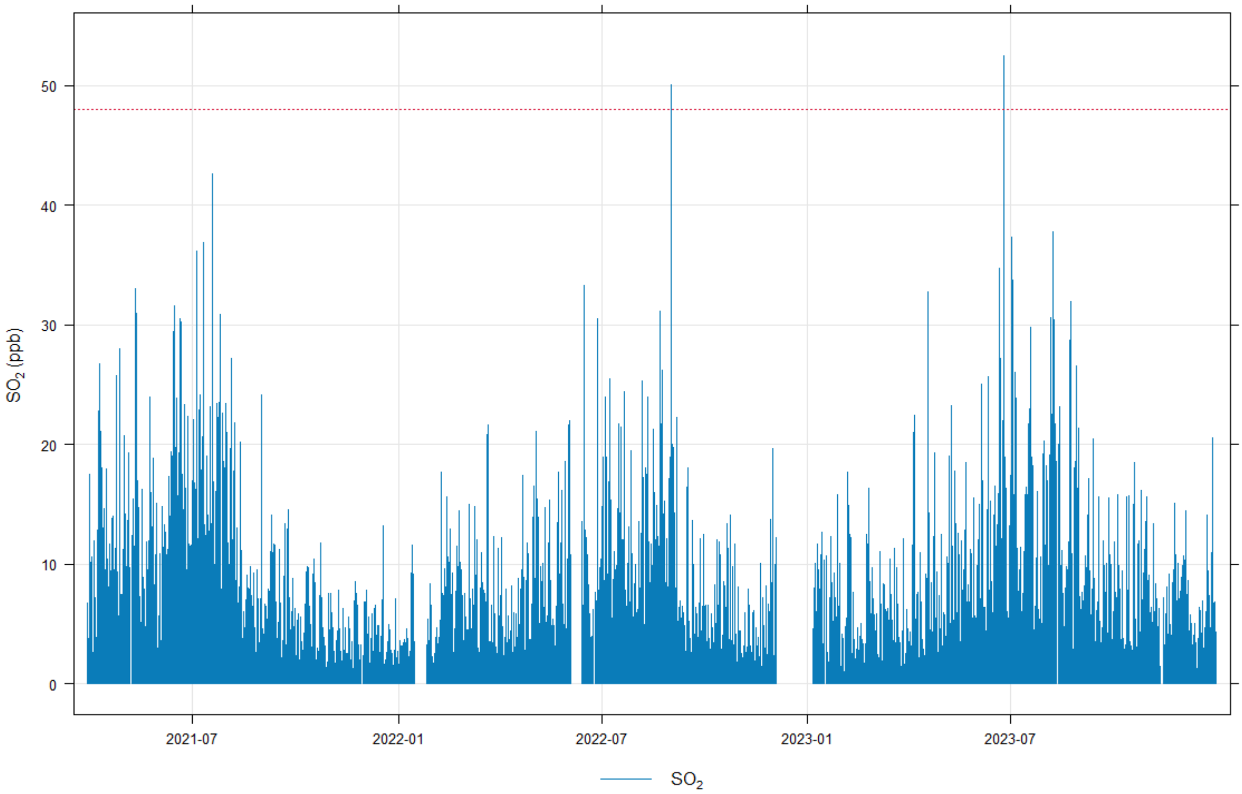

Figure 2-12: Time series for daily SO_2 ground level concentrations measured at the Eskom Phola AQMS (2021-2023)

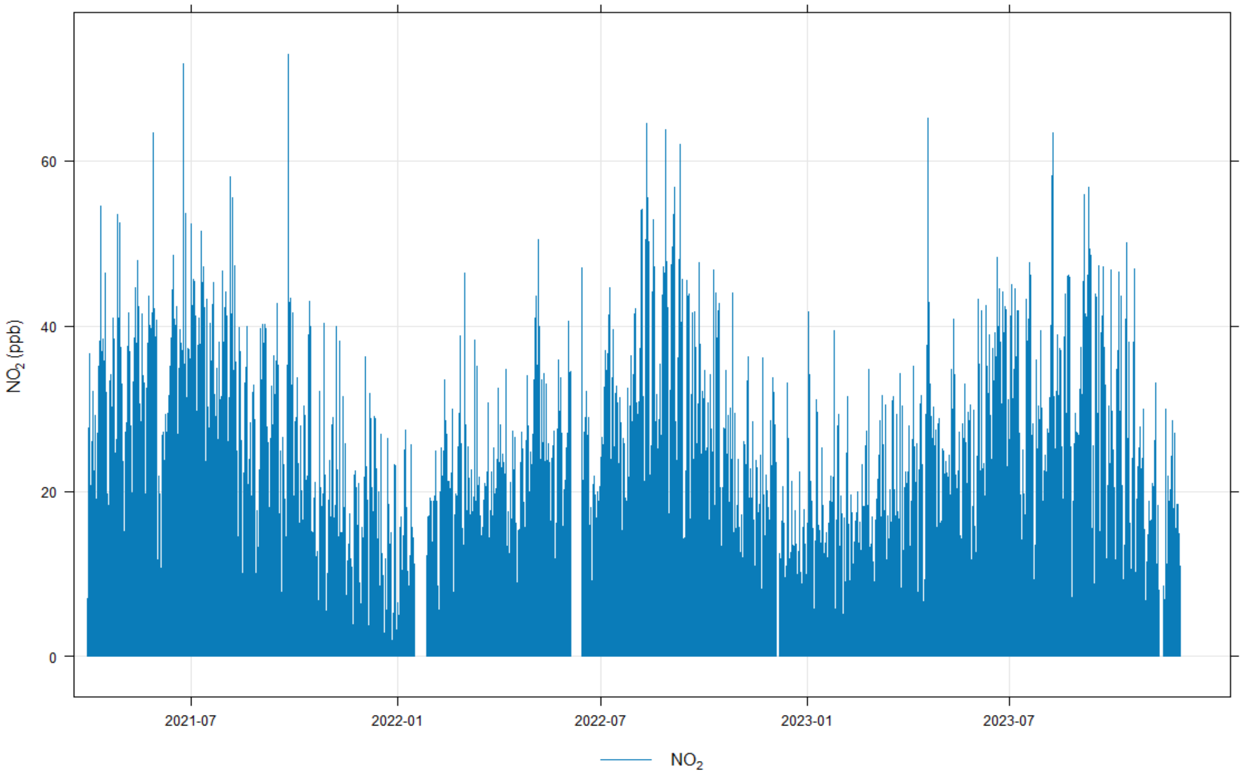

Figure 2-13: Time series for hourly NO_2 ground level concentrations measured at the Eskom Phola AQMS (2021-2023)

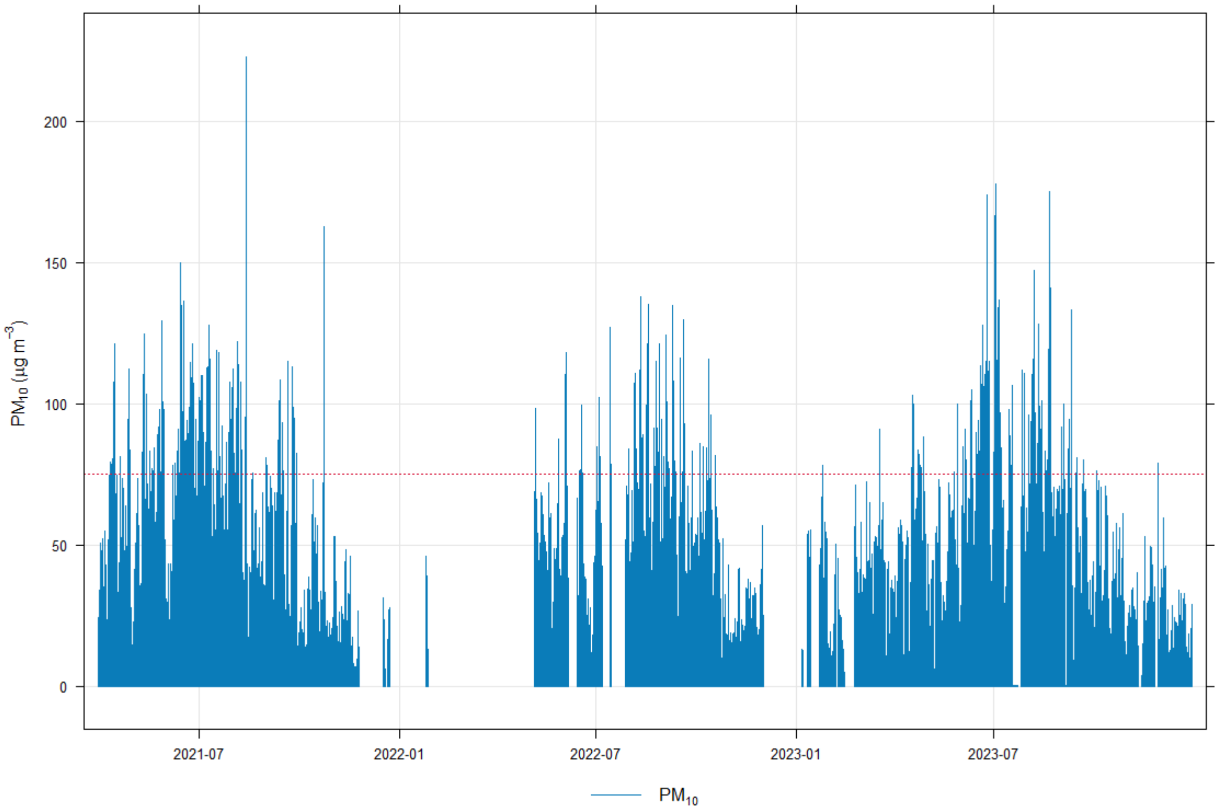

Figure 2-14: Time series for daily PM_{10} ground level concentrations measured at the Eskom Phola AQMS (2021-2023)

2.4.3 Emission source contribution

Source-specific information can be extracted if analyses are performed using a subset of data that has been "conditionally-selected" to exclude superimposed impacts from non-relevant sources (Malby et al., 2013). A common method for source characterisation is the use of bivariate polar plots (Carslaw et al., 2006; Westmoreland et al., 2007; Carslaw and Beevers, 2013; Uria Tellaetxe and Carslaw, 2014). Bivariate polar plots for the Eskom Phola AQMS conditioned for the mean pollutant concentration of hourly SO_2, NO_2 and $PM_{2.5}$ is presented in Figure 2-15.

According to the SO_2 bivariate plot, SO_2 concentrations measured at the Eskom Phola AQMS show a distinct source from the southwest. High concentrations present at high wind speeds are indicative of emissions from buoyant tall-stack sources (industrial emissions). Hence the higher SO_2 concentrations associated with the southwesterly winds are most likely due to emissions from the Kendal Power station.

According to the NO_2 bivariate polar plot, the highest NO_2 concentrations occur under very low wind speed conditions at the centre of Phola. These high concentrations occur under stable atmospheric conditions when non-buoyant ground-level sources are important, such as road transport emissions. The bivariate polar plot confirms that these NO_2 concentrations are the likely impact of vehicle emissions.

According to the PM_{10} bivariate polar plot, elevated particulate concentrations at the Eskom Phola AQMS show contributions from the north, northwest and southeast at higher wind speeds (between 10 and 12 m/s) and from the southwest at medium wind speeds between 6 and 8 m/s. At low wind speeds the symmetrical plot shows a localised contribution, most likely the result of residential fuel burning.

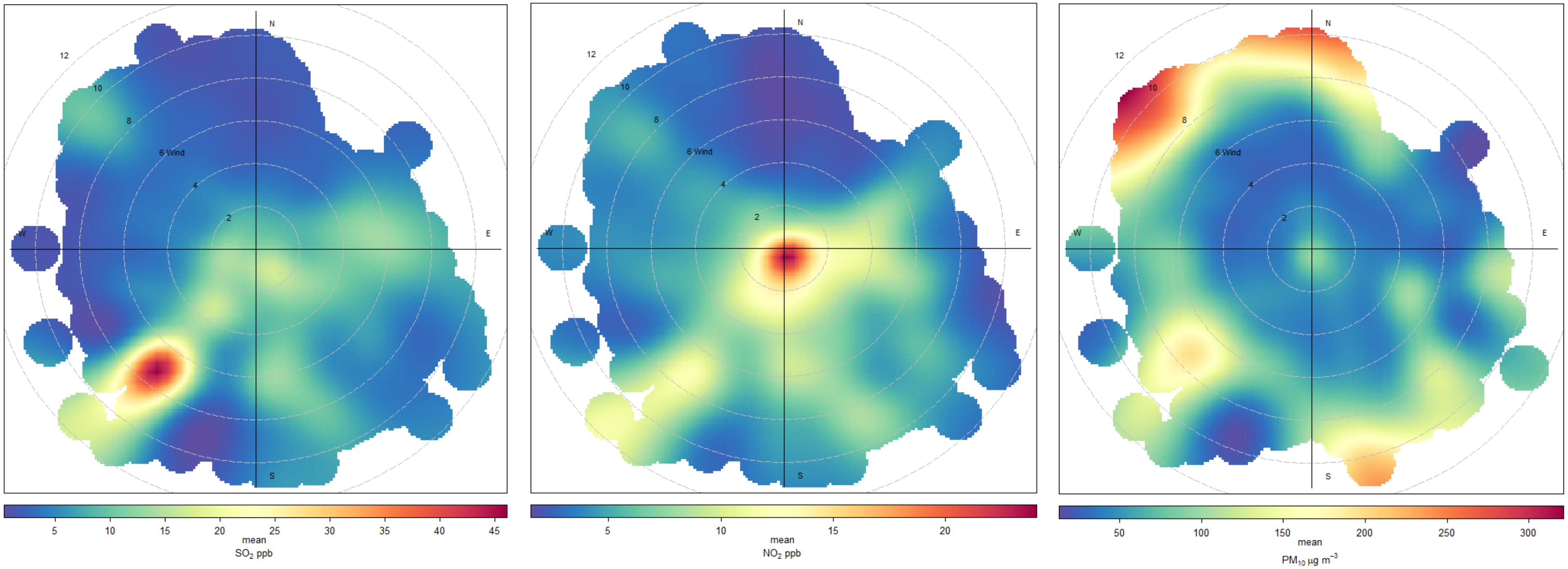

Figure 2-15: Bivariate polar plot of hourly mean SO_2, NO_2 and $PM_{2.5}$, concentrations at the Eskom Phola AQMS for 2021 to 2023

3. MODELLING PROCEDURE

3.1 BACKGROUND

Models have been used for decades to approximate physical systems and make estimates about the nature of a system under study (USEPA, 2004). Graedel and Crutzen (1997) have shown that it has become common practice in the environmental science field to describe complex systems of interacting physical, chemical and biological processes through the design of numerical models. For example, mathematical models are often used for assessing air pollution impacts in order to gain a better insight into this multidimensional (Denzer, 2004) and multidisciplinary (Wang, 2005) challenge.

Atmospheric dispersion models use mathematical equations that simulate the physics (Briggs, 1975; Gifford, 1960; Pasquill, 1983; Turner, 1970) and chemistry (Seinfeld and Pandis, 1998) that control the transport and transformation of pollutants in the atmosphere. They provide a means of estimating air pollutant concentrations and particle deposition in the ambient environment based on information on emissions and the prevailing meteorology (Chen et al., 2001; NSW, 2004).

3.2 ASSESSMENT LEVEL PROPOSED AND JUSTIFICATION

A number of dispersion models are used for regulatory applications in South Africa. The suitability of a particular model for an air quality assessment will vary depending on the complexity and scope of the study; the objectives of the modelling; technical factors and the level of risk associated with the project. According to the Regulations Regarding Air Dispersion Modelling (Gazette No 37804, 2014), a tiered approach in the selection of a suitable air dispersion model is recommended. According to the regulations, it is recommended that simple screening models (Level 1) are considered first before the application of more advanced models (Level 2 and 3).

In this study, a detailed understanding of the air quality impacts (time and space variation of the concentrations) is required. Additionally, this modelling study must be able to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types and chemical transformations. In light of the above, and in accordance with recommendations provided in the Regulations, a Level 3 modelling assessment was regarded as most appropriate for application in this study.

3.3 MODELS USED IN STUDY

3.3.1 METEOROLOGICAL MODEL

Air quality is strongly influenced by meteorology which covers an array of atmospheric processes that determines the evolution of emissions, chemical species, aerosols and particulate matter (Seaman, 2000). The performance of atmospheric dispersion models depends critically on the meteorological data to simulate the fate and transport of air pollution (Busillo et al., 2005; Davakis et al., 2007; Pielke and Uliasz, 1998). The representativeness of meteorological data is a key factor in accurately modelling the dispersion of these pollutants since meteorological conditions are not uniform over larger distances or in complex terrain, coastal environments, or in urban areas (Alapaty, 1994; Moschandreas et al., 2002).

South Africa is constrained by the lack of an adequate network of surface and upper air meteorological stations that are representative of the atmospheric boundary layer near the surface or at higher levels (Zunckel, 2007). Further, spatially and temporally representative wind flow statistics are not widely available for South Africa (Raghunandan et al., 2008). In this study, no upper air meteorological data is recorded within the modelling domain and the nearest upper air station is located at Irene in Pretoria. Due to the scarcity of surface and upper air meteorological stations available for the study area, TAPM was used to provide site-specific and representative meteorological data for the dispersion model.

TAPM

TAPM, developed by the Australian CSIRO Atmospheric Research Division, is an integrated 3-dimensional mesoscale prognostic meteorological and air pollution regulatory model that is controlled by a graphical user interface (Hurley et al., 2005a; Hurley, 2005b; Luhar and Hurley, 2004; Zawar-Reza et al., 2005).

The meteorological component of TAPM is an incompressible, optionally non-hydrostatic, primitive equation model which uses a terrain-following vertical coordinate system for 3-dimensional simulations (Zawar-Reza and Sturman, 2008). It includes comprehensive parameterisations for cloud/rain micro-physical processes, urban/vegetative canopy and soil, turbulence closure and radiative fluxes (Katzfey and Ryan, 1997; Lai and Chang, 2009; Mahrer and Pielke, 1977).

TAPM predicts local-scale flows, for instance sea breezes and terrain-induced circulations, by using meteorological fields obtained from larger scale synoptic analyses (Luhar and Hurley, 2004). TAPM is able to make use of fundamental fluid dynamics and scalar transport equations to predict the underlying meteorology of an area (Hurley, 2005c). It solves momentum equations to determine the mean horizontal wind components, the incompressible continuity equation for vertical velocity, and scalar equations for potential virtual temperature and moisture (Luhar and Hurley, 2004). The model allows for the option of observed wind data to be assimilated into the momentum equations as nudging terms (Luhar and Hurley, 2003; Raghunandan et al., 2008). Potential virtual temperature is determined from an equation combining the conservation of heat and water vapour. Pressure is determined by the application of a Poisson equation to the nonhydrostatic component (Luhar and Hurley, 2003; Hurley 2005b). A detailed description of the equations and parameterisations, including the numerical methods used to solve the model equations, used in the present study is given by Hurley et al. (2005a) and Hurley (2005c).

TAPM uses databases of global terrain height, land use, sea-surface temperature and synoptic meteorological analyses as input. The global terrain height and land use datasets are available at a grid space resolution of approximately 1 km and sea surface temperature and synoptic scale meteorological datasets are available at a 100 km resolution. The global terrain height and land use datasets are sourced from the US Geological Survey (USGS), Earth Resources Observation Systems (EROS) and the Data Center Distributed Active Archive Center (EDC DAAC) data (Hurley, 2005b). Global long-term monthly mean sea surface temperatures are derived from the US National Center for Atmospheric Research (NCAR) and the synoptic scale analyses are obtained from the Australian Bureau of Meteorology.

TAPM has been verified for a number of Australian and international datasets, and results from these studies have shown good model performance for both meteorology and air pollution predictions, particularly for the study of annual extreme (high) concentrations important for environmental impact assessments. The meteorological results show that TAPM performs well in a variety of regions (e.g., coastal, inland and generally complex terrain for sub-tropical to mid-latitude conditions). The pollution results show that TAPM performs well for a range of important phenomena (e.g. nocturnal inversion break-up fumigation; stable, neutral, convective and building wake dispersion; shoreline fumigation; and general dispersion in complex rural and urban conditions). In particular, TAPM performs very well for the prediction of extreme pollution statistics, important for environmental impact assessments, for both non-reactive (tracer) and reactive (nitrogen dioxide, ozone and particulate) pollutants for a variety of sources (e.g. industrial stacks and/or general surface or urban emissions (Hurley et al., 2008).

TAPM has also been used extensively in South Africa for many dispersion modelling studies for AQMPs, Air Quality Impact Assessments, Atmospheric Impact Reports and Offsetting Projects. Some of the important AQMP studies include the first-generation Highveld Priority Area Air Quality Management Plan (DEA, 2011) and the Waterberg-Bojanala Priority Area Air Quality Management Plan: Baseline Characterisation (DEA, 2014). A TAPM verification study has also been conducted in South Africa at two coastal sites (Alexander Bay and Richards Bay) (Raghunandan et al., 2008). In this study, TAPM model output was compared with meteorological data measured at South African Weather Service (SAWS) meteorological stations at these locations. It was concluded that the TAPM model performed exceptionally well.

3.3.2 DISPERSION MODEL

In this study, the US-EPA approved Californian Puff (CALPUFF) modelling suite was used for this Level 3 tier modelling assessment.

CALPUFF MODELLING SUITE

The CALPUFF model is an integrated modelling system which can simulate the effects of time- and space-varying meteorological conditions for pollutant dispersion, transformation and deposition (USEPA, 2005; Zhou et al., 2006). The CALPUFF modelling suite comprises of three main components: CALMET, CALPUFF and CALPOST (Figure 3-1). CALMET is a diagnostic meteorological model that generates hourly surface wind fields and micrometeorological variables on a three-dimensional gridded domain for CALPUFF (Elbir, 2006; Hao et al., 2007; Lopez et al., 2005; Song et al., 2006; Zhou et al., 2003). CALPUFF is a non-steady-state Gaussian based transport and dispersion model. It uses three-dimensional meteorological fields developed by CALMET and a series of overlapping puffs to represent the spatial and temporal distribution of emissions from a source (Scire et al., 2000b; Song et al., 2006). The CALPOST program is a powerful postprocessor used to average and report results based on data in the CALPUFF model output files. (Wang, 2006). A brief overview of the CALMET and CALPUFF models is presented in the sections below.

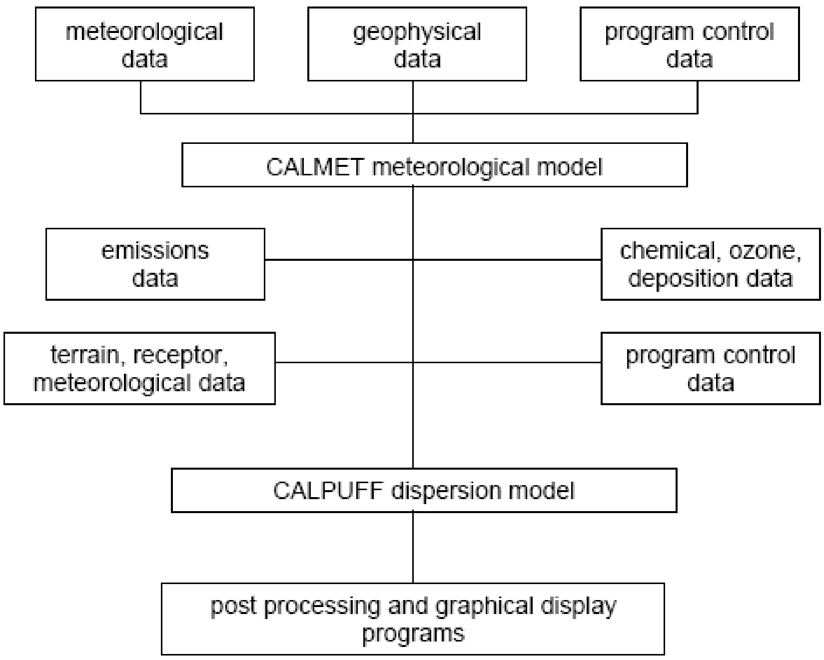

Figure 3-1: CALPUFF modelling system (Source: SRC, 2008)

CALMET

A three-dimensional wind field is computed by the CALMET meteorological model (USEPA, 2005). CALMET requires both geophysical data (terrain elevations and land use categories) and hourly meteorological data (wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure, relative humidity, precipitation and upper air sounding data) (USEPA, 2005; Scire and Robe, 2004).

CALMET consists of an advanced diagnostic wind field generator as well as a micrometeorological module for overwater and overland boundary layers. An initial guess wind field is modified to take account of kinematic effects of terrain, slope flows, valley flows and terrain blocking effects to create a Step 1 wind field. Observational data are then combined with this Step 1 wind field through an objective analysis procedure to generate the final Step 2 wind field (USEPA 2005; Scire 1999a; Scire 2000a). CALPUFF advects and disperses along these wind vectors created by CALMET (Allwine et al., 1998).

CALPUFF

CALPUFF is a non-steady-state, time-and space-dependent Gaussian puff model which is designed to simulate the transport, dispersion, chemical reactions and deposition of gases and particles in the atmosphere (Ainslie and Jackson, 2009; Scire et al., 2000b). CALPUFF treats emissions as a series of continuous puffs. Each puff is allowed to move with the ambient wind flow (Moschandreas et al., 2006). As the wind flow changes from hour to hour, the path of each puff is displaced in a Lagrangian fashion while undergoing Gaussian dispersion. The model predicted concentrations are calculated based on the contributions of each puff as it passes near or over a discrete receptor point in the modelling domain (Scire et al., 2000b).

CALPUFF is able to model four different source types: point, line, volume and area sources within a single modelling domain. The model makes use of similarity theory to estimate the horizontal and vertical plume dispersion coefficients and contains comprehensive algorithms for both near-source stack and building effects (such as building downwash, partial penetration, plume rise) and long-range effects (chemical transformation, deposition, plume fumigation) (Ainslie and Jackson, 2009; Holmes and Morawska, 2006; USEPA, 2005).

The non-steady state approach of the CALPUFF model makes use of a full three-dimensional meteorological field which can account for spatial and temporal variability in the wind field and atmospheric stability (Scire and Robe, 2004). CALPUFF is able to take account of complex terrain effects, wind reversals, wind stagnation, and causality effects over large spatial scales (Beychok, 2005; Hao et al., 2007; Paradiz et al., 2008). These provide a more realistic simulation for dispersion and transport as opposed to steady-state Gaussian plume models (Elbir, 2003; Moschandreas et al., 2006).

3.4 Modelling domains and grid resolution

3.4.1 Meteorological Modelling Domains

TAPM

TAPM was used to model the hourly surface and upper air meteorology for the study area, for the period 2021 to 2023. TAPM was set-up in a nested configuration of two domains. The outer domain is 420 km by 420 km at a 12 km grid resolution, and the inner domain is 105 km by 105 km at a 3 km grid resolution (

Figure 3-2). The larger outer domain is used to initialise the inner fine-resolution modelling domain. The nesting configuration also ensures that topographical effects on meteorology is captured, and that meteorology is well resolved and characterised across the boundaries of the inner domain. These simulations use default databases of global terrain height data, land use and synoptic scale meteorological analyses data as model input, as discussed in Section 3.3.

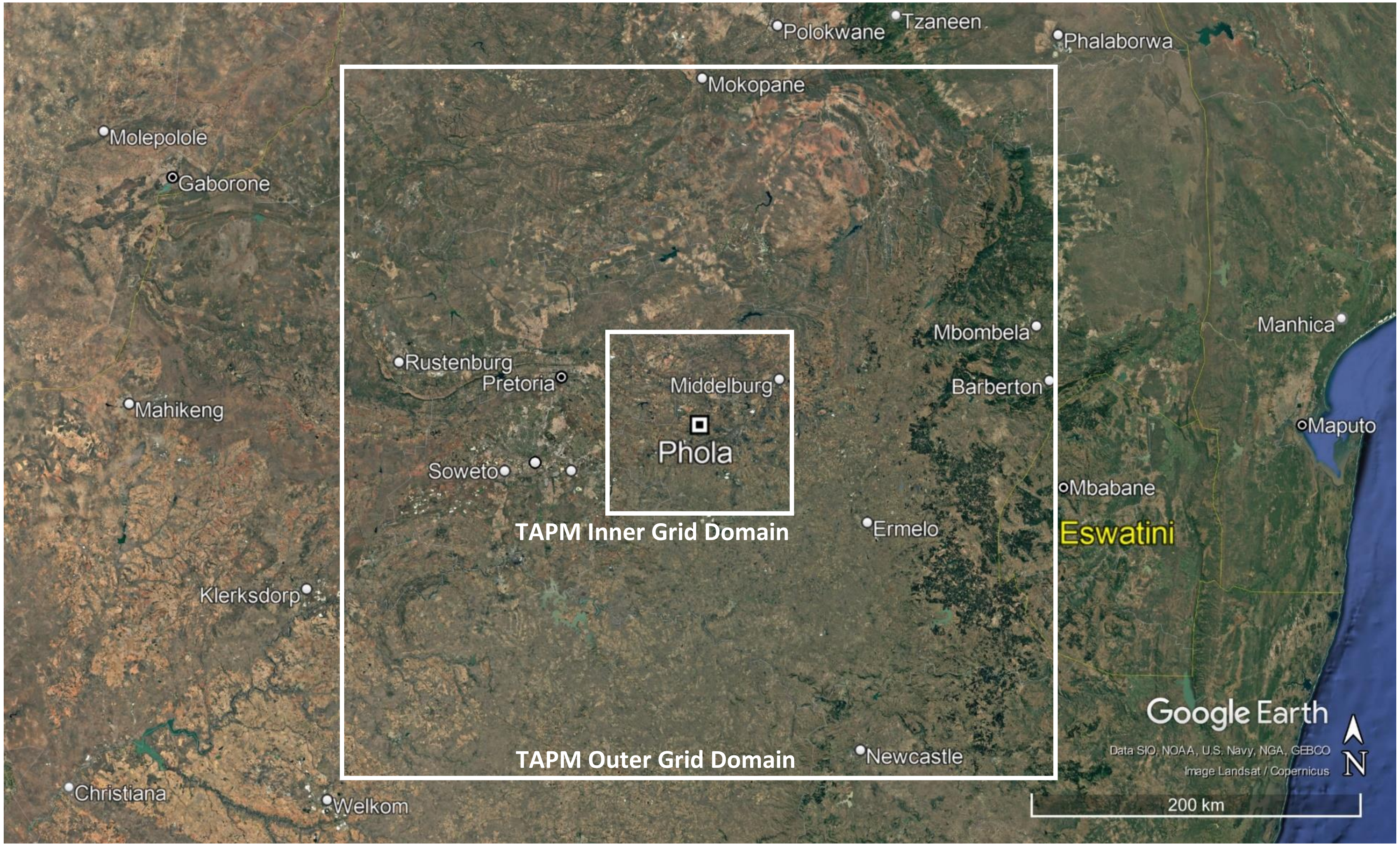

Figure 3-2: Nested grid domains used in the TAPM simulation

CALMET

The CALMET modelling domain for the study area has an extent of 80 km by 80 km with a uniformly spaced horizontal grid resolution of 1 km (

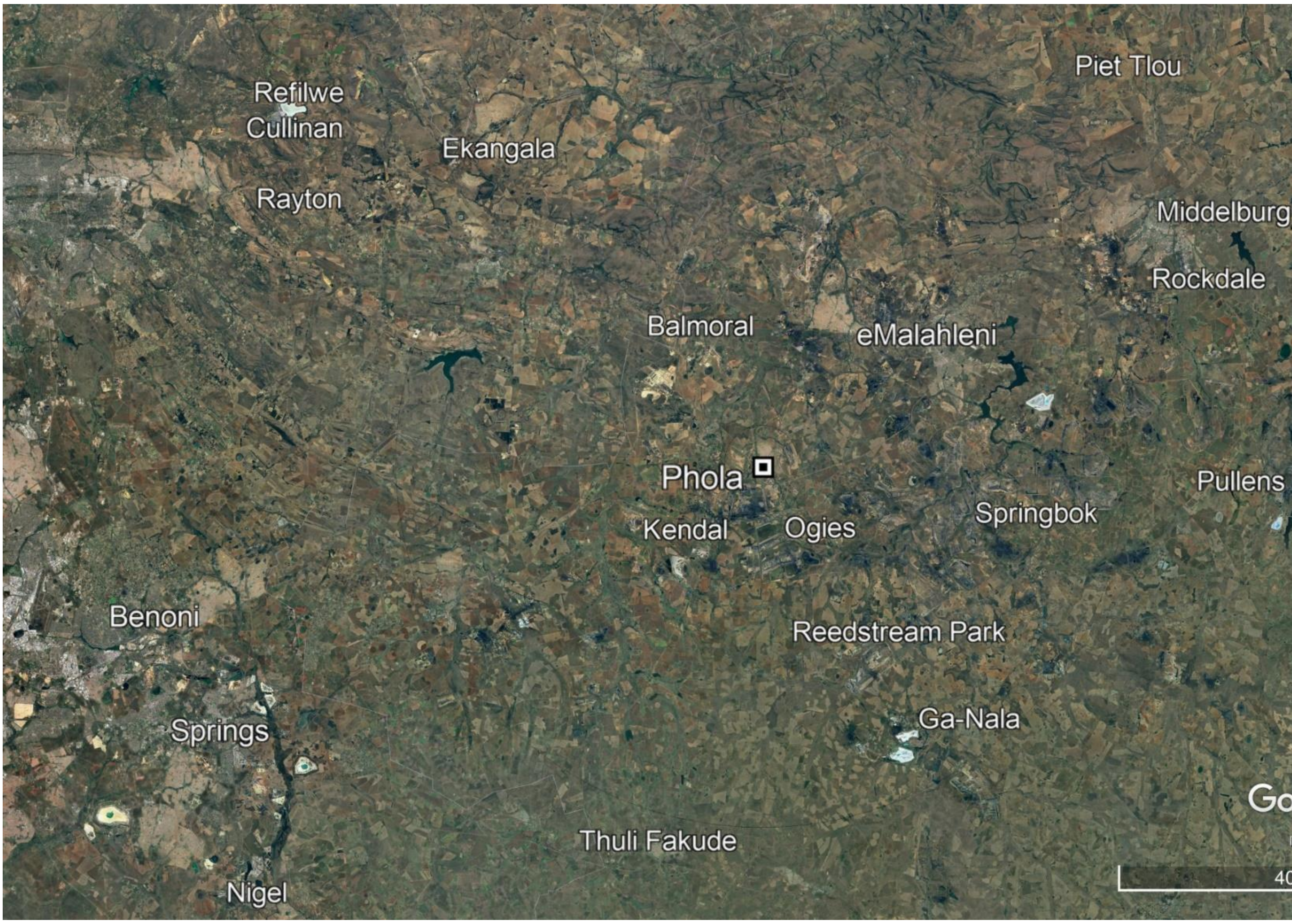

Figure 3-3). The top of the domain was set at 5 km with 12 vertical levels.

3.4.2 Dispersion Modelling Domain

CALPUFF

A primary (coarse resolution) grid and a secondary (fine resolution) grid was used in the CALPUFF simulations (

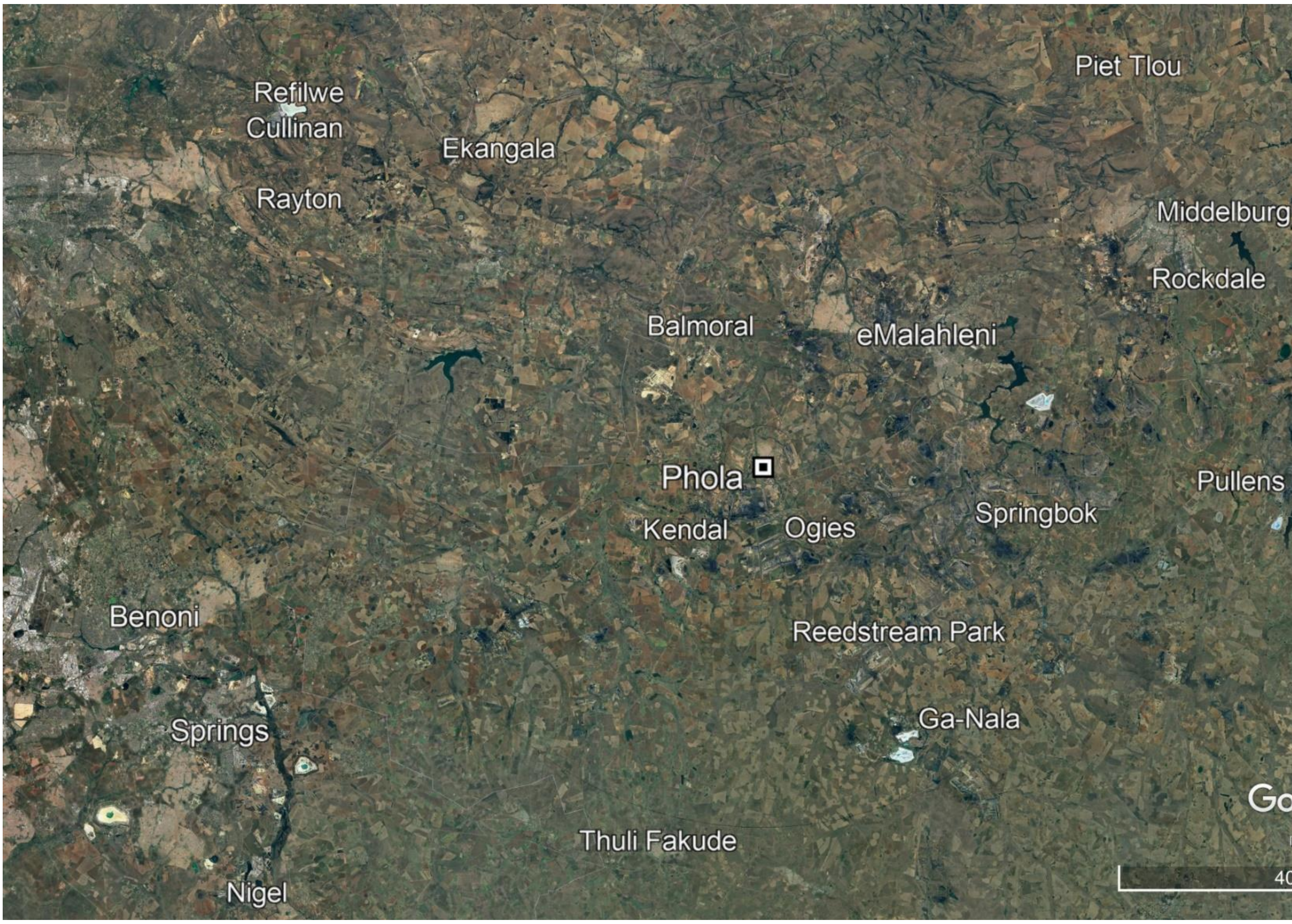

Figure 3-3). The grid specifications for each modelling domain is specified in Table 3-1.

Table 3-1: CALPUFF modelling domain grid specifications

Variable	Primary Grid	Secondary Grid
Spatial Area (km^2)	6 400	64
Grid Distance (km) in x and y direction	80 x 80	8 x 8
Horizontal Grid resolution (m)	1 000	200
Number of grid cells in x and y direction	80 x 80	40 x 40
Total number of gridded receptors in domain	6 400	1 600

Primary Modelling Grid: Greater Phola Airshed

The domain extends 80 km (west-east) by 80 km (north-south) for a CALPUFF modelling domain of 6 400 km^2. It consists of a uniformly spaced Cartesian receptor grid with 1 000 m spacing, giving 6

400 grid cells (80 x 80 grid cells). This modelling domain caters for a range of emission source categories within a 40 km radius around Phola.

SECONDARY MODELLING GRID: PHOLA AIRSHED

The domain extends 8 km (west-east) by 8 km (north-south) for a CALPUFF modelling domain of 64 km^2. It consists of a uniformly spaced Cartesian receptor grid with 200 m spacing, giving 1 600 grid cells (40 x 40 grid cells). This fine grid resolution ensures that dispersion characteristics and ambient concentrations are accurately captured within and in the immediate vicinity of Phola.

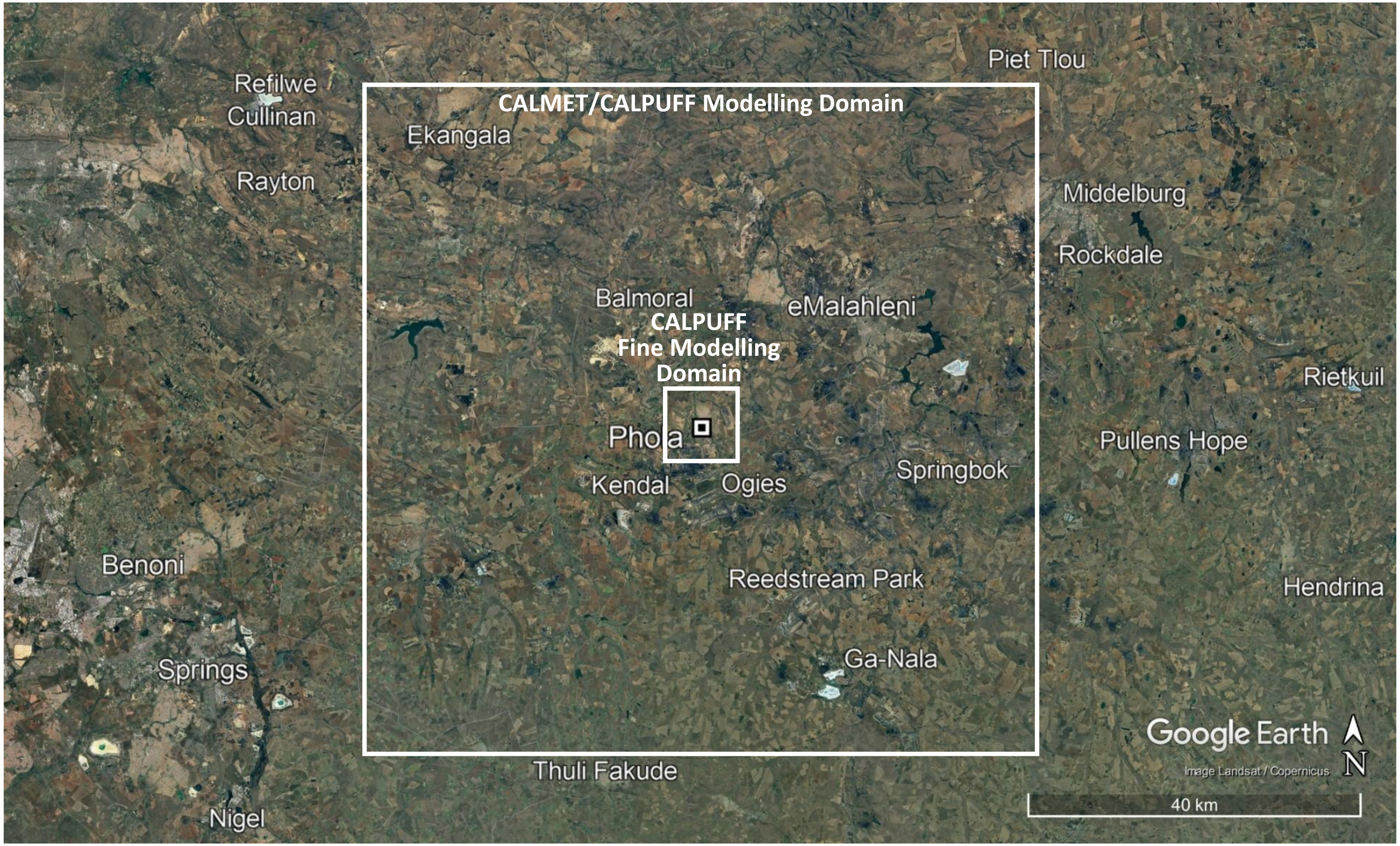

Figure 3-3: CALMET and CALPUFF Modelling Domains

3.5 Model Settings

A summary of model control options for CALMET and CALPUFF is presented in Table 3-2 and Table 3-3, respectively.

Table 3-2: Parameterization of key variables for CALMET

Parameter	Model value
12 vertical cell face heights (m)	0, 20, 40, 80, 160, 320, 640, 1000, 1500, 2000, 2500, 3000, 4000
Coriolis parameter (per second)	0.0001
Empirical constants for mixing height equation	Neutral, mechanical: 1.41 Convective: 0.15 Stable: 2400 Overwater, mechanical: 0.12
Minimum potential temperature lapse rate (K/m)	0.001
Depth of layer above convective mixing height through which lapse rate is computed (m)	200
Wind field model	Diagnostic wind module
Surface wind extrapolation	Similarity theory
Restrictions on extrapolation of surface data	No extrapolation as modelled upper air data field is used
Radius of influence of terrain features (km)	5
Radius of influence of surface stations (km)	Not applicable as continuous surface data field is used

Table 3-3: Parameterization of key variables for CALPUFF

Parameter	Model value
Chemical transformation	Default NO_2 conversion factor is applied
Wind speed profile	Rural
Calm conditions	Wind speed < 0.5 m/s
Plume rise	Transitional plume rise, stack tip downwash, and partial plume penetration is modelled
Dispersion	CALPUFF used in PUFF mode
Dispersion option	Pasquill-Gifford coefficients are used for rural and McElroy-Pooler coefficients are used for urban
Terrain adjustment method	Partial plume path adjustment

3.6 Pollutants simulated

The CALPUFF suite of models was used to predict the dispersion of the following pollutants: SO_2, SO_4, NO_X, HNO_3, NO_3, PM_{10}, $PM_{2.5}$ and TPM (to calculate particulate/dust deposition rates) using the MESOPUFF II Scheme chemical transformation method. The MESOPUFF II Scheme is a pseudo-first-order chemical reaction mechanism for conversion of SO_2 to SO_4 and total NO_X to NO_3. Results of the modelling are presented for SO_2, NO_X as NO_2, PM_{10}, $PM_{2.5}$ and dustfall rates.

The dispersion of the pollutants were simulated for the prevailing meteorological conditions for the period 1 January 2021 to 31 December 2023.

3.7 Total Particulate Calculation

Ambient particulate matter is a complex mixture of inorganic and organic compounds. The NAAQS regulates particulate matter for different size fractions (PM_{10} and $PM_{2.5}$) which are based on epidemiological evidence for mortality and cardiorespiratory health effects.

Sulphate and nitrate constitute a significant portion of the particle mass in the atmosphere. According to Reis *et. al* (2007) few epidemiological studies have included the sulphate content of particulate matter as a specific variable in health effect analyses. There is considerably less data for nitrates.

Reis *et. al* (2007) however demonstrated that epidemiologic and toxicological evidence provide little or no support for a causal association of particulate sulphate and health risk at ambient concentrations. Further, for nitrate-containing particulate matter, there is no epidemiological data and the toxicological evidence does not support a causal association between particulate nitrate compounds and excess health risks. There is insufficient evidence to include or exclude secondary organic processes for sulphates and nitrates as being potentially important to particulate matter associated health risk. (Reis *et. al*, 2007).

This baseline modelling study has taken a conservative approach (Scire, 2014) whereby the total concentrations of particulate matter (PM_{10} or $PM_{2.5}$) was computed as the sum of primary particulate matter concentrations (PM_{10} or $PM_{2.5}$) plus the contribution of concentrations from secondary particulate matter, including ammonium nitrate (NH_4NO_3) and ammonium sulphate ($(NH_4)_2SO_4$) as shown in the equation below:

Total PM_{10} or $PM_{2.5}$ = sum of (PM_{10} or $PM_{2.5}$) + $(NH_4)_2SO_4$ + NH_4NO_3

In this study, the total concentration of particulate matter (either PM_{10} or $PM_{2.5}$) was then compared to the applicable PM_{10} or $PM_{2.5}$ NAAQS (Table 1-2).

3.8 Methodology for determining $PM_{2.5}$ emissions From Eskom Power Station Stacks

In terms of the determination of fine particulate matter emissions ($PM_{2.5}$), it is noted that Eskom utilises the dry bottom boiler emission factors from the United States Environmental Protection Agency (US EPA AP42) (US EPA, 1995) to determine the fine particulate matter (PM) emissions ($PM_{2.5}$). The ratio of the $PM_{2.5}$ to PM_{10} is used to calculate $PM_{2.5}$ from the total PM measured from the Continuous Emission Monitoring System (CEMS) equipment at the respective smokestacks. The utilisation of CEMS equipment is a more accurate representation of site-specific PM and therefore constitutes a Tier 3 method of reporting. (Extracted from uMoya-NILU, 2024a)

The US EPA defines dry bottom boilers as those burning coals with high fusion temperatures resulting in dry ash. In wet bottom boilers, coals with low fusion temperatures are used, resulting in molten ash or slag. Eskom coal fired power stations are therefore considered to have dry bottom boilers. Eskom has either Electrostatic Precipitators (ESPs) or Fabric Filter Plants (FFPs) installed as air pollution control devices in all its coal fired units. The following ratios determined from dry bottom emission factors in the US EPA AP42 are used:

- ESP controlled - 0.024 lb/ton for $PM_{2.5}$ and 0.054 lb/ton for PM_{10} [ratio = 0.44]
- FFP controlled - 0.01 lb/ton for $PM_{2.5}$ and 0.02 lb/ton for PM_{10} [ratio = 0.5] (Extracted from uMoya-NILU, 2024a)

The above ratios for PM_{10}:$PM_{2.5}$ have been applied accordingly at the various power stations as follows:

- Kusile has FFPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.50
- Kendal, Kriel, and Matla have ESPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.44
- Duvha has an FFP on Unit 1 and Unit 2 (Stack 1) hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.50; and ESP on Unit 4, Unit 5 and Unit 6 (Stack 2) hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.44 (Extracted from uMoya-NILU, 2024a)

3.9 Emission Scenarios

In this study, the following emission scenarios were modelled:

- Power Generation
- Residential Fuel Burning
- Waste Burning
- Biomass Burning
- Vehicles – Paved Roads
- Vehicles – Unpaved Roads
- Mining
- All Sources

A comprehensive emissions inventory for each of these scenarios is presented in Section 4.

3.10 Discrete Receptors

The location of discrete receptors that were selected for the Phola modelling domain is presented in Figure 3-4.

Figure 3-4: Location of discrete receptors for the modelling domain

4. EMISSION INVENTORY USED IN MODELLING

The identification of existing sources of emission in the modelling domain and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the existing operations and their associated emissions. In order to identify possible effects of reduction measures in an area it is necessary to prepare a representative emission inventory. In this study, an emission inventory was compiled for a number of source categories within the modelling domain, which includes:

- Power Generation
- Residential Fuel Burning
- Waste Burning
- Biomass Burning
- Vehicles – Paved Roads
- Vehicles – Unpaved Roads
- Mining
- All Sources

4.1 Power Generation

4.1.1 Introduction

Coal has traditionally dominated the energy supply sector in South Africa. Presently, about 80 percent of South Africa's primary energy needs are provided by coal. Through 2032, South Africa is projected to continue generating the majority of its electricity from traditional thermal power sources, primarily coal-fired generation. Approximately 95% of the electricity used in South Africa and 45% of the electricity used in Africa is produced by Eskom (ITA, 2024).

4.1.2 Emission Inventory

In this study, emissions from Eskom's Duvha Power Station, Kendal Power Station, Kriel Power Station, Kusile Power Station and Matla Power Station was included. The emission inventory for the five power stations which accounts for stacks, coal yards and ash dump emissions is compiled using data provided by Eskom. The emission inventory for the five power stations is presented in Table 4-1 and Table 4-2; and location of the stations is shown in Figure 4-1.

.

Table 4-1: Stack parameters and emission rates for the Eskom Power Station Stacks

Source	Height (m)	Diameter (m)	Exit Temp (K)	Exit Velocity (m/s)	SO_2 (t/a)	NO_X (t/a)	PM_{10} (t/a)	$PM_{2.5}$ (t/a)
Duvha Power Station								
Stack 1	300	12.47	403	27	133 273	71 056	5 457	2 728
Stack 2	300	12.47	403	27	133 273	71 056	5 457	2 728
Sub-total					**266 546**	**142 113**	**10 914**	**5 457**
Kendal Power Station								
Stack 1	275	13.51	399	24	174 895	67 870	39 963	17 584
Stack 2	275	13.51	399	24	174 895	67 870	39 963	17 584
Sub-total					**349 790**	**135 740**	**79 927**	**35 168**
Kriel Power Station								
Stack 1	213	14.3	403	19	138 113	118 381	23 407	10 299
Stack 2	213	14.3	403	19	138 113	118 381	23 407	10 299
Sub-total					**276 226**	**236 761**	**46 814**	**20 598**
Kusile Power Station								
Stack 1	220	15.4	323	18	21 281	24 940	737	368
Stack 2	220	15.4	323	18	21 281	24 940	737	368
Sub-total					**42 562**	**49 880**	**1 474**	**737**
Matla Power Station								
Stack 1	213	14.3	397	22.9	124 808	149 131	31 825	14 003
Stack 2	275	12.47	397	30.1	124 808	149 131	31 825	14 003
Sub-total					**249 617**	**298 262**	**63 649**	**28 006**
All Power Stations								
TOTAL					**1 184 740**	**862 755**	**202 777**	**89 965**

Table 4-2: Emission rates for the Eskom Power Station Coal Yards and Ash Dumps

Power Station	Source	Emission Basis	TPM (t/a)	PM_{10} (t/a)	$PM_{2.5}$ (t/a)
Duvha Power Station	Coal Yard	Materials Handling (quantity-based)	0.70	0.33	0.05
		Wind Erosion (surface area-based)	47.71	23.86	9.54
	Ash Dump	Materials Handling (quantity-based)	0.02	0.01	0.00
		Wind Erosion (surface area-based)	4 211.00	2 105.50	842.20
		Sub-total	**4 259.43**	**2 129.70**	**851.79**
Kendal Power Station	Coal Yard	Materials Handling (quantity-based)	1.80	0.85	0.13
		Wind Erosion (surface area-based)	93.38	46.69	18.68
	Ash Dump 1	Materials Handling (quantity-based)	0.15	0.07	0.01
		Wind Erosion (surface area-based)	1 524.87	762.43	304.97
	Ash Dump 2	Materials Handling (quantity-based)	0.02	0.01	0.00
		Wind Erosion (surface area-based)	798.01	399.01	159.60
		Sub-total	**2 418.22**	**1 209.06**	**483.39**
Kriel Power Station	Coal Yard	Materials Handling (quantity-based)	2.99	1.41	0.21
		Wind Erosion (surface area-based)	39.31	19.65	7.86
	Ash Dump	Materials Handling (quantity-based)	0.06	0.03	0.00
		Wind Erosion (surface area-based)	1 739.21	869.61	347.84
		Sub-total	**1 781.58**	**890.71**	**355.92**
Kusile Power Station	Coal Yard	Materials Handling (quantity-based)	0.64	0.30	0.05
		Wind Erosion (surface area-based)	32.79	16.40	6.56
	Ash Dump	Materials Handling (quantity-based)	0.40	0.19	0.03
		Wind Erosion (surface area-based)	1 204.65	602.33	240.93
		Sub-total	**1 238.49**	**619.21**	**247.56**
Matla Power Station	Coal Yard	Materials Handling (quantity-based)	0.60	0.28	0.04
		Wind Erosion (surface area-based)	45.11	22.55	9.02
	Ash Dump	Materials Handling (quantity-based)	0.12	0.06	0.01
		Wind Erosion (surface area-based)	3 134.27	1 567.13	626.85
		Sub-total	**3 180.10**	**1 590.03**	**635.93**
All Power Stations		**TOTAL**	**12 877.82**	**6 438.71**	**2 574.60**

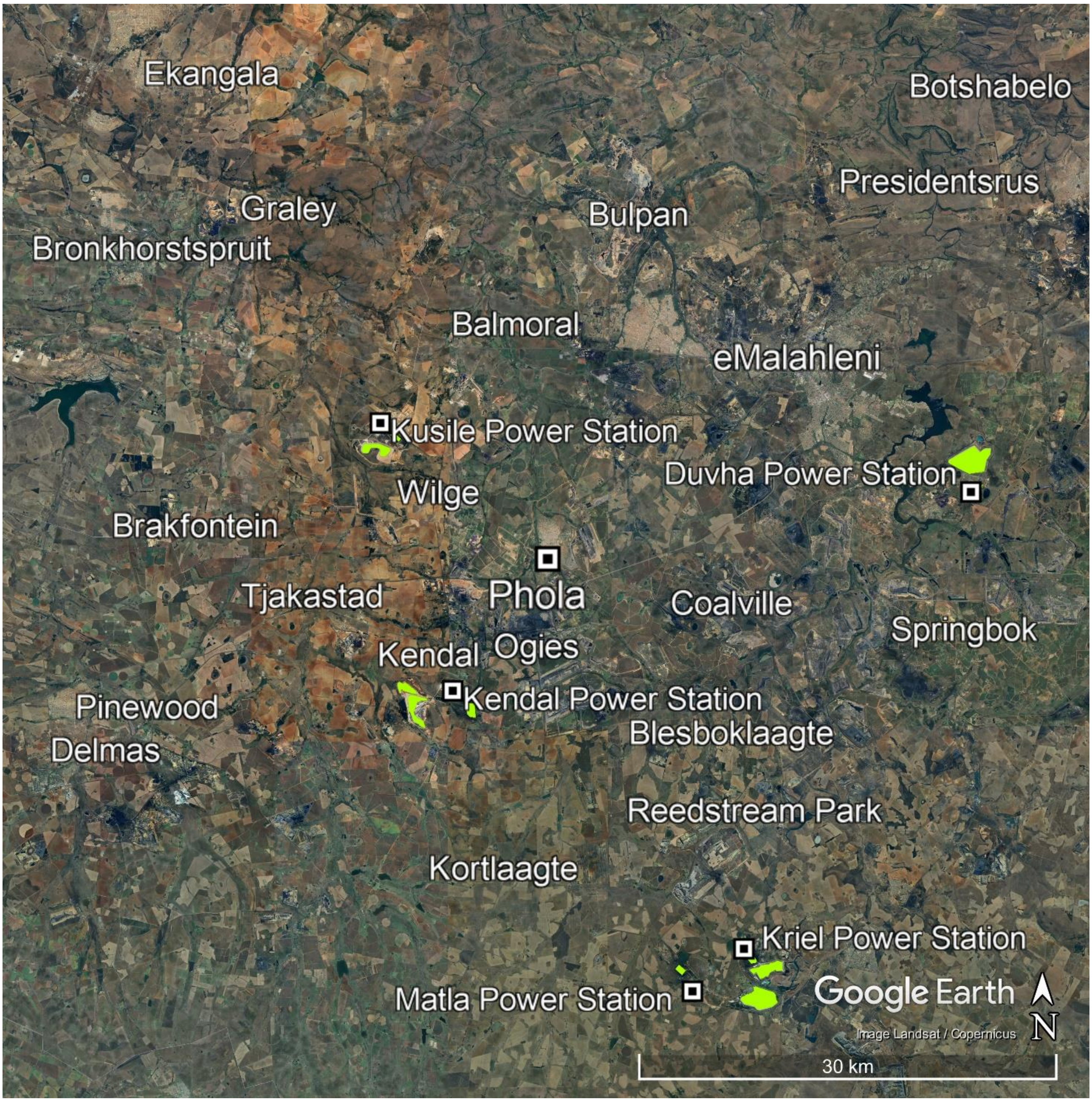

Figure 4-1: Location of the Eskom Power Stations, Coal Yards and Ash Dumps relative to Phola

4.2 Residential Fuel Burning

4.2.1 Introduction

There is growing evidence of a decreased reliance on fossil fuel combustion for energy use in the residential environment in South Africa. This is primarily due to increased access to electricity. According to Statistics South Africa (via the official Census and annual general household surveys), the percentage of households, as of 2019, with access to electricity is 85%. While this does not necessarily mean the total disuse of fossil fuel combustion in those homes (particularly for heating), it does offer an indication of potentially decreased residential fuel combustion. This could potentially be offset by population growth, particularly in areas predominantly reliant on indoor fuel combustion.

The proximity of the emission source to people is one of the key issues concerning household fuel combustion. This issue is exacerbated by inadequate combustion devices and poor indoor ventilation. Important pollutants include PM, CO, SO_2, NO_X and various VOCs. Importantly, not all fuels emit equal quantities of certain pollutants, with the amount of each pollutant emitted depending on the type of fuel burnt. As an example, SO_2 is relevant for coal combustion, while PM is less of a concern for LPG. Considering these pollutant complexities, it is important to understand the type of fossil fuel being burned, for which purpose and in which area to ensure the development of appropriate air pollution interventions.

The spatial variability and different pollutant contributions (both primarily driven by variability in fuel use by type) need to be captured in detail to estimate a gridded representation of emissions from residential fuel burning. Approaches to derive an emission inventory for residential fuel use generally rely on activity data from the 2011 and 2022 census community data. The data was sourced from the Statistics South Africa Superweb2 data catalogue's 2011 Census community profile (https://superweb.statssa.gov.za/webapi/jsf/dataCatalogueExplorer.xhtml).

The 2011 dataset contained detailed population statistics and number of households per municipal level, as well as population and number of households per ward level. Due to the lack of population statistics and number of households per ward level for the 2022 data set, population and number of households per ward level for the 2022 period was calculated by upscaling the 2011 household and population data. This was done by taking the 2011 municipal data and 2011 town data to calculate the ratio of town against municipality. This ratio would then be applied to the 2022 municipal data to calculate the town's household and population numbers.

The 2022 household and population numbers were utilised in a bottom-up approach to develop area-specific emission inventories for the study.

4.2.2 Methodology

The emission inventory development process for the Residential Fuel Burning emission inventory employed a bottom-up approach; and the spatial aspect was refined using a dwelling inventory.

Bottom-up

The 2022 household numbers per ward level were utilised for the development of the residential fuel burning emission inventory. Literature values were utilised with the value of 2.4 tonne of coal being assumed to be burned at the household (HH) level per annum as informed by the HPA health study

(HPAHS) (CSIR, 2017). This approach is aligned with the recently published HPA Second-Generation AQMP Baseline Report (DFFE, 2024).

Additionally, an area surveillance assessment was conducted on the residential areas in the modelling domain, and a scaling factor was introduced to the 2.4 tonne of coal assumed to be burned at the household (HH) level per annum if the residential areas are more affluent.

4.2.3 EMISSION FACTORS

An emission factor (EF) is a quantity of a pollutant emitted relative to an activity metric, such as the quantity of fuel or material burned. It is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere, with an activity associated with the release of that pollutant. For instance, an EF for the release of SO_2 from combustion of coal would be expressed in grams (g) SO_2 emitted per kilogram (kg) of coal combusted. EFs are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. EFs are generally used in calculating the rate at which a pollutant is being released from a source (emission rate), which can be used to simulate the concentration of the pollutant at a receptor. The general equation (1) for emissions estimation is:

$$E_i = F_B \times EF_i \quad \text{Equation 1}$$

Where:

- E_i: The emission of pollutant i
- F_B: The amount of fuel burned
- EF_i: Emission factor of the fuel burned

A comparison of emission factors was done, considering those from the FRIDGE study (Scorgie et al., 2004), the USEPA AP-42 dataset, the GAINS United States and Australia model (Amann et al., 2011), Ballard-Tremeer (1997), Britton (1998), Scorgie (2012) and Makonese et al. (2015). Many of the South African studies focused on coal. A hybrid selection from these studies is considered in this household fuel combustion emissions methodology and are presented in Table 4-3.

Table 4-3: Emission factors used for residential fuel combustion

Pollutant	LPG		Paraffin		Coal		Wood	
	Emission Factor (g/kg)	Source	Emission Factor (g/kg)	Source	Emission Factor (g/kg)	Source	Emission Factor (g/kg)	Source
SO_2	0.01	FRIDGE	0.851	FRIDGE	11.6	Scorgie, 2012	0.123	Ballard-Tremeer, 1997
NO_X	1.4	FRIDGE	1.5	FRIDGE	3.95	Makonese et al., 2015	1.224	AP-42
PM_{10} [(a)]	0	NA	0	NA	0	Makonese et al., 2015	1.035	AP-42
$PM_{2.5}$	0.068	AP-42	0.359	AP-42	16.146	Makonese et al., 2015	13.745	AP-42

Note: (a) PM_{10} represents only the coarse fraction (i.e., PM with a diameter 2.5 µm to 10 µm)

For alignment with the recently published HPA Second-Generation AQMP Baseline Report (DFFE, 2024), Table 4-4 is a summary of the EFs utilised in this study.

Table 4-4: Emission factors used for residential coal combustion

Fuel	$PM_{2.5}$	PM_{10}	SO_2	NO_2 as (NO_X)
Coal (g/kg)	12.01	12.91	9.91	4.55

4.2.4 Emission Inventory

Emission estimates were calculated by multiplying the total fuel use by emission factors in Table 4-4. Table 4-5 summarises the pollution contribution of each residential fuel burning fuel type to the total residential fuel burning emission estimated for the Phola modelling domain. Table 4-5 indicates that the highest emissions in terms of residential fuel burning are PM_{10} and $PM_{2.5}$, followed by SO_2 and NO_X.

Table 4-5: Pollution contribution summary for residential coal burning estimated for the Phola modelling domain (tonne/annum)

Fuel Type	SO_2	NO_X	PM_{10}	$PM_{2.5}$
Coal	5 622.18	2 581.32	7 324.15	6 813.56

In this study, emissions from residential fuel burning is calculated at Sub Place level. With respect to the modelling, the Sub Place level emissions were applied only over areas which corresponded specifically to residential areas (Figure 4-2).

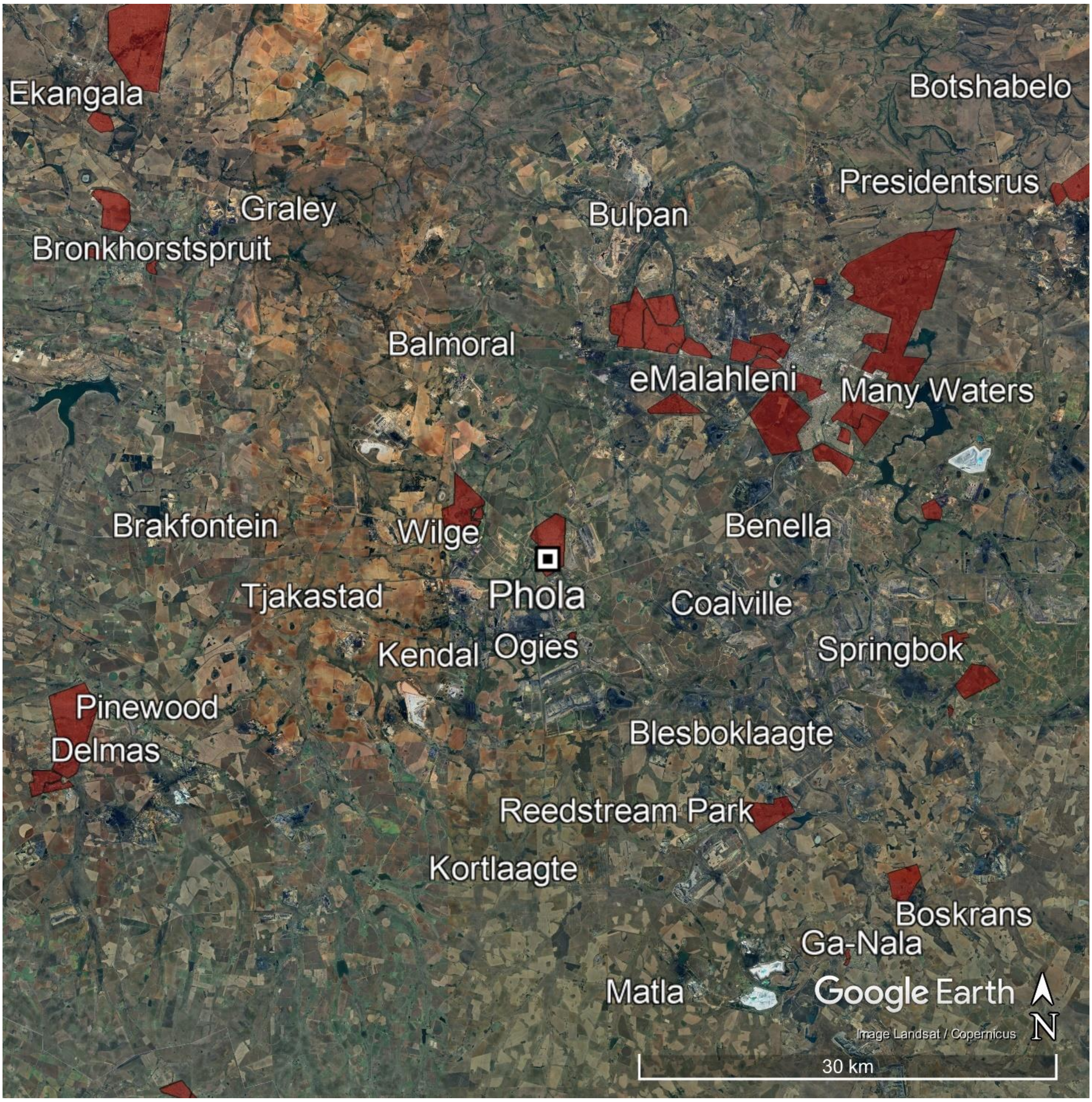

Figure 4-2: Location of residential areas within the Phola modelling domain for which Residential Fuel Burning emissions were applied

4.3 Waste Burning

4.3.1 Introduction

In South Africa, open burning of waste typically occurs in low-income settlements where municipal collection of waste is infrequent and waste generation is high due to the high population density in these areas. In the absence of municipal waste collection, residents are forced to find alternative means of disposal other than through formal landfills. Disposal can be done either through open burning or burial of waste. Open burning of waste has a negative impact on ambient air quality.

Open burning of residential waste can impact air quality through the emission of a range of pollutants. In this emission inventory, an international database was used to estimate the emissions from waste burning in the Phola modelling domain by following a top-down approach. The approach for the development of the inventory is described below.

4.3.2 METHODOLOGY

In this study, the approach used to estimate domestic waste burning emissions is based on Wiedinmyer et al. (2014), which follow IPCC methods (IPCC, 2006). Based on Equation 1, the emission of pollutant i (Ei) are estimated as the product of the emission factor of the waste (EFi) and the amount of waste burned (WB). The generalized equation to estimate waste burned is shown in Equation 2.

$$E_i = W_B \times EF_i \qquad \text{Equation 1}$$

Where:

- E_i: The emission of pollutant i
- W_B: The amount of waste burned
- EF_i: Emission factor of the waste

$$W_B = P \times P_{frac} \times MSW_P \times B_{frac} \qquad \text{Equation 2}$$

Where:

- W_B: The amount of waste burned
- P: Population
- P_{frac}: The fraction of the population accounts whose waste is not collected i.e., assumed to burn their waste
- MSW_p: The mass of annual per capita waste production
- B_{frac}: The fraction that is available to be burned that is actually burned

In this study, waste burning emissions are based on local data relating to waste accumulated per person and per composition i.e., waste generated per person per capita. Waste information was taken from Jeffares & Green (Pty) Ltd. (2016), in which waste composition and the amount for 2015 were calculated and assessed for six municipalities in South Africa. According to Equation 2, population is another variable required to estimate the amount of waste burned. Local municipality data (population data) were used to calculate a waste per person per year estimate. The population data was calculated utilising the same approach as described for residential fuel burning.

According to the 2018 Sasol Waste Collection Interventions (WCI) Study (Mamadi and Co., 2018), waste generated per capita was estimated at 0.612 tonne/person/annum. This rate (waste generated per capita) is assumed to be representative of the Phola study area. Equation 2 takes into account that some of the waste is not combustible. For example, glass and metals will not readily burn, thus a burn fraction is required. The IPCC recommended fraction of 0.6 is used i.e., 60% of the waste generated by people that do not have waste removal services is burned.

Additionally, an area surveillance assessment was conducted on the residential areas in the modelling domain, and a scaling factor was introduced to the 0.612 tonne/person/annum of waste being generated at the population per annum if the residential areas are more affluent. Another assumption was introduced to the 60% of the waste generated by people who do not receive removal services is burned that the composition of the waste is a 50:50 split between paper and plastic.

In this study, emissions from waste burning is calculated at Sub Place level. With respect to the modelling, the Sub Place level emissions were applied only over areas which corresponded specifically to residential areas (Figure 4-3).

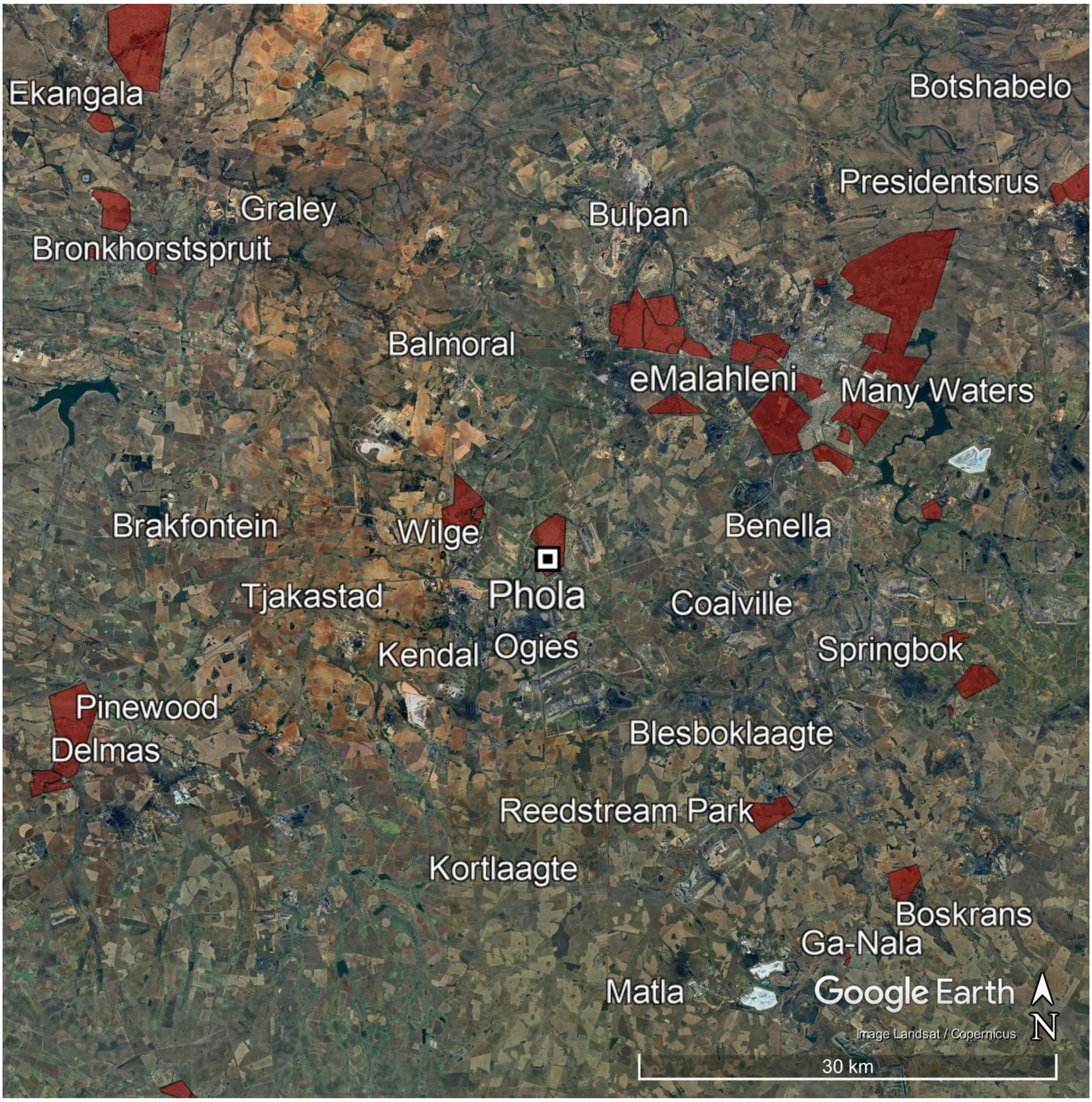

Figure 4-3: Location of residential areas within the Phola modelling domain for which Waste Burning emissions were applied

4.3.3 Emission factors

The most recent compilation of waste emission factors for a South African context are presented in the Sasol South Africa Emission Factors for Criteria Pollutants from Solid Waste Material Combustion Report (Mamadi & Co., 2018). In this report, several categories of materials are identified that are commonly found in waste burned in South African townships. A weight distribution for the composition of waste materials collected by the Sasol WCI program is presented in Figure 4-4. The major waste components identified in this program were paper, leather/rubber, textile, plastic bottles and bags, ceramic, metal, and glass. Emission factors used for estimating SO_2, NO_X, PM_{10} and $PM_{2.5}$ due to waste burning emissions is presented in Table 4-6.

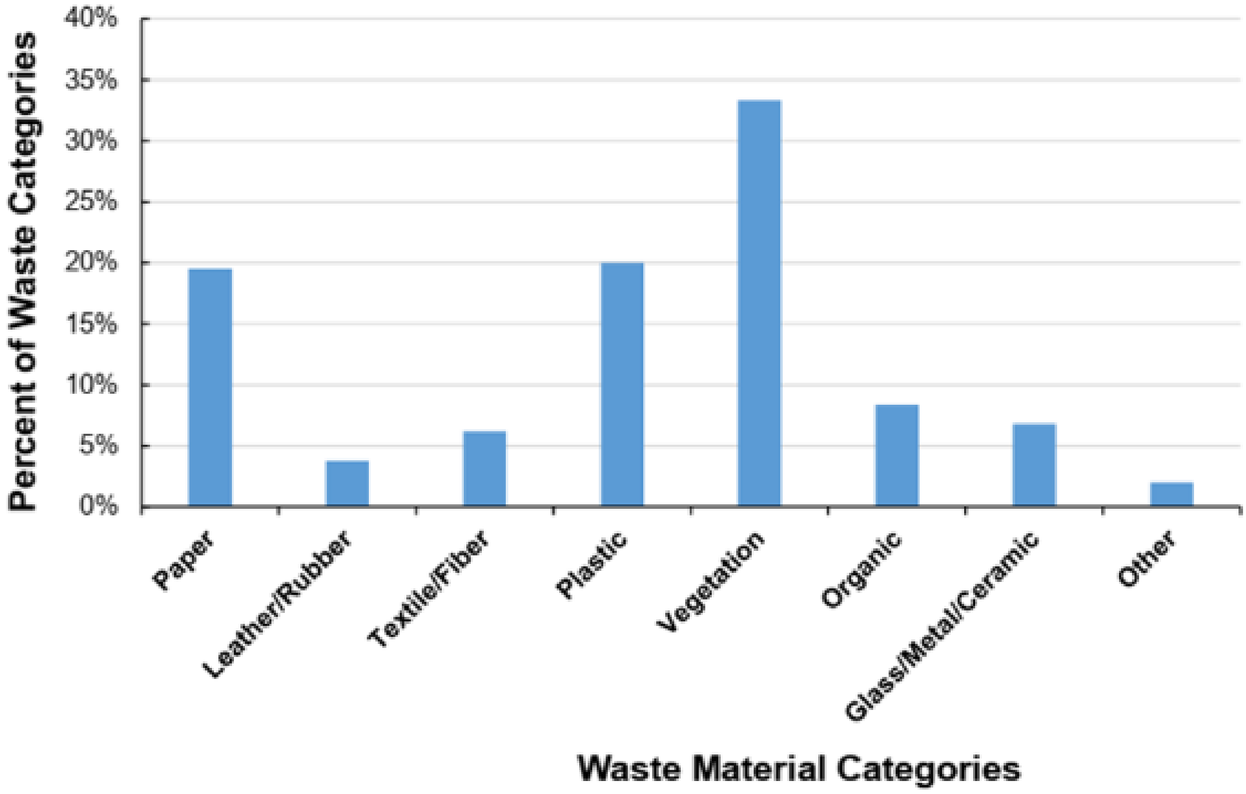

Figure 4-4: Weight fraction of municipal solid waste categories collected by Sasol (data provided by Mr Warren Carter, Sasol Technology)

Table 4-6: Waste burning emission factors

Emission Factors (g/kg fuel)				
	SO_2	NO_X	PM_{10}	$PM_{2.5}$
Paper	0.33	1.66	15.16	15.21
Plastic	0.36	10.61	722.47	651.0

4.3.4 Emission Inventory

Equation 2 is applied to the residential waste generated per capita and the emission factors detailed in Table 4-6 are applied thereafter, thereby determining grams per species emitted per kilogram of waste burned. Emissions of SO_2, NO_X, PM_{10} and $PM_{2.5}$ for the Phola study area due to waste burning is presented in Table 4-7. Compared to SO_2 and NO_X, it is evident that PM_{10} and $PM_{2.5}$ have the highest emission loading in the area.

Table 4-7: Emission inventory for waste burning emissions estimated for the Phola modelling domain

Pollutant	SO_2	NO_X	PM_{10}	$PM_{2.5}$
Emission Rate (tonnes/annum)	38.73	196.50	1 911.99	1 904.43

4.4 Biomass Burning

4.4.1 Introduction

Biomass burning refers to the large scale burning of vegetation, which includes savanna, forests and grasslands, domestic fuels and agricultural wastes (Andreae, 1991; Crutzen and Andreae, 1990). Open fires, such as wildfires, prescribed burns, agricultural fires, and land-clearing fires, are sources of atmospheric pollutants. Fire activity contributes to local, regional, and global emissions of greenhouse gases including carbon dioxide (CO_2) and methane (CH_4), reactive gases such as non-methane organic gases (NMOGs) and nitrogen oxides (NO_X) that form ozone, dioxins and other air toxics, and particulate matter (PM).

Fire emissions and their transport change the atmospheric composition, which cause impacts at many scales, with implications for air quality, regional and global climate, visibility and human health outcomes. Many factors contribute to the spatial and temporal patterns and severity of fires and their emissions, including agricultural, forest, and waste management practices, land use change, climatic factors such as temperature, rainfall, and drought conditions, and ecosystem diversity and health.

Accurate estimates of fire emissions are required to understand chemistry and climate, to assess ambient pollutant concentrations and population exposure, and to evaluate the effectiveness of emissions control programs for air quality planning and management.

In southern Africa, biomass burning occurs predominantly during the dry season corresponding to the period from May to October (Cahoon et al., 1996; Scholes et al., 1996a, 1996b; Scholes and Andreae, 2000; Swap et al., 1996). The majority of fires on the Highveld are thought to be anthropogenic in nature and include veld fires, burning of grazing land and crop-residue (DEFF, 2010). The biomes of South Africa (Figure 4-5) which are categorised as high to extreme risk include the following: fynbos, savanna and grassland. Mpumalanga is predominantly a grassland biome, thus an area at high to extreme risk of veld fires.

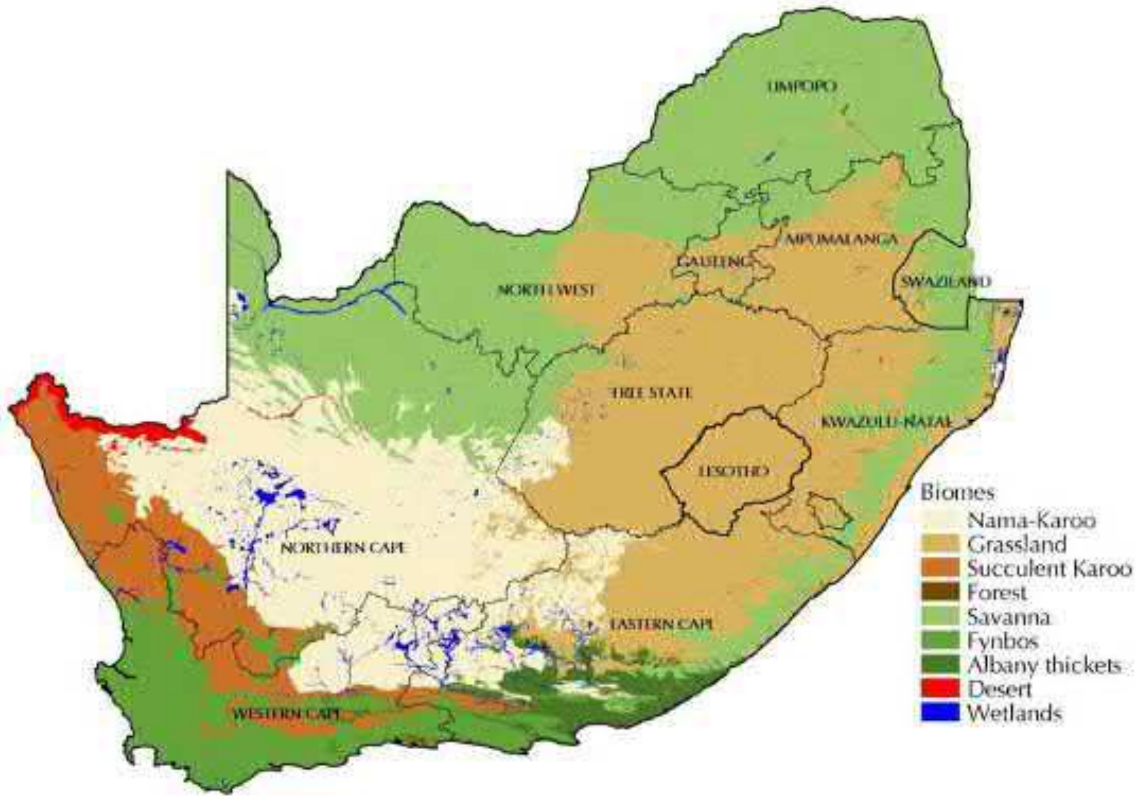

Figure 4-5: South African Biomes (SANBI, 2004)

4.4.2 Methodology

The Fire Inventory from NCAR version 2.5: an updated global fire emissions model for climate and chemistry applications

The FINN (Fire INventory from the National Center for Atmospheric Research (NCAR)) inventory (Wiedinmyer et al., 2011) was developed more than a decade ago to provide daily global estimates of pollutant emissions from open fires with a high spatial and temporal resolution for use in air quality, atmospheric composition, and climate modelling applications. The National Center for Atmospheric Research (NCAR) has served as the central repository for FINN global emissions files spanning from 2002–2020. FINN emission estimates have been applied in regions of the world that experience high fire activity to evaluate the influences on air quality and public health to assess emissions trends, to examine the effects of changing climate and development patterns on wildfire emissions and in comparisons with surface, aircraft, and satellite-based observations. Real-time emissions estimates from FINN version 1 (FINNv1) are currently used in the NCAR Whole Atmosphere Community Climate Model (WACCM) chemistry and aerosol forecasts.

The Fire INventory from NCAR version 2.5 (FINNv2.5) is an updated global fire emissions model that provides publicly available emissions of trace gases and aerosols for various applications, including use in global and regional atmospheric chemistry modelling. FINNv2.5 is an updated version of the FINN version 1 framework, with many updates to better represent burned area, vegetation burned, and chemicals emitted.

Some of the major updates include:

- The use of active fire detections from the Visible Infrared Imaging Radiometer Suite (VIIRS) at 375 m spatial resolution, which allows smaller fires to be included in the emissions processing.
- The calculation of burned area has been updated to improve aggregate fire detections, which better accounts for larger fires and enables using multiple satellite products simultaneously for emissions estimates.
- Fuel characterization and emissions factors have also been updated in FINNv2.5.

The FINNv1 model is based on a bottom-up approach to estimate the emissions described by Wiedinmyer et al. (2011). In FINNv1, global observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on board the National Aeronautics and Space Administration's (NASA) Terra and Aqua satellites are used to detect fire activity, beginning with the MODIS Rapid Response (MRR) system or the MODIS Adaptive Processing System (MODAPS) Collection 5 (Davies et al., 2009).

Fuel characterization in FINNv1 is based on the Collection 5 MODIS Land Cover Type (LCT) product for 2005 (Friedl et al., 2010), with land cover classifications defined by the International Geosphere–Biosphere Programme (IGBP) and the Collection 3 MODIS Vegetation Continuous Fields (VCF) product for 2001 (Carroll et al., 2011). Fuel loadings are assigned from Hoelzemann (2004) or Akagi et al. (2011). Estimates of fuel burned use the approach of Ito and Penner (2004). Emissions factors by land cover classification for trace gases and particulate air pollutants in FINNv1 are based on the published literature (Akagi et al., 2011; Andreae and Merlet, 2001; Andreae and Rosenfeld, 2008; McMeeking, 2008).

FINN version 2.5 (FINNv2.5) has extensive updates to the input data and processing used for the detection of fire activity, characterization of annual land use and/or land cover and vegetation density, determination of area burned, and the application of fuel loadings by global region compared to the FINNv1 configuration. FINNv2.5 also includes revisions to emissions factors based on the current literature.

Methods Used for the Development of FINNv2.5

FINNv2.5 was released in 2022. A global emissions database for the period 2002 to 2021 has been created for public use, for incorporation in emission inventories, chemical modelling and climate modelling applications. FINNv2.5 uses the same FINNv1 bottom-up methodology (Wiedinmyer et al., 2011) as defined by the following overall equation:

$$E_i = A(x,t) \times B(x) \times FB \times EF_i$$

where the emissions (*E*; mass of pollutant *i*) is the product of the area burned at location *x* and time *t* [*A*(*x*,*t*)], the biomass at location *x* [*B*(*x*)], the fraction of biomass that is burned (FB), and an emissions factor (EF_i; mass of pollutant *i* per biomass burned).

The FINNv2.5 model framework has the following three components:

- Burned area and land cover determination
- Fuel consumption and emissions calculation
- Speciation of the non-methane organic gases.

Fire Location and Timing

FINNv2.5 first determines the burned area from daily satellite detections of active fires. FINNv2.5 uses MODIS detections at a 1 km^2 resolution (as in FINNv1), and adds an option to use active fire detections at 375 m resolution from the Visible Infrared Imaging Radiometer Suite (VIIRS), which is on board the Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite, in isolation or together with MODIS active fire data. The use of VIIRS 375 m detections is regarded as a major advancement from the use of MODIS-only fire detections, as this product is able to capture small fires better.

The MODIS Collection 6 (MCD14DL) and VIIRS active fire products are obtained from NASA's Fire Information for Resource Management System (FIRMS) data portal. The MODIS product provides the location, overpass time (Coordinated Universal Time, UTC), and confidence of daily fire detections. Data confidence in the MODIS product is specified by a numerical scale of 0 % to 100 %. Detections with a confidence specification that is less than 20 % are eliminated from calculations in FINNv2.5, as implemented in earlier versions of FINN.

With its improved spatial resolution of 375 m, the VIIRS product provides a more sensitive detection of the fires of relatively small areas, fully global coverage, improved mapping of large fire perimeters, and improved nighttime performance relative to MODIS fire detections (Schroeder et al., 2014). Detection confidence is provided by the VIIRS product and is specified by three categories, i.e. low, nominal, and high. In the FINNv2.5 preprocessor, detections with a confidence specification identified as low are eliminated from the analysis. Only data attributed to thermal anomalies from vegetation fires are included in the analysis. Thermal anomalies associated with active volcanos or static land sources are eliminated from the analysis.

The processing of the two simultaneous fire products in FINNv2.5 does not lead to double-counting of the fires; the FINNv2.5 method determines the spatial union of all adjacent detections for a given day as the daily burned area of a fire. The identity of the sensor is not relevant for the determination of the burned area, as long as the pixel size for each detection is correctly represented (i.e., 0.14 km^2 for VIIRS and 1 km^2 for MODIS).

BURNED AREA

FINNv1 estimates burned area for each fire pixel identified individually, and the nominal pixel size for the MODIS fire detections of 1 km^2 is assumed per detection. Spatially overlapping detections are eliminated from further analysis. It was recognized that for large fires in forested regions, an array of multiple discrete detections is typically reported, and an estimate of a contiguous area that represents the total area burned by a fire is needed.

In FINNv2, a new approach is adopted where the burned area estimate is improved to better represent the area associated with each fire. In the new approach used in FINNv2.5, each reported active fire detection is assigned a square area of 0.14 km^2 from VIIRS or 1 km^2 from MODIS, based on the nominal horizontal resolution of the data. Detections determined to be in proximity with one another are aggregated by two different approaches, depending on the land cover type and forest cover. Initially, it is assumed that multiple detections by adjacent pixels in a satellite sensor array are part of a larger fire, and these detections are merged. The scan and track sizes of the satellite pixel are provided by the fire detection product and define the actual resolution of the fire detection. The scan and track sizes for each fire detection are used for identifying groups of records that represent adjoining or overlapping detections. A rectangle with easterly and northerly sizes equal to 110 % of the scan and track sizes is established for each detection, with the objective of identifying adjacent neighbouring detections but not for direct application to the burned area estimation. Fire detections are identified as being from one larger fire when any of the satellite detection rectangles overlap. To minimize an overestimation of the burned area, a convex hull is generated between corresponding pairs of detection rectangles that directly intersect. The union of pairwise convex hulls from a cluster forms an extended fire polygon that represents the tentative estimated burned area for a single fire event or group of nearby fires for the day. This approach effectively fills any gap between instrument resolution squares (Wiedinmyer and Emmons, 2023).

For each of the extended polygons, the MOD44B v006 MODIS/Terra VCF annual product is overlaid, and the average tree cover fraction is determined. For forested areas with tree cover ≥50 %, as determined by the VCF product, the merged polygons are accepted as the final burned area estimate. Otherwise, the merging is not used, and instead, an alternative, more conservative, approach is applied to determine the burned area for the region. This alternative approach is used to prevent overestimation of emissions in regions with many small fires, as in the savanna fires in sub-Saharan Africa. The alternative polygon aggregation is achieved by aggregating nearby detections only when the instrument pixels themselves are intersecting and therefore not with the extended detection footprints. The result is an aggregation algorithm that is repeated with a smaller set of detections to determine the alternative conservative set of polygons (denoted as the conservative fire polygon). The final burned area polygons is ultimately a composite of polygons based on these two different aggregation approaches (Wiedinmyer and Emmons, 2023).

Subsequently, the final burned area polygons are subdivided using a Voronoi tessellation algorithm in order to develop emissions estimates by land cover classification. Each of the undivided final burned area polygons are assigned a unique fire ID to enable users to group emission estimates from a presumed single fire event (Wiedinmyer and Emmons, 2023).

FUEL LOADING AND VEGETATION INPUTS

The NASA MODIS VCF product provides estimates of the percentage of bare surface, herbaceous, and forested cover at a horizontal resolution of 250 m. For each fire area, the subdivided polygons are overlaid on the vegetation cover data from the MOD44B v006 MODIS/Terra VCF annual product. The VCF data for the prior year are chosen, so that the VCF before any land cover changes due to fire are used in the emissions estimation process. The VCF raster is clipped to the geometry of the fire polygon, and the averages of the VCF tree, herbaceous, and bare cover are calculated for each fire polygon (Wiedinmyer and Emmons, 2023).

FINNv2.5 uses the Terra and Aqua combined MODIS LCT MCD12Q1 Version 6 data product with the International Geosphere–Biosphere Programme (IGBP) classification scheme as its default land cover information. Use of the LCT and VCF products in FINNv2.5 is an improvement on FINNv1. FINNv1 used one static map of LCT and VCF (from 2002) for any year processed. FINNv2.5 employs year-specific MODIS LCT and VCF maps that change annually. Furthermore, the specific vegetation assignments for each subdivided polygon enable different vegetation types and coverage to be represented across larger fires. These input data and processes enable better representation of the vegetation that is burned. All fire polygons are assigned to 1 of 13 global regions (Wiedinmyer et al., 2011) used to assign fuel loadings. This completes the first component of the FINNv2.5 modelling framework and results in a file of daily burned areas and associated land cover information (Wiedinmyer and Emmons, 2023).

EMISSION CALCULATION

The next step of the model framework is the emissions calculation. In this step, the daily burned area and associated vegetation information (described above) are assigned associated fuel loadings. Using the same process described by Wiedinmyer et al. (2011), where the biomass burned is assigned based on land cover type and global region (B), the fraction of the biomass that is burned (FB) is assigned as a function of tree and herbaceous cover, emissions factors (EFs) are determined based on land cover, and daily pollutant emissions estimates are calculated following Eq. (1). Overall, the emissions calculation process follows this framework, as described by Wiedinmyer et al. (2011).

Similar to earlier FINN versions (Wiedinmyer et al., 2011), the 16 IGBP land cover classifications of the LCT product are mapped to consolidated vegetation types, depending on the land cover class and latitude that distinguish tropical, temperate, and boreal forests (Table 4-8). The consolidated vegetation types used in FINNv2.5 are grassland and savanna, woody savanna or shrubs, tropical forest, temperate forest, boreal forest, temperate evergreen forest, and crops.

The fuel loading, or the potential maximum amount of biomass available to be burned ($B(x)$ in Eq. 1), is assigned by generic vegetation type and global region (Table 4-9). Selected values were updated for FINNv2.5 from earlier versions of FINN, based on van Leeuwen et al. (2014). The fuel loading for crops was updated to 902 g m^{-2}, based on an average from the literature (Akagi et al., 2011; van Leeuwen et al., 2014; Pouliot et al., 2017). Emissions factors are then assigned based on the generic vegetation type (Table 4-10).

Table 4-8: LCT IGBP and generic vegetation type descriptions

IGBP LCT description	LCT value	Generic vegetation type	Generic vegetation value
Evergreen needleleaf forests	1	If latitude >50, then boreal forest; otherwise, temperate evergreen forest	5,6
Evergreen broadleaf forests	2	If latitude >-23.5 and	3, 4
Deciduous needleleaf forests	3	If latitude >50, then boreal forest; otherwise, temperate forest	5,4
Deciduous broadleaf forests	4	Temperate forest	4
Mixed forests	5	If latitude >5, then boreal forest; if latitude >-23.5 and	5, 3, 4
Closed shrublands	6	Woody savanna or shrubs	2
Open shrublands	7	Woody savanna or shrubs	2
Woody savannas	8	Woody savanna or shrubs	2
Savannas	9	Grassland and savanna	1
Grasslands	10	Grassland and savanna	1
Permanent wetlands	11	Grassland and savanna	1
Croplands	12	Croplands	9
Urban and built-up lands	13	If tree cover 40 and 60, then assign based on latitude	**
Cropland/natural vegetation mosaics	14	Grassland and savanna	1
Permanent snow and ice	15	Remove	
Barren	16	Grassland and savanna	1
Waterbodies	17	Remove	
Unclassified	255	Remove	

** if latitude > 50, then Boreal Forest; if latitude > -30 and < 30, then Tropical Forest; Else, Temperate Forest

Table 4-9: Fuel loadings (g/m^2) assigned by generic land cover type and global region as described by Wiedinmyer et al. (2011), unless noted otherwise (values in bold indicate those updated for FINNv2.5, based on van Leeuwen et al. (2014)

Global region	Tropical forest	Temperate forest	Boreal forest	Woody savanna/ shrublands	Savanna and grasslands[e]
North America	28 076[a]	**10 661[c]**	**17 875[c]**	4762	976
Central America	**26 500[c]**	11 000		2224	418
South America	**26 755[c]**	7400		3077	**624[c]**
Northern Africa	25 366	3497		2501	**382[c]**
Southern Africa	25 295	6100		2483	**411[c]**
Western Europe	28 076[a]	7120	6228	4523	1321
Eastern Europe	28 076[a]	11 386	8146	7752	1612
North central Asia	6181[b]	20 807	**14 925[c]**	11 009	2170
Near East	6181[b]	10 316		2946	655
East Asia	**14 941[c]**	7865		4292	722
Southern Asia	**26 546[c]**	14 629		5028	1445
Oceania	16 376	**13 535[c]**		**2483[d]**	**552[c]**

[a] Tropical forest class added for North America and Europe (in LCT). [b] All of Asia is assigned equal tropical forest values. [c] Taken from van Leeuwen et al. (2014). [d] Taken as the same for African woody savanna from van Leeuwen et al. (2014). [e] Croplands are assigned the same fuel loading as grasslands.

Table 4-10: Emissions factors (g/kg) for FINNv2.5

Chemical species	Generic vegetation index and type						
	1	2	3	4	5	6	9
	Savanna grasslands[a]	Woody savanna/ shrubs	Tropical forest	Temperate forest[b]	Boreal[c]	Temperate evergreen forest[b]	Crops[d]
Carbon dioxide (CO_2)	1686	1681	1643	1510	1565	1623	1444
Carbon monoxide (CO)	63	67	93	122	111	112	91
Methane (CH_4)	2	3	5.1	5.61	6	3.4	5.82
Non-methane organic gases (NMOGs)[e]	28.2	24.8	51.9	56	48.5	49.3	51.4
Hydrogen (H_2)	1.7	0.97	3.4	2.03	2.3	2	2.59
Nitrogen oxides (NO_X as NO)	3.9	3.65	2.6	1.04	0.95	1.96	2.43
Sulfur dioxide (SO_2)	0.9	0.68	0.4	1.1	1	1.1	0.4
Particulate matter with diameters less than 2.5 µm ($PM_{2.5}$)	7.17	7.1	9.9	15	18.4	17.9	6.43
Total particulate matter (TPM)	8.3	15.4	18.5	18	18.4	18	13
Total particulate carbon (TPC)	3	7.1	5.2	9.7	8.3	9.7	4
Particulate organic carbon (OC)	2.6	3.7	4.7	7.6	7.8	7.6	2.66
Particulate black carbon (BC)	0.37	1.31	0.52	0.56	0.2	0.56	0.51
Ammonia (NH_3)	0.56	1.2	1.3	2.47	1.8	1.17	2.12
Nitrogen oxide (NO)	2.16	0.77	0.9	0.95	0.83	0.95	1.18
Nitrogen dioxide (NO_2)	3.22	2.58	3.6	2.34	0.63	2.34	2.99
Non-methane hydrocarbons (NMHCs)	3.4	3.4	1.7	5.7	5.7	5.7	7
Particulate matter with diameters less than 10 µm (PM_{10})	7.2	11.4	18.5	16.97	18.4	18.4	7.02

[a] Emissions factors for tropical forests, savannah/grasslands, and woody savannah/shrubs are updated to the average values from Akagi et al. (2011; updated in February 2015). [b] Emissions factors for temperate forest and temperate evergreen forests are the average values from Akagi et al. (2011; updated February 2015), and the results are from Liu et al. (2017), Paton-Walsh et al. (2014), and Urbanski (2014). For temperate evergreen forest, only the results from evergreen forests are included. [c] Boreal forest emissions factors are the average of Akagi et al. (2011), with the emissions factors from boreal forest taken from Urbanski (2014). [d] Crop emissions factors are updated with the average values from Akagi et al. (2011) and results from Fang et al. (2017), Liu et al. (2016), Santiago-De La Rosa et al. (2018), and Stockwell et al. (2015; Table S3). [e] NMOG emissions factors now include identified and unidentified compounds.

4.4.3 Emission Inventory

The FINNv2.5 model was run in two ways to produce emissions for evaluation and assessment, namely (1) for comparison with the previous version of FINN (FINNv1.5) using MODIS-only fire detections and calculated starting in 2002 (FINNv2.5(MODIS)) and (2) by using both MODIS and VIIRS fire detections and calculated starting in 2012 (FINNv2.5(MODIS + VIIRS) (Wiedinmyer and Emmons, 2023).

For all emitted species, FINNv2.5(MODIS + VIIRS) global emissions are higher than, and approximately double, those predicted by FINNv1.5. This is the case, even when only MODIS fire detections are considered. The increase in emissions from previous versions is primarily due to the new processing of the area burned. In previous versions, the fire area was determined from a satellite detection pixel only; the updated version here also includes the composite of many detections into larger areas of fire activity. The inclusion of VIIRS into the FINNv2.5(MODIS + VIIRS) inventory globally adds approximately 25 % above the FINNv2.5(MODIS) processing for all emitted species. Further, emissions of NMOGs and the individual species that make up NMOGs (e.g., CH_2O and C_2H_6) are increased significantly due to the use of updated emissions factors from recent field campaigns. Previous studies have shown low biases in FINN regional and species-specific estimates. The updated version is expected to correct some of these prior biases (Wiedinmyer and Emmons, 2023).

FINNv2.5(MODIS + VIIRS) emissions estimates are overall at the higher end of the range of annual global total emissions compared to other commonly used emission inventories, likely due to a combination of the aggregated burned areas and the fact that FINNv2.5(MODIS + VIIRS) includes fire information from VIIRS, which captures more small fires. Globally, fire emissions peak in August–September, with the largest emissions in Southern Hemisphere Africa and Southern Hemisphere South America (Wiedinmyer and Emmons, 2023).

The biomass emissions used in the study has been extracted using the extents of the modelling domain. The FINNv2.5 biomass burning emissions are calculated over a period spanning from 2002–2021. Biomass burning emissions are not available for 2022. An average of the 2020 and 2021 period have therefore been averaged to provide an annual average emission rate for biomass burning emissions. The annual average biomass burning emissions for the modelling domain is presented in Table 4-11. The location of biomass burning fires for the 2020 and 2021 period is presented in Figure 4-6.

Table 4-11: Estimated biomass burning emissions

Pollutant	SO_2	NO_X	PM_{10}	$PM_{2.5}$	TPM
Emission Rate (tonnes/annum)	247.63	54.09	2 550.06	2 451.40	3 666.53

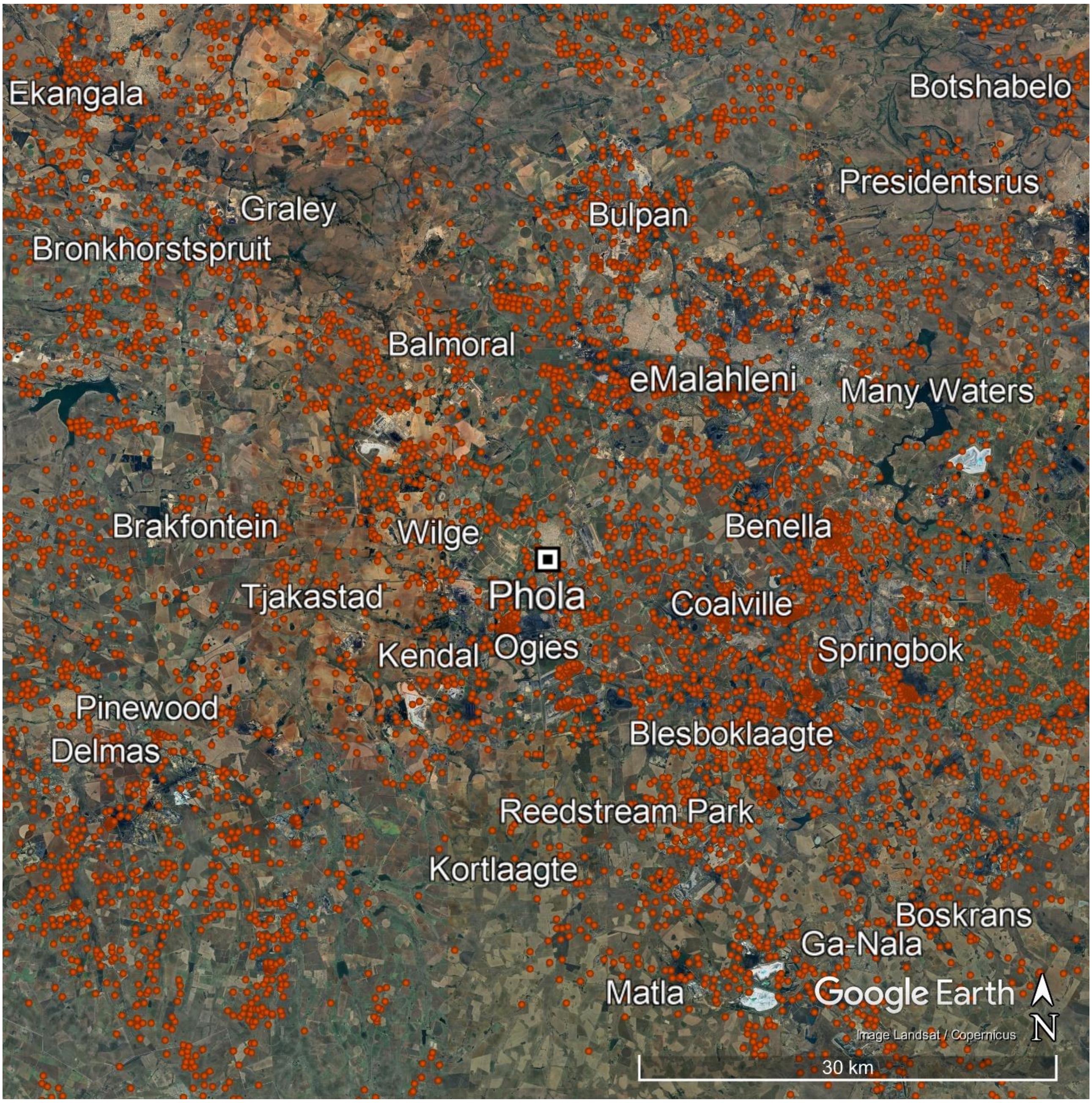

Figure 4-6: Location of biomass burning fires (indicated by orange dots)

4.5 Vehicles – Paved Roads

4.5.1 Introduction

A paved road is defined as any road that has a semi-permanent surface placed on it (for example, asphalt or concrete). In this section, emissions are calculated for exhaust emissions, brake, tyre and road wear for vehicles travelling on paved roads.

Emissions from vehicles arise during the different cycles of driving from start-up, during driving, evaporation from the engine and fuel line, and during re-fueling (DEFF, 2010). Particulate matter is also emitted from brake, tyre and road wear (DEFF, 2013). Other pollutants associated with vehicle emissions include SO_2, NO_2, carbon monoxide, benzene and lead. In this study, only SO_2, NO_X, and particulates (PM_{10} and $PM_{2.5}$) will be considered. The emission rates are co-dependent on various factors relating to vehicle parc (vehicle class, model, speed and maintenance); fuel specifications and environmental factors (Samaras *et al*., 1999). Considering the complexity of vehicle emission inventory development, this study has opted to use the COPERT vehicle emission estimation model which is regarded as the EU standard vehicle emissions calculator and has been used in other regulatory strategic documents such as the Second Generation Vaal Triangle Airshed Priority Area (VTAPA) Air Quality Management Plan (DEFF, 2020). COPERT stands for COmputer Programme to calculate Emissions from Road Transport. It uses vehicle population, mileage, speed and other data such as ambient temperature and calculates emissions and energy consumption for a specific country or region. As an initial input basis of the emission estimates, a detailed road network of the region in question is required for which the associated vehicle population, mileage, speed and other data are estimated. The road network within the Great Phola Airshed is presented in Figure 4-7.

The network shown in Figure 4-7 is sourced from the World Bank data CatLog for South African roads delineated by the Word Bank (https://datacatalog.worldbank.org/dataset/south-africa-roads) and based on the South African national roads network.

The dataset classifies roads into three basic classes i.e., Primary, Secondary and Tertiary with road traffic apportioned according to these classifications with "Primary" carrying high volumes of traffic and "Tertiary" carrying less traffic. Thus, two factors play a role in emission intensity when considering these three types of roads. Primary roads may carry more vehicle volume and lead to higher emissions, together with congestion (therefore lowering speed and travel time) can also increase emissions. In general, factors that impact vehicle emissions estimates are:

- Fuel type
- Fuel specifications
- Engine technology
- Engine capacity
- Vehicle speed
- Vehicle age
- Engine/exhaust temperature
- Number of kilometres travelled.

Other, more detailed factors requiring information that is generally not available (particularly on such a large scale) are gearing, driving style, tyre friction and road grading, and are generally not available in a South African context.

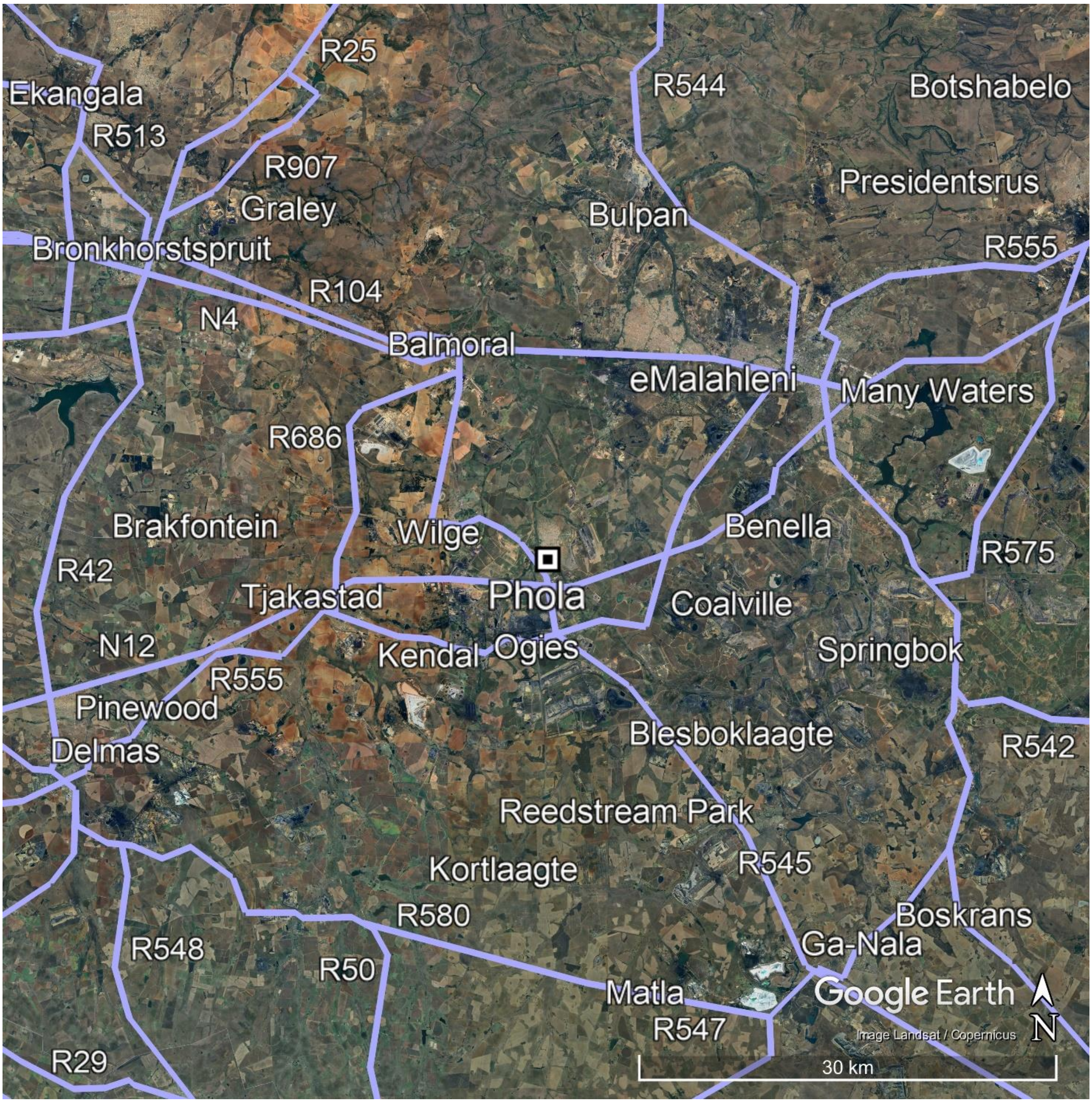

Figure 4-7: Road Network within the Greater Phola Airshed modelling domain

The basis of deriving vehicle emissions is an estimate of Vehicle Kilometres Travelled (VKT). This data represents an activity to which emission factors are applied. The emission factors are dependent on all other factors noted above and are accounted for in the COPERT model. Thus, any approach to generate a vehicle emission inventory includes an estimation of VKT and use of appropriate emission factors generated via COPERT. The level of detail included in each factor varies depending on available information which is required at the grid cell level for the most accurate estimation results. This is not necessarily possible for all the above-listed factors because many (for example, fuel type) are not tracked at a fine scale.

Thus, assumptions are made using spatial surrogates to generate a finer resolution emission inventory that is spatially representative. There are instances when very detailed information is available (such as traffic count data); however, these are then often spatially limited. Assumptions are then used to extrapolate this data to the larger spatial scale – this is termed a bottom-up approach – more detail on this approach is provided in section below. When larger scale, but more generalised data exists e.g., Provincial or District Municipality Level Fuel Sales, assumptions are made to create a finer scale variation based on surrogates – this is termed a top-down approach. Both these approaches are viable when estimating vehicle emissions, but largely depend on the data available.

4.5.2 Methodology

As detailed above, estimation of the on-road vehicle emission inventory in this study has employed both a top-down and bottom-up approach. This is possible due to road count data being available from various sources which is also inherently contained in the road network data set i.e. Primary, Secondary and Tertiary classified roads. For both the top-down and bottom-up methodologies, the common underlying spatial units are the World Bank data CatLog for South African roads road links (Figure 4-7). Vehicle classes for which emissions are estimated are presented in Table 4-12.

Table 4-12: Vehicle classes for which emissions are estimated

eNaTIS Classification	ADDT Light
Motor Cars and Station Wagons	Car Diesel
	Car Petrol
	SUV Diesel
	SUV Petrol
Motorcycles, Quads and Tricycles	MotoBike Petrol
LDV'S, Panel Vans etc	LCV Diesel
	LCV Petrol
eNaTIS Classification	**ADDT Heavy**
Trucks	HCV1 Petrol
	HCV1 Diesel
	HCV2 Diesel
	HCV3 Diesel
eNaTIS Classification	**AADT Very Heavy**
Trucks	HCV4 Diesel
	HCV5 Diesel
	HCV6 Diesel
	HCV7 Diesel
	HCV8 Diesel
eNaTIS Classification	**ADDT Bus**
Buses, bus trains, minibuses	Bus
Taxi	Minibus Taxis

It is important to note that various vehicles may be travelling on a particular piece of road at any given moment which requires a comprehensive vehicle typology or parc to be developed for which emissions will be estimated. Considering this, emissions for the classes listed in Table 4-12 are estimated which follow the electronic National Traffic Information System (eNaTIS) broad classifications as reported in the provincial statistics. This is then used to calibrate the COPERT model. A top-down approach uses fuel sales to estimate VKT and allocates this to roads by their type; however, the bottom-up approach serves as a starting point of the emission inventory.

BOTTOM-UP

Road count data is used to estimate VKT for each count station by applying the count to the immediate road link and this data is contained within the World Bank data CatLog for South African roads delineated by the Word Bank. The extents are limited in this way because there is no other methodology to describe traffic flow in other links around the station, except using a full-scale network flow model. These links are then removed from the full road network together with estimated fuel consumption for that link by converting VKT to fuel-use using fuel efficiency data that is also generated by the COPERT model. This ensures there is no double counting of both VKT and spatial features. All VKT are converted into fuel consumption using the efficiency data extracted from the COPERT model (see “Emission Factors” section below). This fuel consumption is subtracted from the provincial fuel sales, together with the road links associated with counts, going into the top-down methodology. The SANRAL count data is also useful in that average vehicle speeds are given. Using this information, it was possible to assign typical speeds for different World Bank data CatLog Road types. These speeds are necessary for selecting appropriate emission factors further in the process. Figure 4-8 shows the average speeds for light, heavy and overall classes for each World Bank data CatLog Road class. After all bottom-up estimations are done, the remaining road network is used for the top-down approach.

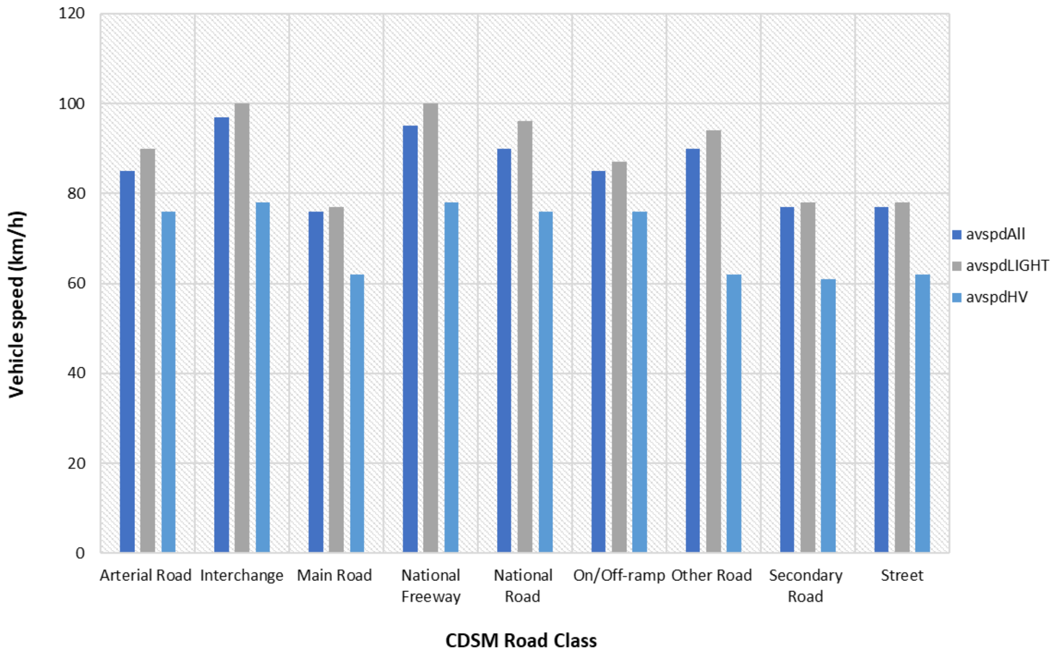

Figure 4-8: Average vehicle speeds for all light and heavy-duty vehicles for each CDSM road class (derived from SANRAL count data)

TOP-DOWN

The top-down approach uses provincial fuel sales and fuel efficiency data (from COPERT; see "emission factors" section) to estimate VKT. A key assumption is that fuel sales equate to fuel consumption. This is the case for total national volume, however, the possibility of fuel sales being consumed elsewhere is likely when looking at regional fuel sales. Therefore, Magisterial District sales are used rather than provincial sales (also available from the Department of Energy (DoE)) to minimize this effect. DoE obtained fuel sale data is classified into "Travel Analysis Zone" (TAZ) which comprises of various towns to which fuel/VKT is associated to specific road links.

Once fuel sales are allocated to TAZ, it is necessary to disaggregate further down to road level. This is accomplished by using data from the South African Road Classification and Access Manual (SARCAM) (SANRAL, 2012). Tables B and C of the manual provide typical average annual daily traffic (AADT) for different road classes. These typical road AADTs were used to proportionally distribute fuel to different World Bank data CatLog for South African roads classes. The result of this process is unique road classes, to which typical AADT from the SARCAM can be assigned. Fuel within each TAZ is then distributed by the typical AADT proportion amongst classes.

The final level of disaggregation is achieved by then allocating fuel proportionally within classes based on link length. The result is a fuel consumption estimate on each of the remaining (after removals from the bottom-up processing) World Bank data CatLog for South African roads. This fuel consumption is converted to VKT using the COPERT-derived fuel efficiency data.

4.5.3 Emission Factors

In this study, “hot running” (thermally stabilized engine and exhaust treatment) emission factors were derived from the COPERT 5 (version 5.0.1145) model. The model is developed by EMISIA SA and supported by the European Environment Agency (EEA). The methodological approach (and thus formulae) for COPERT 5 is identical to the Tier 3 methodology laid out in the EMEP/EEA air pollutant emission inventory guidebook 2013 (European Environment Agency, 2013) for “Exhaust emissions from road transport” (Part B, Section 1.A.3.b.i-iv).

The COPERT approach was chosen since all other locally derived emissions factors (e.g., Stone, 2000; Wong, 1999; Wong and Dutkiewicz, 1998) provided an emission factor at a generalized single speed; while what is required for this emission inventory is a speed-based estimate since emission factors are sensitive to vehicle speed that are effectively linked to the World Bank data CatLog for South African roads and vehicle speeds. Additionally, locally derived emission factors represent a much older vehicle fleet; typically, pre-EURO2. Emission factors were modelled for EURO 1-6 stage vehicles from the classes specified in Table 4-13. An approximate manufacture years for each EURO stage is also listed in Table 4-13.

Table 4-13: Vehicle EURO stage and corresponding manufacture years

EURO Stage	Vehicle Model Year
EURO 1	1992 – 1995
EURO 2	1996 – 1999
EURO 3	2000 – 2004
EURO 4	2005 – 2009
EURO 5	2010 – 2014
EURO 6	2015 – current

Emission factors for SO_2, NO_X, and particulates were estimated in COPERT for speeds from 20 to 120 km/hr (in 20 km/hr increments). COPERT also estimated fuel consumption (i.e., efficiency in l/km) for each speed. Note that in practice the closest speed emission factor is matched to the specific speeds for vehicles travelling on that road. The full emission factor/fuel consumption dataset thus comprised 4 536 factors (6 EURO classes by 6 speeds by 18 vehicle classes by 7 pollutants).

Since there is no indication of vehicle age or technology within the activity data used (both counts for the bottom-up and fuel sales for the top-down) it is necessary to aggregate the emission factors by EURO stage. To simply take an average would not be accurate since that would assume all vehicle ages exist at an equal proportion in the vehicle parc. This is not true as newer vehicles enter the parc, older ones leave, resulting in a shift towards newer vehicles.

The spread of vehicle age in a parc can be determined through scrapping curves. A weighted average of emission factors between EURO stages can then be obtained to derive a single emission factor per vehicle class and pollutant (still at the different speeds). The scrapping curve used in this study is based on Merven et al., (2012) eNaTIS calibrated (year 2010). Weibull cumulative distribution functions show probability of vehicle survival as a function of age. These functions are then applied to the time periods relevant to this study. The scrapping curves used for each class is presented in Figure 4-9 (after Merven et al., 2012). These curves were used for deriving an age proportion weighted average emission factor for each speed and pollutant per vehicle class. The diesel NO_X emission factors derived from COPERT is presented in Figure 4-10 illustrates the importance of vehicle speed.

The emission factors were then applied to the VKT per vehicle class and road type to derive an annual emission estimate per road link for all pollutants of concern. For verification, the VKT and fuel consumption estimates derived from the COPERT model are adjusted to ensure a +/- 10% agreement with petrol and diesel fuel sales determined for each TAZ, ensuring accurate estimation of emissions in each area.

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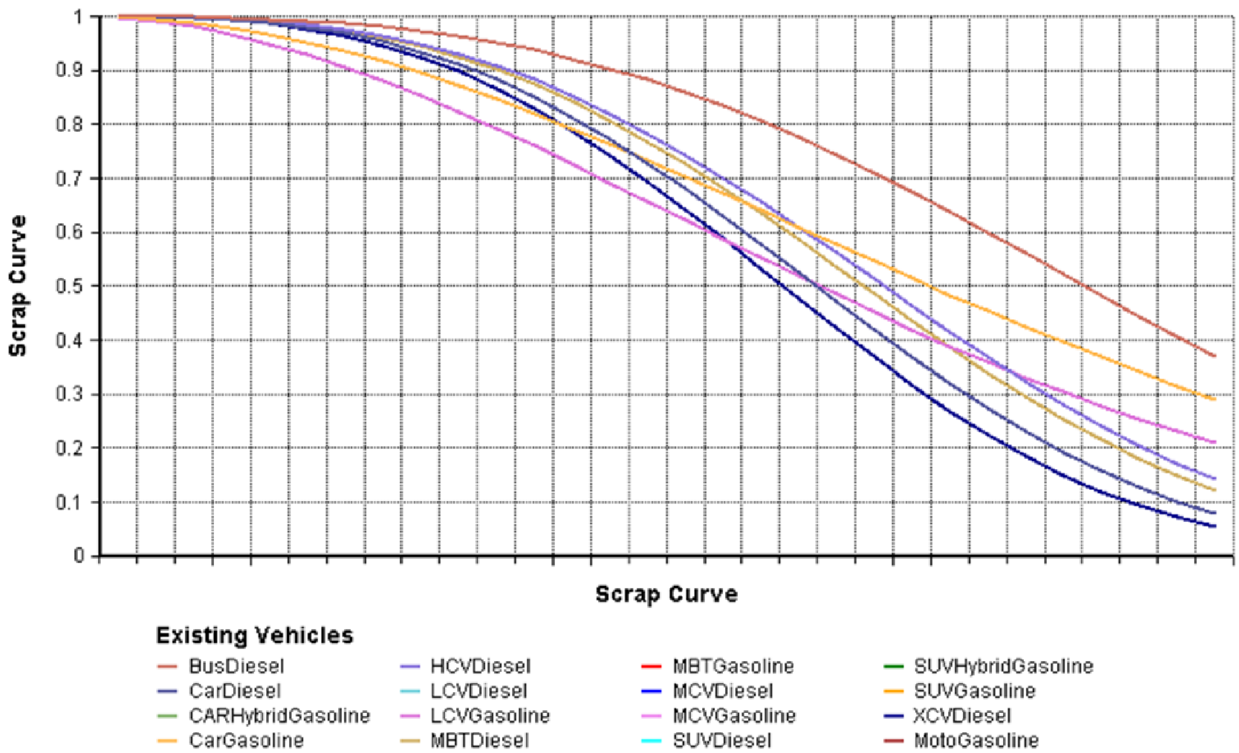


Figure 4-9: Base year scrapping curves for the vehicle technology types in the vehicle parc model (After Merven et al., 2012)

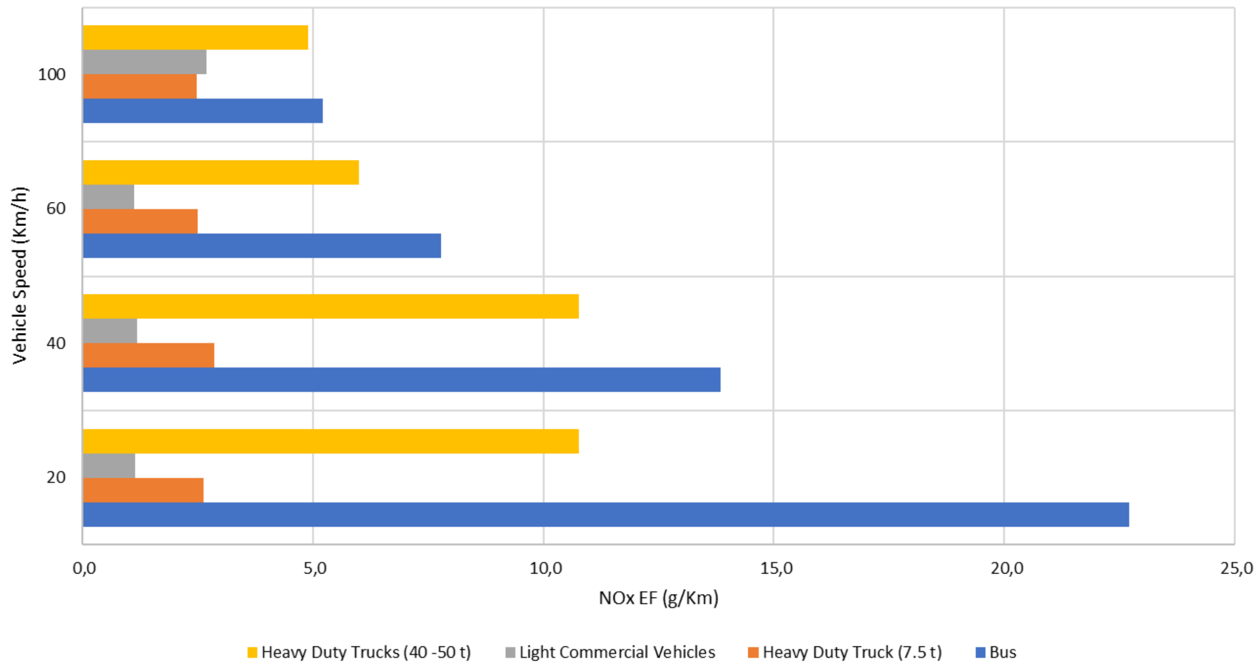


Figure 4-10: NO_X emission factors for diesel classes

4.5.4 Emission Inventory

Expectedly, higher on-road vehicle emissions are observed in areas with greater fuel sales. Having the greatest volume of daily traffic and fuel sales subsequently results in the greatest emission from on-road vehicles in the region. Table 4-14 presents the total tonnage of estimated annual tonnage of estimated on-road vehicle emissions within the Phola modelling domain.

Table 4-14: Estimated on-road vehicle emissions (tonnes/annum) within the Phola modelling domain

Pollutant	SO_2	NO_X	PM_{10}	$PM_{2.5}$
Emission rate (tonnes/annum)	133.57	8 991.08	183.00	183.00

4.6 Vehicles – Unpaved Roads

4.6.1 Introduction

An unpaved road is a road which has a surface that does not meet the definition of a paved road. The road surface may be dirt, rock, gravel, or other non-solidified material and may have a dust palliative applied (*dust palliatives* are substances applied to roads or ground surfaces to reduce airborne dust and its health impacts). Unpaved roads often contribute a significant amount of atmospheric dust formed due to re-suspension of road material by vehicles, and observed as a dust cloud behind the driving vehicle. If a dust suppressant is applied to an unpaved road, this segment of road is still considered to be an unpaved road surface.

Most of the roads in South Africa are classified as gravel roads. A gravel road is a type of unpaved road surfaced with gravel that has been brought to the site from a quarry or stream bed. In many cases, replacement of gravel on these roads may not always be available or feasible. In 2016, SANRAL estimated between 74-79% of South African roads are gravel (https://www.arrivealive.co.za/The-South-African-National-Roads-Agency-LTD). Most of these roads are found within rural areas but a large percentage of these gravel roads are also found in urban areas. According to the roads infrastructure statistics, presented by the Mpumalanga Provincial Department (Mpumalanga Province, 2023), 60% of the Mpumalanga road network is considered gravel, and these gravel roads are in very poor condition. It is expected that a large portion of the unpaved road network in Mpumalanga is found in outer lying urban areas and within townships.

The climatology of a particular place is controlled primarily by its latitude, which determines the amount of solar radiation that is received, its distance from the sea and the height above sea level. Secondary influences on climate are the general circulation of the atmosphere, the nature of the underlying surface and topography. South Africa lies in the sub-tropical high-pressure belt, which causes the general circulation over the sub-continent to be generally anticyclonic above 700 hPa for most of the year. The Mpumalanga Highveld lies in temperate latitudes between 25º 25' S and 27º 31' S, and varies between 1500 and 1900 m above sea level. As a result, the Highveld experiences a temperate climate with dry winters according to the Köppen Climate Classification system. Winters are mild and dry, but cold at night when frost may occur. Rain occurs in summer and temperatures are warm. The rain is mostly a consequence of the development of low-pressure troughs over the central plateau in summer and the dry winters are due to the dominant subtropical high pressure system. The temperate temperatures are the consequence of the relatively high altitude (DEA, 2011).

The average rainfall in the Highveld varies from about 900 mm in the higher lying areas in the east to about 650 mm in the west. Rainfall is almost exclusively in the form of showers and thundershowers and occurs mainly in the summer from October to March, with the maximum in January. Winters are typically dry, but some rain does occur (DEA, 2011). This combined with potentially intense traffic in the urban areas, unpaved roads may present a significant local source of PM (Naidoo, 2023).

When a vehicle travels on an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Emissions caused by vehicles can be minimized by paving, windbreaks, frequent water and/or environmentally friendly chemical applications, and using gravel as a means of dust suppression.

LOCATION OF UNPAVED ROADS

Google Earth satellite imagery was used to map out locations of unpaved roads, mainly focusing on densely populated townships within the modelling domain. Based on the satellite imagery, it is noted that there are a few main roads and access roads within townships that are paved. This accounts for a very small fraction of the total length of all roads within a township. From a modelling perspective, a modelling exercise to include all unpaved road segments would be an exceptionally time-consuming exercise and would require exceptionally long model run-times. It was therefore decided to include the unpaved roads as area sources. Area sources corresponding with unpaved roads, which has been used in the modelling is presented in Figure 4-11.

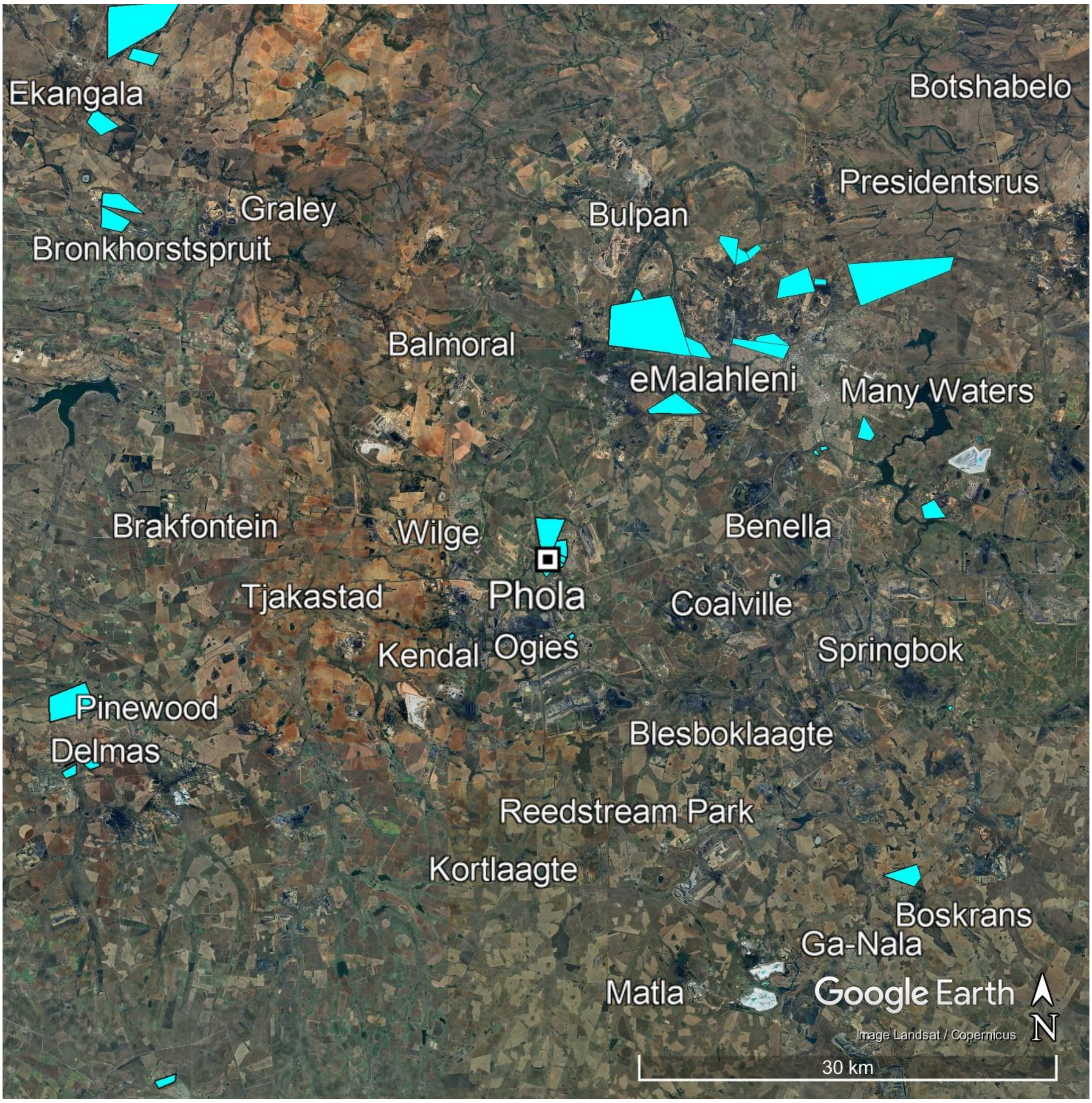


Figure 4-11: Location of areas corresponding with unpaved roads for the Greater Phola Airshed

ASSUMPTIONS

For development of the emission inventory, there was no available information for critical input data. A number of assumptions had to be made based on best judgement. To streamline the modelling process, the following profile was created based on a 1 square kilometre of a high-density township:

- Approximately 1000 homes are located within 1 square kilometre of a township, representing 1000 families.
- 50% of these homes have a car, but only half of them are used on a regular basis for travelling to work, dropping off children at school or for shopping. It is therefore assumed that 250 cars

travel on the unpaved roads on a daily basis. It is also assumed that each car travels on approximately 1 km of unpaved roads per day.

- Many children and family members depend on public transport for travelling to school or work or to shopping centres. It is assumed that 1 minibus taxi and 1 bus is in operation on a daily basis. It is also assumed that each minbus taxi travels and truck travels on approximately 20 km of unpaved roads per day.
- Goods (for example building material, furniture, food supplies to spaza shops) also need to be transported to and/or from the townships. It is therefore assumed that 1 truck is in operation within the area on a daily basis, travelling 10 km per day.

The total VKT is presented in Table 4-15.

Table 4-15: Total VKT

Trip length (VKT)	Trucks	Buses	Taxis	Cars
Round trip (km)	10	20	20	1
Number of trucks	1	1	1	250
Number of trips	1	1	2	1
Number of days	365	365	365	365
Total distance (km)	3650	7300	14600	91250

In this section, emissions are calculated for exhaust emissions for vehicles travelling on unpaved roads; and particulate emissions from unpaved road surfaces.

4.6.2 Methodology – Vehicle Exhaust Emissions from Unpaved Roads

The EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2022) provides a methodology, emission factors and relevant activity data to enable exhaust emissions to be calculated for the following categories of road vehicles:

- Passenger cars (NFR code 1.A.3.b.i)
- Light commercial vehicles (1) (< 3.5 t) (NFR code 1.A.3.b.ii)
- Heavy-duty vehicles (2) (> 3.5 t) and buses (NFR code 1.A.3.b.iii)
- Mopeds and motorcycles (3) (NFR code 1.A.3.b.iv)

It does not cover non-exhaust emissions such as fuel evaporation from vehicles (NFR code 1.A.3.b.v), tyre wear and brake wear (NFR code 1.A.3.b.vi), or road wear (NFR code 1.A.3.b.vii).

Emission Factors

The Tier 1 and Tier 2 emission factors have been calculated from detailed emission factors and activity data using the Tier 3 method.

The Tier 1 emission factors have been derived from the Tier 3 methodology using 1995 fleet data for the EU-15. The upper limits of the stated ranges in the emission factors correspond to a typical uncontrolled (pre-Euro) technology fleet, and the lower limit of the range corresponds to an average EU-15 fleet in 2005. The suitability of these emission factors for a particular country and year depends on the similarity between the national fleet and the assumptions used to derive the Tier 1 emission factors.

The Tier 2 emission factors have been calculated based on average driving and temperature conditions for the EU-15 in 2005. These emission factors assume average urban, rural and highway driving mileage shares and speeds for the EU-15. Again, the suitability of these emission factors depends on the similarity between the national driving conditions and the average of EU-15.

The Tier 3 emission factors have been derived from experimental (measured) data collected in a range of scientific programmes. The emission factors for old-technology passenger cars and light commercial vehicles were taken from earlier COPERT/CORINAIR activities (Eggleston et al., 1989), whilst the emissions from more recent vehicles are calculated on the basis of data from the Artemis project. (Boulter and Barlow, 2005; Boulter and McCrae, 2007).

Tier 2 emission factors are stated in units of grammes per vehicle-kilometre, and for each vehicle technology. These average European emission factors were determined using the Tier 3 methodology which follows in using typical values for driving speeds, ambient temperatures, highway-rural-urban mode mix, trip length, etc. A figure for fuel consumption (g/km), which is derived from carbon balance is also provided, so that fuel-based pollutants such as SO_2 can be calculated.

Vehicle exhaust emissions for unpaved roads was calculated using an estimate of Vehicle Kilometres Travelled (VKT) and Tier 2 exhaust emission factors provided in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2022). Emissions were calculated for passenger cars, light commercial vehicles, heavy-duty vehicles and buses.

Emission factors are based on the "PRE-ECE" and "conventional" technology class. PRE_ECE refers to emission technology of the 1970s and the conventional class refers to a very limited fleet of such vehicles which is still in circulation and no particular emission standards are applicable.

EMISSION RATES ON 1 SQUARE KILOMETRE BASIS

The emission rates for vehicle exhaust emissions from unpaved roads on 1 square kilometre basis is presented in Table 4-16 together with the VKT, fuel consumption and emission factors.

Table 4-16: Emission rates for vehicle exhaust emissions from unpaved roads on a 1 square kilometre basis together with the VKT, fuel consumption and emission factors

	Fuel Consumption Data	Fuel Usage	Emission Factors				Emission Rates			
			Heavy Duty Vehicles - 16-32t				Emission Rates (tonnes/annum)			
VKT (km)	Fuel consumption (g/km) for Diesel (500 ppm Sulphur)	Total Fuel Used by All Trucks (kg)	NO_X (g/km)	SO_2 (kg/kg)	PM_{10} (g/km)	$PM_{2.5}$ (g/km)	NO_X	SO_2	PM_{10}	$PM_{2.5}$
3 650	251.00	916.15	10.70	0.00050	0.42	0.42	0.03906	0.00046	0.00153	0.00153
			Buses				Emission Rates (tonnes/annum)			
VKT (km)	Fuel consumption (g/km) for Diesel (500 ppm Sulphur)	Total Fuel Used by All buses (kg)	NO_X (g/km)	SO_2 (kg/kg)	PM_{10} (g/km)	$PM_{2.5}$ (g/km)	NO_X	SO_2	PM_{10}	$PM_{2.5}$
7 300	2 671.80	2 671.80	16.50	0.00050	0.91	0.91	0.12045	0.00134	0.00664	0.00664
			Taxis				Emission Rates (tonnes/annum)			
VKT (km)	Fuel consumption (g/km) for Petrol (10 ppm Sulphur)	Total Fuel Used by All taxis (kg)	NO_X (g/km)	SO_2 (kg/kg)	PM_{10} (g/km)	$PM_{2.5}$ (g/km)	NO_X	SO_2	PM_{10}	$PM_{2.5}$
14 600	1 241.00	1 241.00	3.09	0.00001	0.0023	0.0023	0.04511	0.00001	0.00003	0.00003
			Passenger Cars				Emission Rates (tonnes/annum)			
VKT (km)	Fuel consumption (g/km) for Petrol (10 ppm Sulphur)	Total Fuel Used by All cars (kg)	NO_X (g/km)	SO_2 (kg/kg)	PM_{10} (g/km)	$PM_{2.5}$ (g/km)	NO_X	SO_2	PM_{10}	$PM_{2.5}$
91 250	7 026.25	7 026.25	2.53	0.00001	0.0022	0.0022	0.30782	0.00009	0.00027	0.00027
							TOTAL Emission Rates (tonnes/annum)			
							NO_X	SO_2	PM_{10}	$PM_{2.5}$
							0.51244	0.00190	0.00846	0.00846

4.6.3 Methodology – Particulate Emissions from Unpaved Road Surfaces

The particulate emissions of concern from unpaved roads are total particulate matter (TPM) including PM_{10} and $PM_{2.5}$. The quantity of dust emissions from a given segment of unpaved road varies with the volume of traffic, the condition of the road, the number of vehicles passes, the vehicle characteristics (e.g. vehicle weight, speed and number of wheels), the properties of the road surface material being disturbed (e.g. silt content, moisture content), and the climatic conditions (e.g., frequency and amounts of precipitation). Dust emissions from unpaved roads have been found to vary directly with the silt content in the road surface material.

In this study, the calculation methodology of unpaved roads emissions from resuspension of loose material on road surfaces due to vehicle travel is based on the USEPA Compilation of Air Pollutant Emission Factors, 5th Edition, Volume 1 (AP-42) Chapter 13 – Miscellaneous Sources, 13.2.2. The following generalised equation is used to determine the annual emissions of each size of PM from unpaved road surfaces (USEPA, 2006):

$$E_x = VKT*EF_x*ADJ*(1-CE/100) \quad (1)$$

Where:

- E_x: Emission of contaminant x (kg)
- VKT: Annual total vehicle kilometres travelled (km)
- EF_x: Emission factor of contaminant x (kg/VKT)
- ADJ: Adjustment factor for precipitation, snow cover and frozen days
- CE: Applied Dust Control Method's efficiency (%)

The following sections describe the process that was followed when using equation 1.

Total Vehicle Kilometres Travelled (VKT)

The VKT represents the kilometres travelled by all vehicles on the unpaved roads. This includes cars, minibus taxis, buses and heavy-duty trucks. The annual VKT should be obtained using the best available data. This can be odometer readings, the length of roads and the number of vehicles and vehicle classes travelling on the unpaved roads on a typical day. If no data is available, surveys should be conducted throughout the year on representative days of operation to estimate the total VKT.

No such data is available for this study. VKT has been calculated using assumptions outlined in the Introduction of this section and is presented in Table 4-15.

EMISSION FACTORS

The USEPA has developed an empirical equation (equation 2) for vehicles travelling on unpaved road surfaces (at industrial sites). The equation takes into account the silt content of the roadway and the mean weight of the vehicles travelling on the road. (For more information, refer to AP 42, Chapter 13: Miscellaneous Sources, Section 2.2, (USEPA, 2006)).

The emission factor in metric units (that is, kilograms/VKT) is calculated using the following equation:

EF = k*(s/12)^a*(W/2.72)^b (2)

Where:

- EF: Size-specific emission factor (kg/VKT)
- s: Surface material silt content (%)
- W: Mean vehicle weight, tonnes (metric)
- k, a, b: Numerical constants for calculation (refer to Table 4-17)

Table 4-17: Numerical constants used in the unpaved industrial road dust emission factor

Constant	$PM_{2.5}$	PM_{10}	TPM
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

The silt content (s) of an unpaved road may be obtained using the USEPA test method (Appendix C.1: Procedures for sampling surface/Bulk dust loading, AP-42, USEPA, 2003). Site-specific values for silt content was not available for unpaved roads in the study area. As recommended by AP42, an appropriate mean value from Table AP-42 13.2.2-1 (USEPA, 2006) (reproduced below in Table 4-18), should be used as a default value, in the absence of measured values. It is understood that the use of default values may affect the quality of estimated values. In this study, a silt value of 8.3 (Stone quarrying and processing – Haul road to/from pit) was chosen.

Table 4-18: Typical silt content values of surface material on industrial unpaved roads (USEPA, 2006)

Industry	Road use or surface material	Silt content (%)
Copper smelting	Plant road	17
Iron and steel production	Plant road	6
Sand and gravel processing	Plant road	4.8
Sand and gravel processing	Material storage area	7.1
Stone quarrying and processing	Plant road	10
Stone quarrying and processing	Haul road to/from pit	8.3
Taconite mining and processing	Service road	4.3
Taconite mining and processing	Haul road to/from pit	5.8
Western surface coal mining	Haul road to/from pit	8.4
Western surface coal mining	Plant road	5.1
Western surface coal mining	Scraper route	17
Western surface coal mining	Haul road (freshly graded)	24
Construction sites	Scraper routes	8.5
Lumber sawmills	Log yards	8.4
Municipal solid waste landfills	Disposal routes	6.4

Adjustment Factor (ADJ) for Precipitation, Snow Cover and Frozen Days (Natural Mitigation)

Road dust emissions are reduced due to the natural mitigation effects of precipitation (rain and snow falls), as well as on frozen or snow-covered roads. Equation 1 assumes that no dust emissions occur on days with precipitation exceeding 0.2 mm or on days when the road surface is covered with snow or is frozen without high traffic volume.

The ADJ value used in equation 1 is determined using the following equation:

$$ADJ = (Working\ Days - (p+snow))/Working\ Days \qquad (3)$$

Where:

- ADJ: Adjustment factor for precipitation, snow cover and frozen days
- Working Days: The number of operating days per year
- p: Estimated Annual Working Days with precipitation exceeding 0.2 mm
- snow: The estimated Annual Working Days when the roads were frozen or snow-covered and wet for winter

With respect to precipitation (and snow-covered days), the number of days with the specified precipitation parameters corresponds to 71 days according to long term climate statistics (SAWB, 1980).

Dust Control Methods (CE)

Several techniques are used to reduce road dust emissions caused by vehicular travel on unpaved road surfaces, such as the application of water or chemical dust suppressants (Buonicore and Davis, 1992; USEPA, 1987). Watering is the most common control technique used for unpaved road surfaces (AMEC, 2007). The control efficiency of watering depends on the application rate, the elapsed time between applications, traffic volume and meteorological conditions. Chemical stabilization is also used to reduce emissions of road dust from unpaved surfaces. Its control efficiency depends on the material used and the method of application. Table 4-19 lists available dust control methods and their respective efficiencies.

Table 4-19: Dust control methods and efficiencies (USEPA, 2006)

Dust control techniques	Control Efficiency (CE)
Watering twice a day	55%
Watering more than twice a day	70%
Chemical suppressants	80%

In this study, it is assumed that no dust reduction mechanisms are applied on unpaved roads. No control efficiencies have therefore been applied.

Emission Rates on 1 square kilometer basis

The emission rates for particulates from unpaved road surfaces on a 1 square kilometre basis is presented in Table 4-20 together with the VKT, emission factors, adjustment factor for natural mitigations, and the emission rate before and after mitigation.

Table 4-20: Emission rates for particulates from unpaved roads on a 1 square kilometre basis together with the VKT, emission factors, adjustment factor for natural mitigations, and the emission rate before and after mitigation

Vehicle Type	Pollutant	VKT (km)	EF Uncontrolled kg/VKT)	Total Release (tonnes)	Adjustment factor ADJ for natural mitigations	Annual adjusted emissions for natural mitigation (tonnes)
Trucks	TPM	3650	3.05	11.12	0.81	8.96
	PM_{10}		0.87	3.17	0.81	2.55
	$PM_{2.5}$		0.09	0.32	0.81	0.26
Buses	TPM	7300	2.39	17.44	0.81	14.05
	PM_{10}		0.68	4.97	0.81	4.00
	$PM_{2.5}$		0.07	0.50	0.81	0.40
Taxis	TPM	14600	1.12	16.42	0.81	13.23
	PM_{10}		0.32	4.68	0.81	3.77
	$PM_{2.5}$		0.03	0.47	0.81	0.38
Cars	TPM	91250	0.80	72.83	0.81	58.66
	PM_{10}		0.23	20.76	0.81	16.72
	$PM_{2.5}$		0.02	2.08	0.81	1.67

4.6.4 Emission Inventory

The Emission Inventory for the Vehicles – Unpaved Roads category is presented in Table 4-21 for all pollutants in the Phola modelling domain. It must be noted that the emissions presented is the total emissions made up of vehicle exhaust emissions and emissions from unpaved road surfaces.

Table 4-21: Emission Inventory for the Vehicles – Unpaved Roads Category

Pollutant	SO_2	NO_X	PM_{10}	$PM_{2.5}$	TPM
Emission Rate (tonnes/annum)	0.17	46.61	2 461.17	246.81	8 631.59

4.7 Mining

4.7.1 Introduction

Mines can be classified as either underground mines or open pit mines. Open pit and underground mining sometimes occur in combination. At underground mines, rock dumps, tailings dams, and load-out facilities are the main sources of dust emissions, whereas at open pit mines the same sources exist, with additional sources including blasting, loading, haulage, clearing, surface disturbance and exposure. Air quality issues relating to mining are mainly centred around particulate impacts, which include dust deposition, and health impacts associated with PM_{10} and $PM_{2.5}$ (Schwegler, 2012).

Mine tailings are made up of fine particles. When dry, these particles can be a significant source of dust problems. In Gauteng for example, tailings storage facilities which are no longer in operation have the potential to generate dust on windy days and can cause impacts over a wide area, especially during the dry season. Dust originating from coal and iron ore mining are a particular nuisance as they cause discolouration, and sometimes permanent damage. In the case of iron ore, these impacts usually occur near the site of operations, shipping zones, and in the vicinity of material handling (Schwegler, 2012).

Mines are not static as they have a continuously changing footprint in terms of haul road location and distance, the size and height of ore stockpiles, waste rock and tailings sites, and have varying production and mine development rates. The measurement and prediction of dust from mining sites is highly complex due to a wide range of potential emission sources and source types, many of which are diffuse and can be highly variable in nature. To add to the complexity, environmental factors such as rainfall, temperature, wind characteristics have a direct impact on the amount of dust generated by a mine. This is in contrast to point sources such as stacks, where process conditions dictate emission rates which can also be accurately monitored or modelled. In spite of this, methods used for dust dispersion modelling have progressed over the years to the point where dispersion modelling has now become an integral component of mine air quality planning (Schwegler, 2012).

Emission inventories generated for mines, particularly open-cast mines, are generally more complex than those for industries. A typical emissions inventory for a mine should include haul roads (geographical location and lengths of road segments, number of vehicles and vehicle types), area and geographical location of exposed surfaces, blasting data in terms of size and frequency of blasting, and material properties such as moisture and silt content of exposed surfaces and mined material. The emissions inventory should distinguish between total suspended particulates (TSP), PM_{10} and $PM_{2.5}$. Emissions estimates may also need to be modified to account for specific dust emission controls such as watering, re- vegetation, and chemical dust suppressants (Schwegler, 2012).

4.7.2 Location of Mining Areas

Google Earth satellite imagery was used to map out locations and extents of all mining areas within the modelling domain. These mining areas are assumed to include all potential emission sources such as open cast pits, haul roads, ore stockpiles, waste rock dumps and tailing facilities. Mining areas which appear to be dormant, rehabilitated or in the process of being rehabilitation were not considered as a source of mining emissions. Area sources corresponding with mining areas, which has been used in the modelling is presented in Figure 4-12.

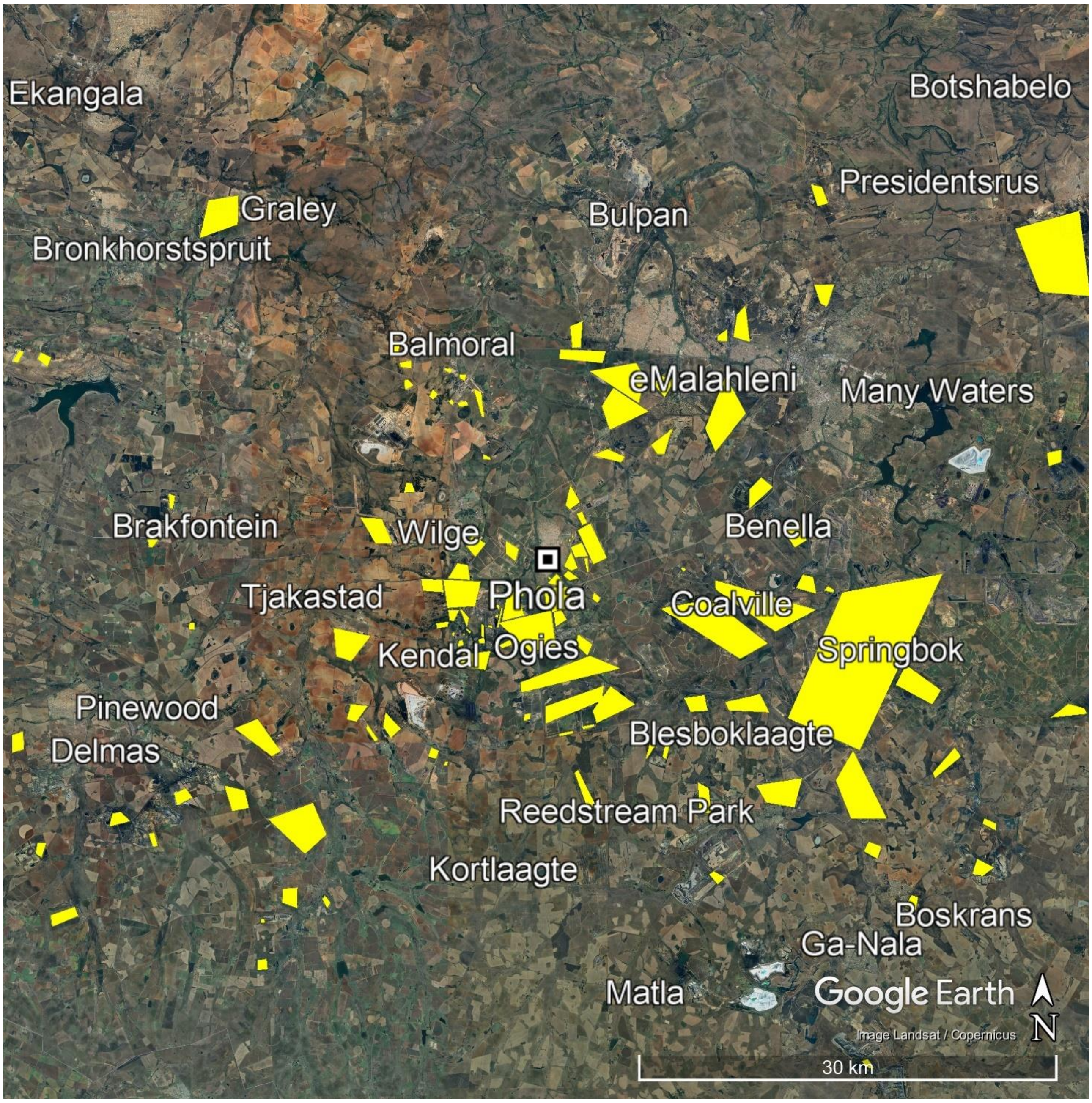


Figure 4-12: Location of areas corresponding with unpaved roads for the Greater Phola Airshed

4.7.3 Methodology for the Development of Emission Factors for the Mining Sector

The South African National Atmospheric Emission Inventory System (NAEIS) contains emissions information for mines. However, DEFF was not able to provide ARM with the NAEIS emissions data due to data policy privacy issues. An important point to consider is that at the 12th Air Quality Governance Lekgotla in 2017, it was reported that only a small percentage of the Mine and Quarry Sector reported to NAEIS (around 10%). Considering the contribution of the mining sector to the particulate matter, this omission means that the national inventory for PM source strength is grossly underestimated nationally (DEA, 2017). The completeness of this dataset as at 2024 has not been published, and therefore remains uncertain.

Currently, there are no country-specific emission factors for the mining sector. The NAEIS emission factors for mining operations in South Africa is based on the US EPA, IPCC and other international databases. These emission factors are based on material throughput of a facility. Information on material throughput of mines captured in the NAEIS database was also not made available to ARM. Again, the completeness of this dataset as of 2024 has not been published, and therefore remains uncertain.

Research suggests that open pit coal mines emit 0.726 kg of TPM and 0.180 kg of PM_{10} per Mg of coal produced. This study is based on a standardised emissions inventory methodology for open pit mining which was applied to seven of the eight open pit coal mine companies operating in the north part of Colombia for the years 2007, 2008 and 2009. The coal mines operational parameters were provided directly by each mining company (Huertasa et al., 2012). While it is noted that Columbian study is indeed based on sound scientific principles, the emission factors could not be used by ARM as it requires the throughput of mining facilities.

In order for ARM to derive representative emission factors for the mining sector in South Africa, it therefore needed to be based on the surface footprint of opencast mining areas and mining studies undertaken in South Africa. The surface footprint of mining areas over the study area was determined using Google Earth satellite imagery. As discussed in the previous section, these areas are assumed to include all potential emission sources such as open cast pits, haul roads, ore stockpiles, waste rock dumps and tailing facilities. In terms of the mining studies, ARM used information from detailed emission inventories developed for 3 recent opencast mining studies in the country. These studies were undertaken for the following mines:

- **Klipfontein Mine**
    - Draft Basic Assessment Report for the Expansion of the Klipfontein Opencast Operations (Inclusion of the Klipfontein Western Expansion).
    - The Basic Assessment was carried out by Alta van Dyk Environmental Consultants (Alta van Dyk Environmental Consultants, 2024a) for Sibanye Rustenburg Platinum Mines (Pty) Ltd.
    - The emission inventory for this study was compiled by uMoya-NILU Consulting (uMoya-NILU, 2024b).
- **N’Komati Anthracite Mine**
    - N’Komati Anthracite Mine - Integrated Environmental Authorisation for Open Cast Mining Areas and Expansion of the Madadeni Underground Area.

  - The Environmental Impact Assessment was carried out by Alta van Dyk Environmental Consultants (Alta van Dyk Environmental Consultants, 2024b) for N'Komati Anthracite (Pty) Ltd.
  - The emission inventory for this study was compiled by uMoya-NILU Consulting (uMoya-NILU, 2023).
- **Middellaagte Mine**
  - Draft Basic Assessment Report and Environmental Management Programme for the Proposed Expansion of the Middellaagte Opencast Pit Project, Environmental Authorisation and Waste Management Licence.
  - The Basic Assessment was carried out by Alta van Dyk Environmental Consultants (Alta van Dyk Environmental Consultants, 2024c) for the Limberg Mining Company (Pty) Ltd.
  - The emission inventory for this study was compiled by Airshed Planning Professionals (Airshed Planning Professionals, 2024).

In all three studies, emission factors used for the calculation of TPM, PM_{10} and $PM_{2.5}$ are the most recent factors published in the United States Environmental Protection Agency (US EPA), AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 11: Mineral Products Industry (Section 11.9 Western Surface Coal Mining; Section 11.19.1 Sand and Gravel Processing; Section 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing) (USEPA, 2009a) and Chapter 13: Miscellaneous Sources (Section 13.2.2 Unpaved Roads; Section 13.2.4 Aggregate Handling and Storage Piles; Section 13.2.5 Industrial Wind Erosion; Section 13.3 Explosive detonations) (USEPA, 2009b).

In each study, a comprehensive emission inventory has been developed for the respective mines using a bottom-up approach, providing a reliable estimation of emissions. In other words, actual mine activity data for the assessments has been used with emission factors to estimate particulate emissions for specific mining activities and areas.

An overview of mining activities included in each of the emission inventories are as follows:

- Open Cast Mine Pit
  - Overburden Removal
  - Boring/Blast Hole Drilling
  - Blasting
  - Material Handling - Opencast ROM
  - Wind Erosion - Opencast ROM
- Process Plant – Crushing and Screening

- Primary Crushing
- Secondary Crushing
- Screening
- Fine Screening
- Conveyor Transfer Point
- Process Plant ROM
  - Material Handling
  - Wind Erosion
- Topsoil Stockpiles
  - Material Handling
  - Wind Erosion
- Overburden Stockpiles
  - Material Handling
  - Wind Erosion
- Unpaved Plant Haul Roads

In all inventories, it is noted that the largest source of particulates is vehicle entrainment from the mine haul roads.

The total emission of TPM, PM_{10} and $PM_{2.5}$ estimated for each mine and the footprint of each mine (total mining area within mine boundary where mining activities are concentrated) is presented in Table 4-22. The total TPM, PM_{10} and $PM_{2.5}$ for all three mines was then divided by the total mine footprint to derive an emission factor for TPM, PM_{10} and $PM_{2.5}$ in tonnes/m^2/annum. Two emission factors were developed. The first emission factor assumes that 100% of the mining area is active and the second emission factor assumes that 40% of the area is active. It must be noted that in reality, mining activities do not take place all over a mine at once. Rather, mining activities are focused on particular areas within the mine boundary, and moves sequentially as the mining plan dictates. In turn, this means that emissions do not occur across the entire mining area, but over focused areas. In light of the above considerations, the second emission factor was therefore used in this study.

Table 4-22: Total emission of TPM, PM_{10} and $PM_{2.5}$ estimated for the Klipfontein Mine, N'Komati Anthracite Mine and Middellaagte Mine; together with the footprint of each mine and resultant emission factor

	Emission Rate (tonnes/annum)			(m^2)
	TPM	PM_{10}	$PM_{2.5}$	Mine Footprint
Klipfontein Mine	373.04	106.92	13.47	1 600 000
N'Komati Anthracite Mine	616.88	180.09	40.36	4 200 000
Middellaagte Mine	985.90	322.40	108.60	950 000
Total	**1 975.82**	**609.41**	**162.43**	**6 750 000**
	Emission Factor (tonnes/m^2/annum)			
	TPM	PM_{10}	$PM_{2.5}$	
Emission factor (assuming 100% of area is active)	**0.000293**	**0.000090**	**0.000024**	
Emission factor (assuming 40% of area is active)	**0.000117**	**0.000036**	**0.000010**	

4.6.4 Emission Inventory

The Emission Inventory for the Mining emission source category is presented in Table 4-23 for all pollutants in the Phola modelling domain.

Table 4-23: Emission Inventory for the Vehicles – Unpaved Roads Category

Pollutant	PM_{10}	$PM_{2.5}$	TPM
Emission Rate (tonnes/annum)	10 068.07	2 683.46	32 642.47

4.8 All Sources

In order to assess potential cumulative impacts and possible synergistic effects, emissions from all source categories are modelled at once. In this section, the total emissions for SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall are presented for the primary and secondary modelling domains.

Primary Modelling Grid: Greater Phola Airshed

A summary of emissions of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for each source category for the Greater Phola Airshed is presented in Table 4-24.

Table 4-24 is used to calculate the percent contribution of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for the Greater Phola Airshed as a function of the seven emission source categories and is presented in Table 4-25.

Pie charts are used to illustrate the percent contribution for each pollutant. These are compared with the percent contribution for each pollutant for the Phola Airshed in Figure 4-13 for SO_2, Figure 4-14 for NO_X, Figure 4-15 for PM_{10}, Figure 4-16 for $PM_{2.5}$ and Figure 4-17 for dustfall.

A basemap showing all emission source categories within the Greater Phola Airshed (primary, coarse resolution modelling domain) is presented in Figure 4-18.

SECONDARY MODELLING GRID: PHOLA AIRSHED

A summary of emissions of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for each source category for the Phola Airshed is presented in Table 4-26.

Table 4-26 is used to calculate the percent contribution of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for the Phola Airshed as a function of the seven emission source categories and is presented in Table 4-27.

Pie charts are used to illustrate the percent contribution for each pollutant. These are compared with the percent contribution for each pollutant for the Greater Phola Airshed in Figure 4-13 for SO_2, Figure 4-14 for NO_X, Figure 4-15 for PM_{10}, Figure 4-16 for $PM_{2.5}$ and Figure 4-17 for dustfall.

A basemap showing all emission source categories within the Phola Airshed (secondary, fine resolution modelling domain), together with discrete receptors is presented in Figure 4-19.

Table 4-24: Emission Inventory for SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for the seven emission source categories in the Greater Phola Airshed

	Emission rate (tonnes/annum)				
Emission Source Category	**SO_2**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**TPM**
Power Generation	1 184 740.46	862 755.33	209 216.17	92 539.93	12 877.82
Residential Fuel Burning	5 622.18	2 581.32	7 324.15	6 813.56	
Waste Burning	38.73	196.50	1 911.99	1 904.43	
Biomass Burning	247.63	54.09	2 550.06	2 451.40	3 666.53
Vehicles – Paved Roads	133.57	8 991.08	183.00	183.00	
Vehicles – Unpaved Roads	0.17	46.61	2 461.17	246.81	8 631.59
Mining			10 068.07	2 683.46	32 642.47
All Sources	1 190 782.75	874 624.93	233 714.61	106 822.59	57 818.41

Table 4-25: Emission source contribution (%) of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall as a function of the seven emission source categories for the Greater Phola Airshed

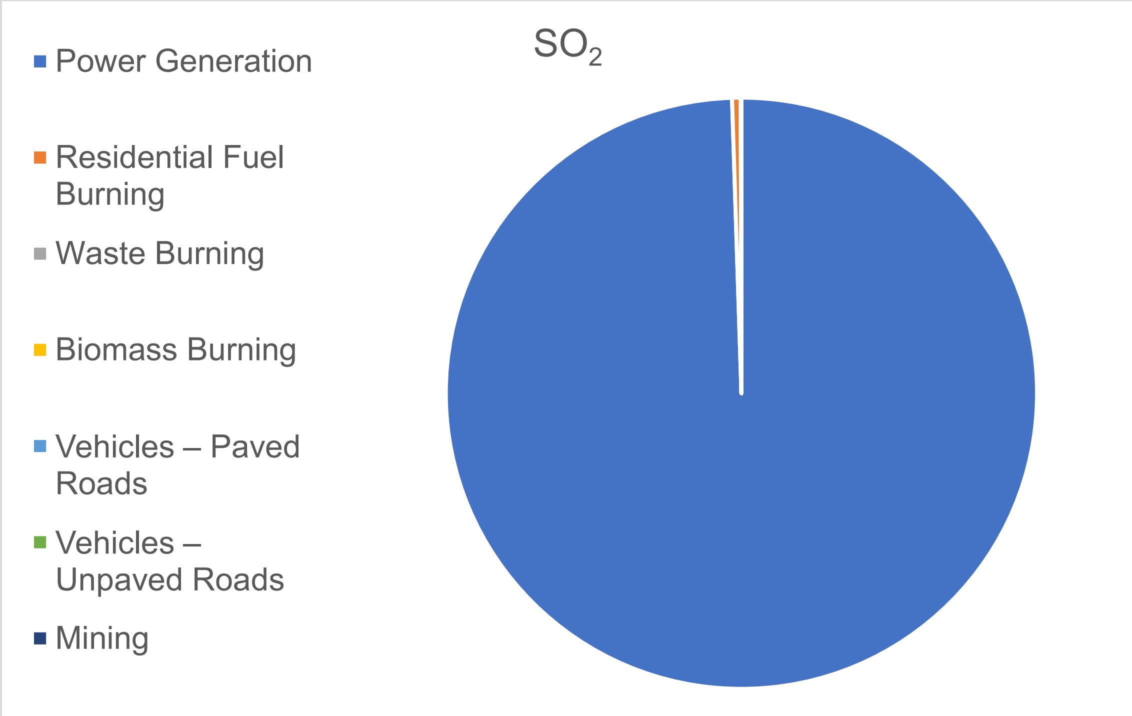
	Emission Source Contribution (%)				
Emission Source Category	**SO_2**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**TPM**
Power Generation	99.49	98.64	89.52	86.63	22.27
Residential Fuel Burning	0.47	0.30	3.13	6.38	0.00
Waste Burning	0.00	0.02	0.82	1.78	0.00
Biomass Burning	0.02	0.01	1.09	2.29	6.34
Vehicles – Paved Roads	0.01	1.03	0.08	0.17	0.00
Vehicles – Unpaved Roads	0.00	0.01	1.05	0.23	14.93
Mining	0.00	0.00	4.31	2.51	56.46
All Sources	100.00	100.00	100.00	100.00	100.00

Table 4-26: Emission Inventory for SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall for the seven emission source categories in the Phola Airshed

	Emission rate (tonnes/annum)				
Emission Source Category	**SO_2**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**TPM**
Power Generation					
Residential Fuel Burning	291.04	133.63	379.15	352.72	
Waste Burning	2.12	10.76	104.74	104.32	
Biomass Burning	1.27	0.28	13.12	12.61	18.87
Vehicles – Paved Roads	3.71	252.64	5.17	5.17	
Vehicles – Unpaved Roads	0.01	3.45	182.16	18.27	638.85
Mining			448.49	119.54	1 454.09
All Sources	298.17	400.76	1 132.83	612.63	2 111.81

Table 4-27: Emission source contribution (%) of SO_2, NO_X, PM_{10}, $PM_{2.5}$ and dustfall as a function of the seven emission source categories for the Phola Airshed

	Emission Source Contribution (%)				
Emission Source Category	**SO_2**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**TPM**
Power Generation	0.00	0.00	0.00	0.00	0.00
Residential Fuel Burning	97.61	33.34	33.47	57.57	0.00
Waste Burning	0.71	2.69	9.25	17.03	0.00
Biomass Burning	0.43	0.07	1.16	2.06	0.89
Vehicles – Paved Roads	1.24	63.04	0.46	0.84	0.00
Vehicles – Unpaved Roads	0.00	0.86	16.08	2.98	30.25
Mining	0.00	0.00	39.59	19.51	68.86
All Sources	100.00	100.00	100.00	100.00	100.00



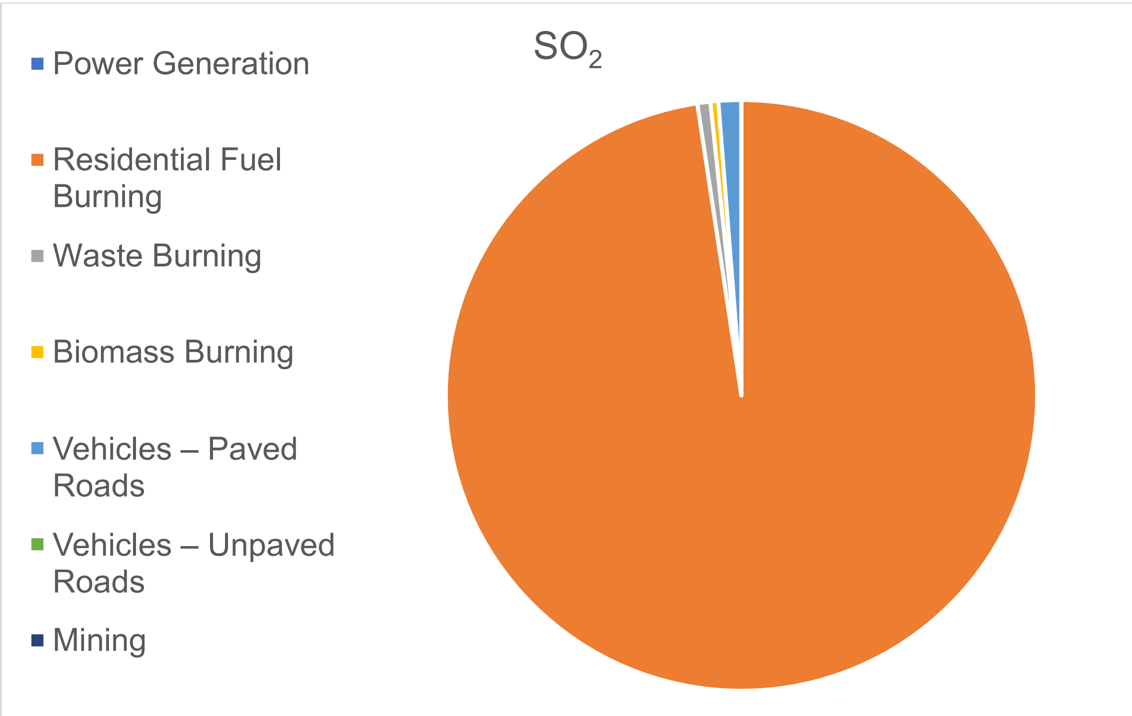
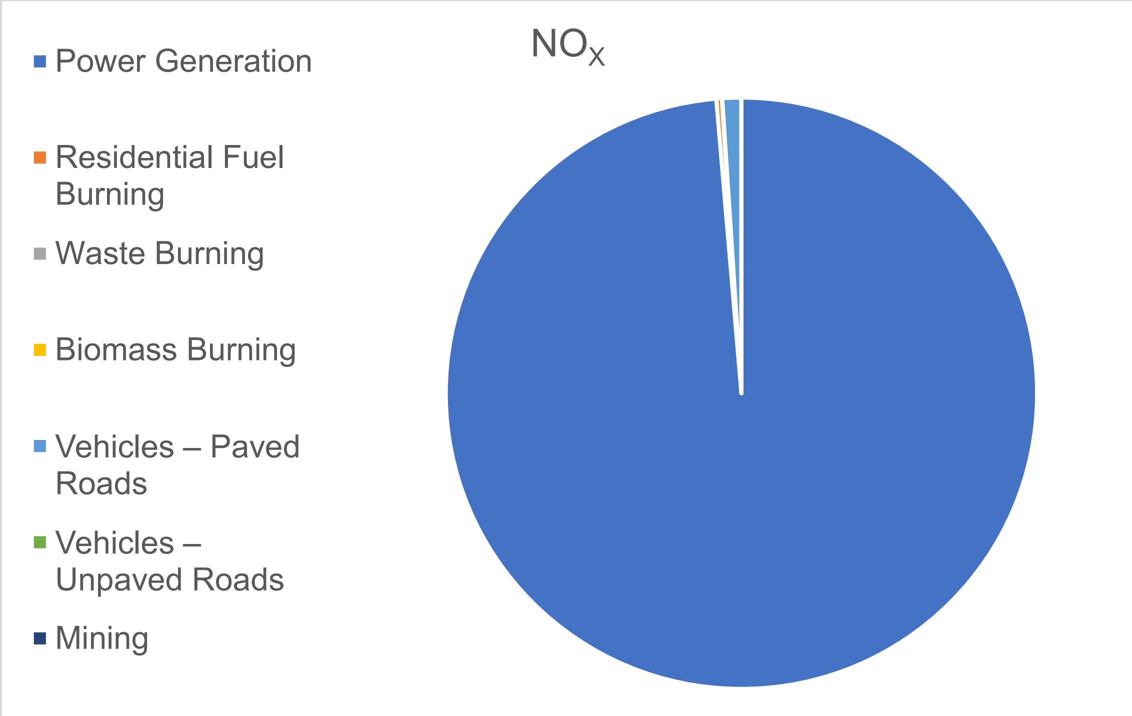


Figure 4-13: Emission source contribution (%) of SO_2 as a function of the seven emission source categories for the Greater Phola Airshed (top) and for the Phola Airshed (bottom)



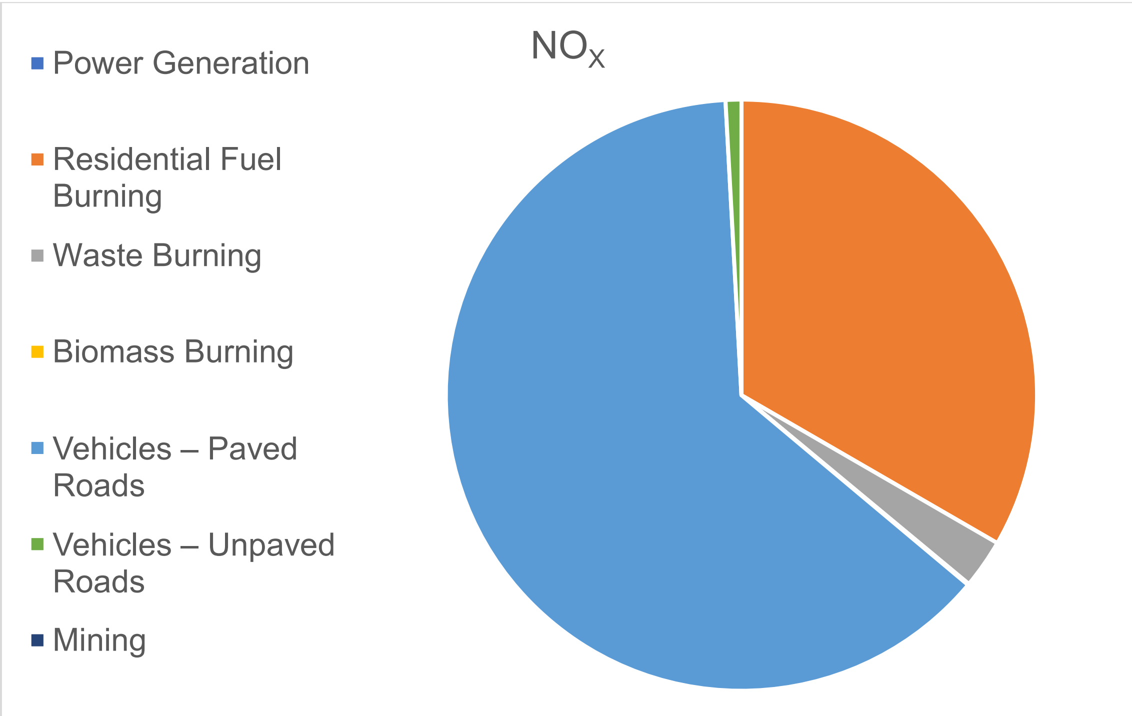
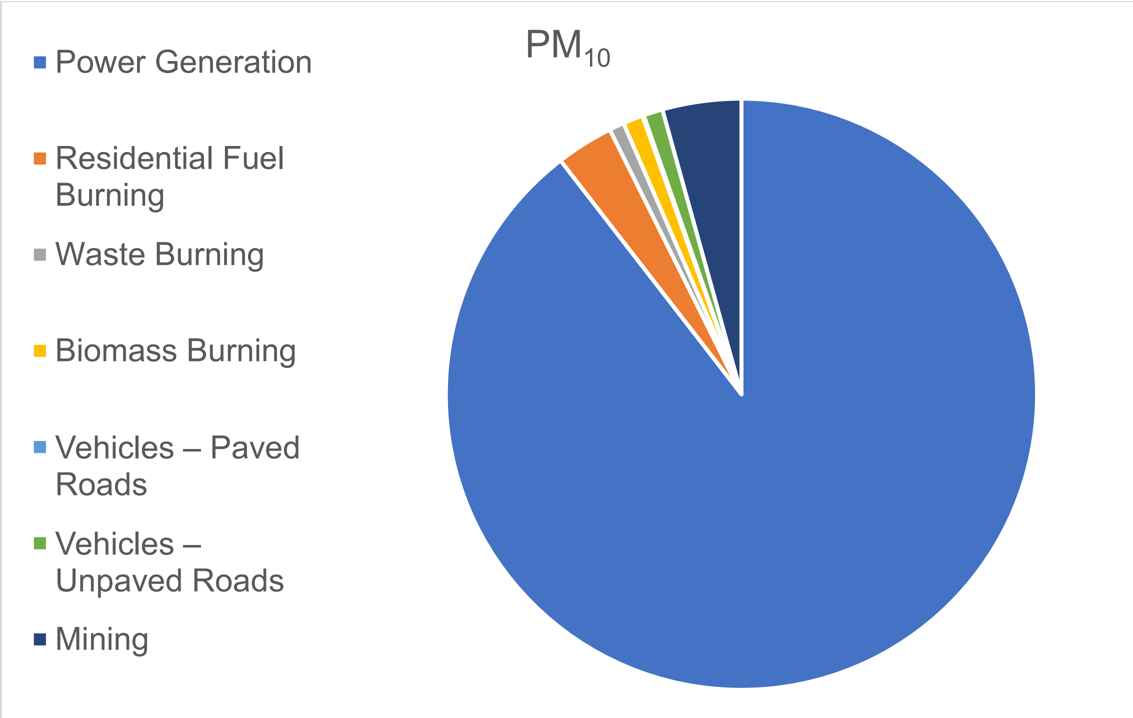


Figure 4-14: Emission source contribution (%) of NO_X as a function of the seven emission source categories for the Greater Phola Airshed (top) and for the Phola Airshed (bottom)



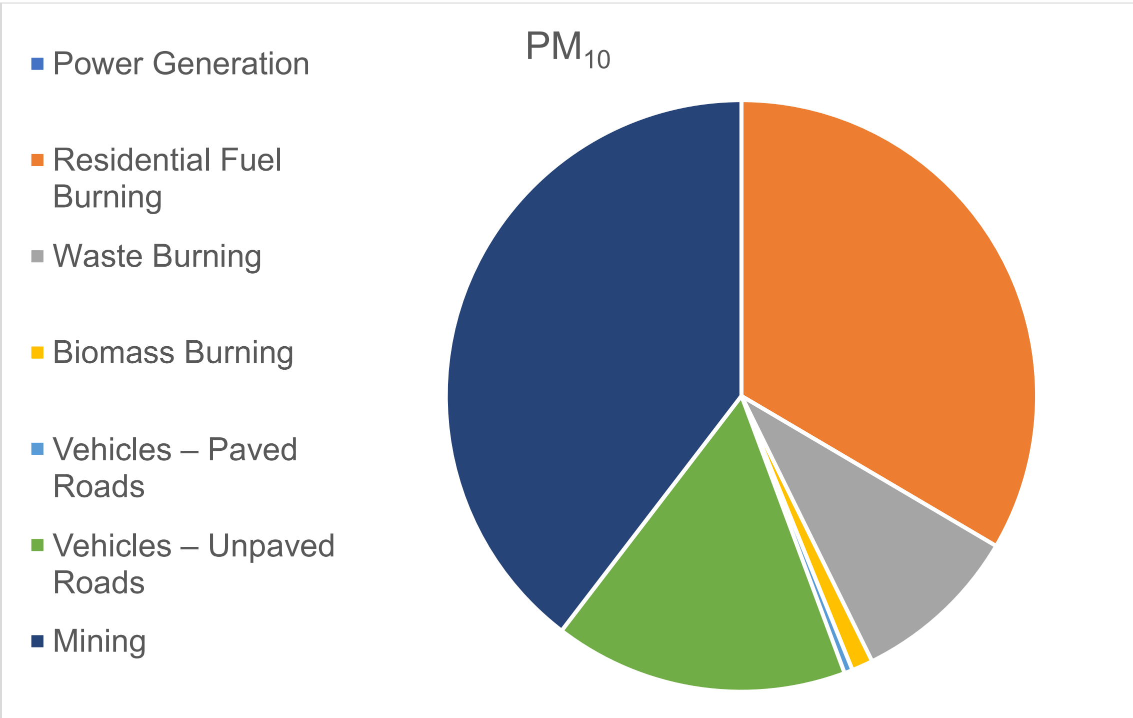
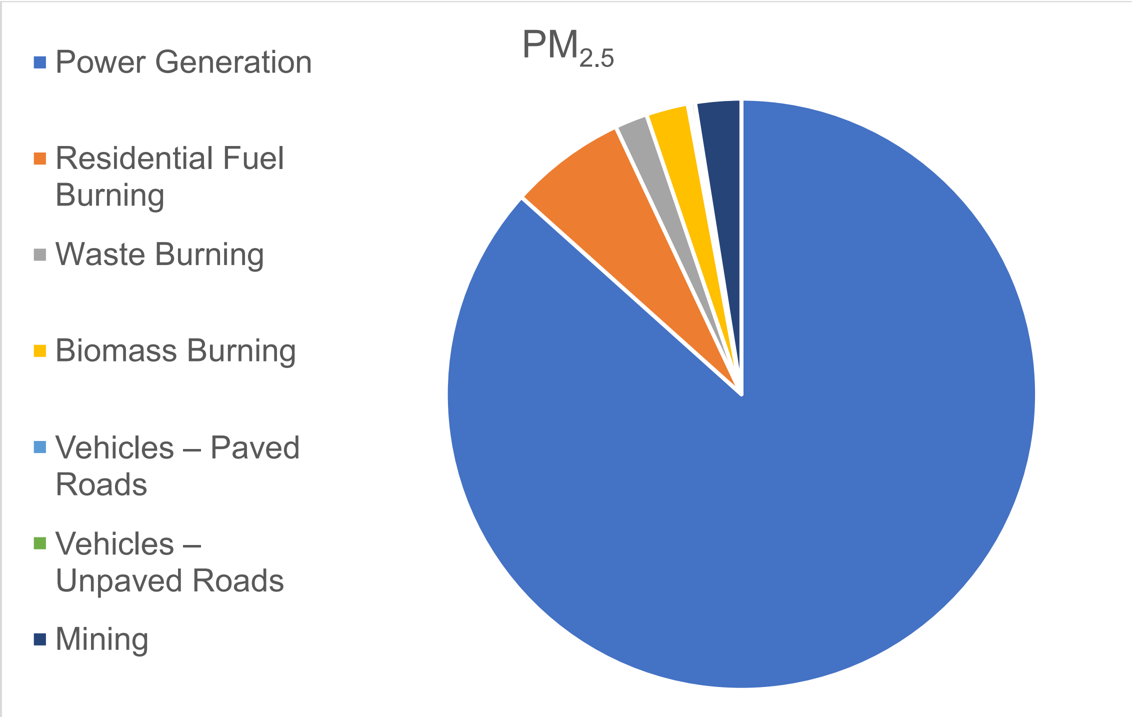


Figure 4-15: Emission source contribution (%) of PM_{10} as a function of the seven emission source categories for the Greater Phola Airshed (top) and for the Phola Airshed (bottom)



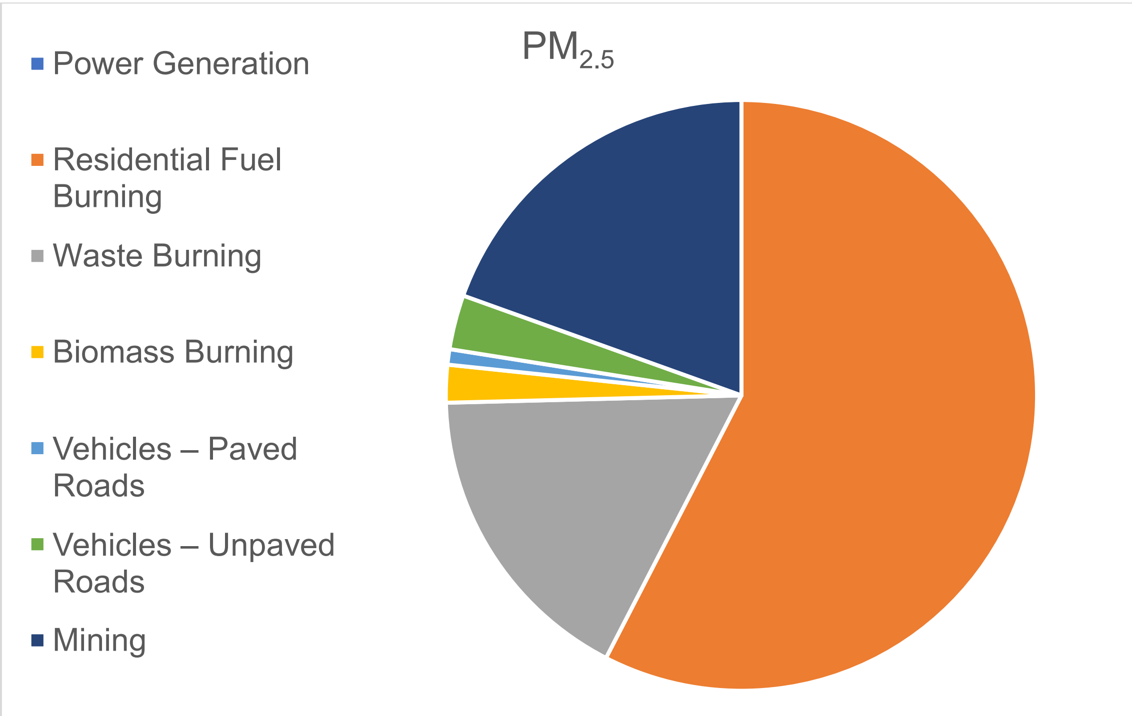
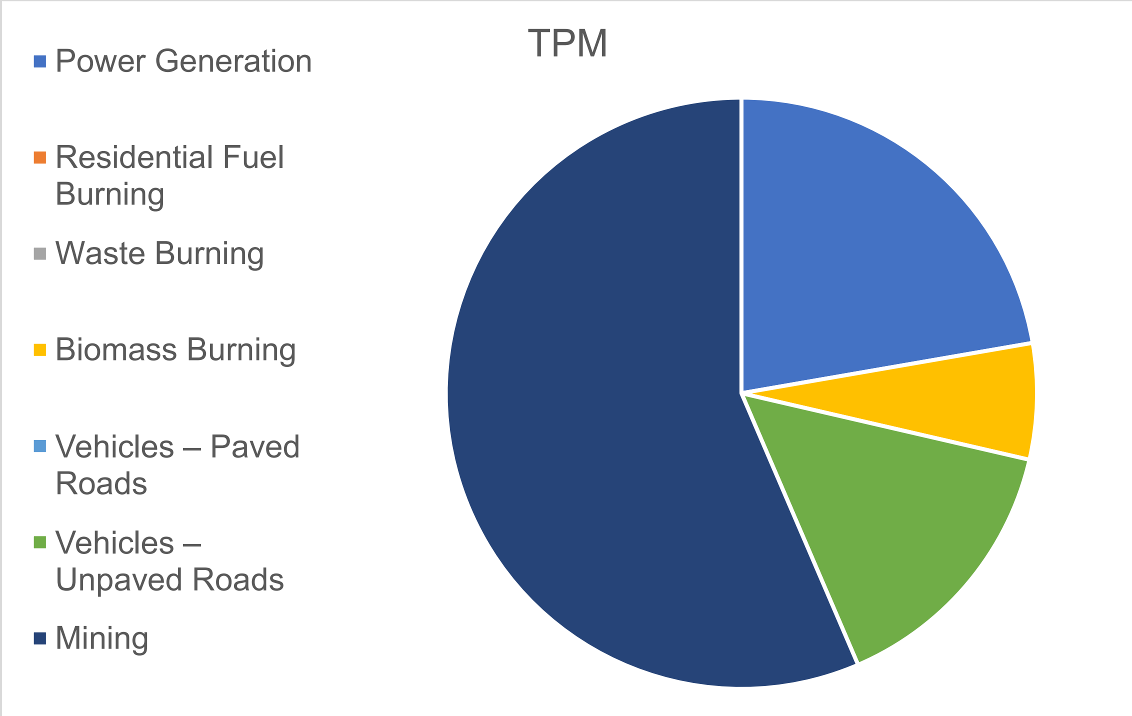


Figure 4-16: Emission source contribution (%) of $PM_{2.5}$ as a function of the seven emission source categories for the Greater Phola Airshed (top) and for the Phola Airshed (bottom)



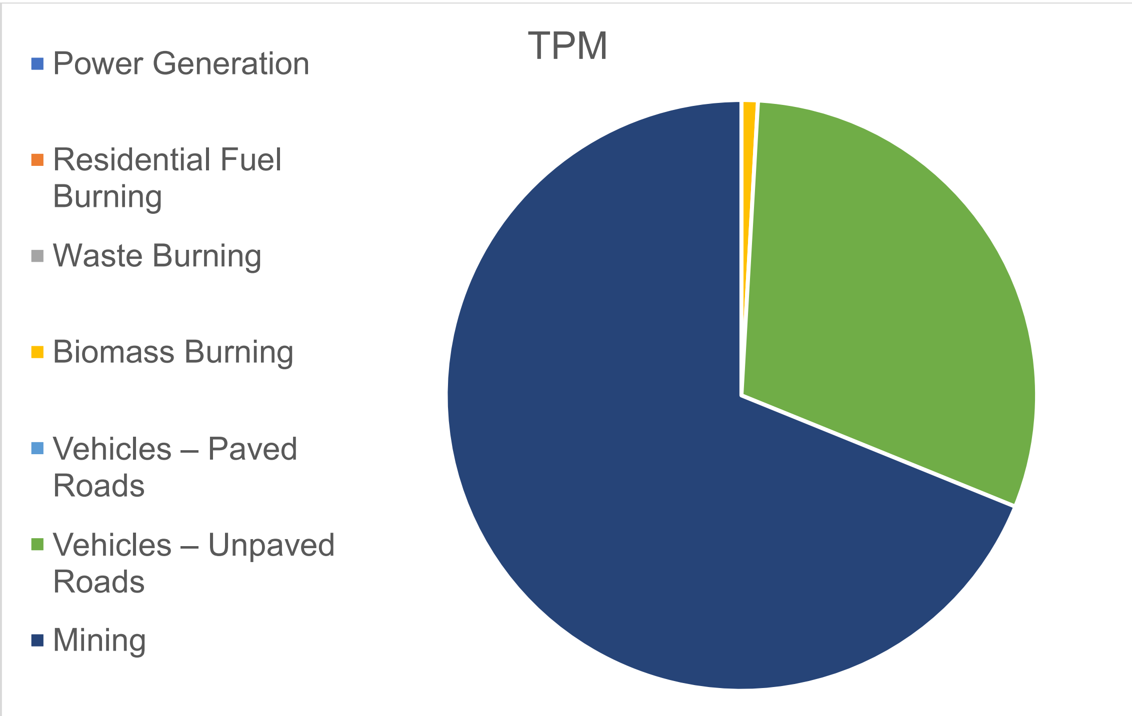


Figure 4-17: Emission source contribution (%) of dustfall as a function of the seven emission source categories for the Greater Phola Airshed (top) and for the Phola Airshed (bottom)

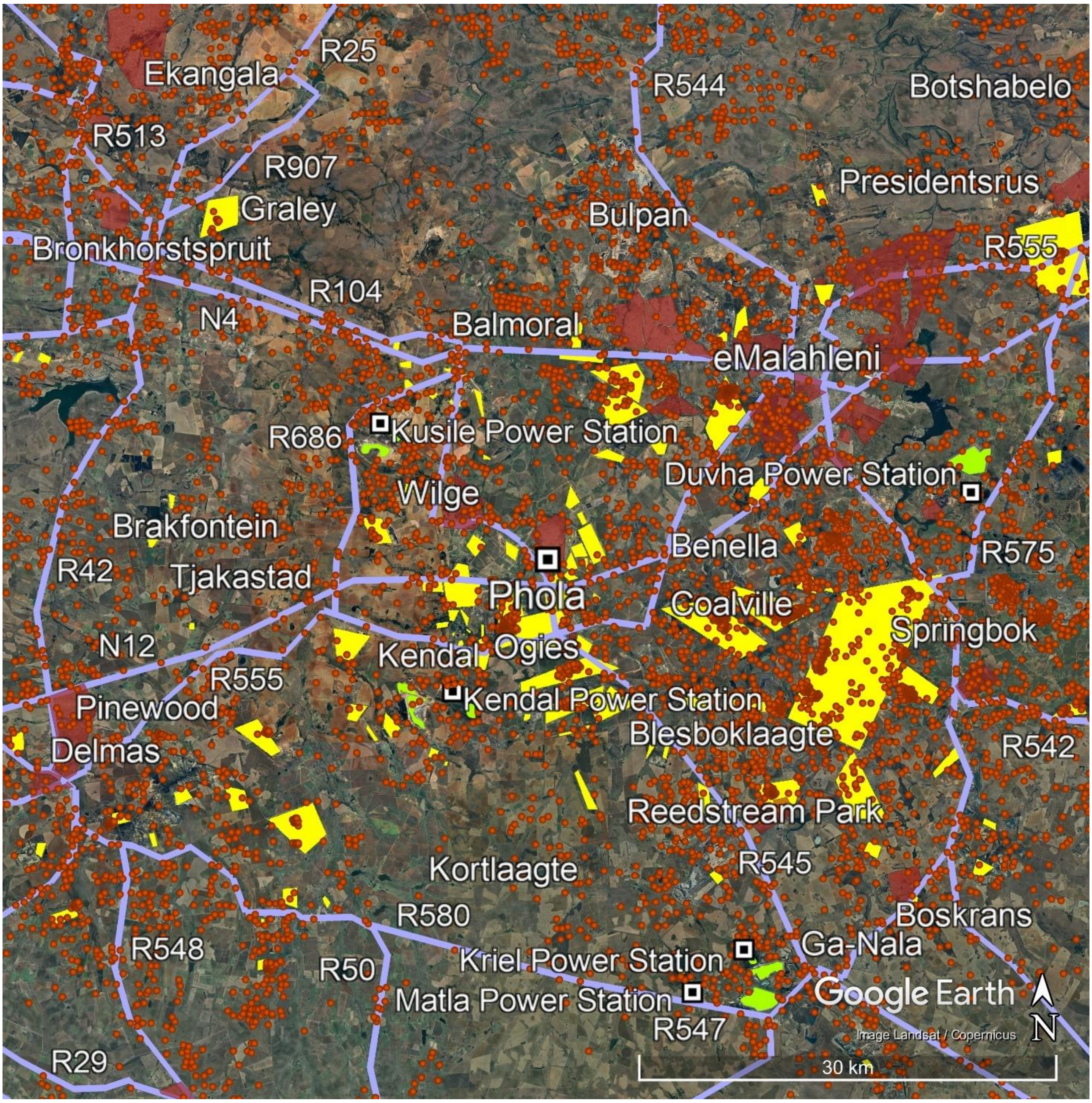


Figure 4-18: Overview of all emission source categories within the Greater Phola Airshed

Figure 4-19: Overview of the Phola Airshed, together with discrete receptors

5. RESULTS & DISCUSSION

The CALPUFF dispersion model uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. In this study, the CALPUFF dispersion model was used to predict ambient concentrations and dustfall rates within the modelling domain, based on emissions from eight emission source categories and meteorological data for a three-year period spanning from 2021 to 2023. In this section, model predicted results are presented for SO_2, NO_2, PM_{10} and $PM_{2.5}$ and assessed against the respective NAAQS. Model predicted dustfall rates are presented and assessed against the National Dustfall Standard.

This section is made up of several sub-sections as follows:

- Predicted SO_2 ambient concentrations
    - 1-hour SO_2
    - 24-hour SO_2
    - Annual SO_2
- Predicted NO_2 ambient concentrations
    - 1-hour NO_2
    - Annual NO_2
- Predicted PM_{10} ambient concentrations
    - 24-hour PM_{10}
    - Annual PM_{10}
- Predicted $PM_{2.5}$ ambient concentrations
    - 24-hour $PM_{2.5}$
    - Annual $PM_{2.5}$
- Predicted dustfall rates
- Source Contribution
    - SO_2 ambient concentrations
    - NO_2 ambient concentrations
    - PM_{10} ambient concentrations
    - $PM_{2.5}$ ambient concentrations

In each subsection for SO_2, NO_2, PM_{10} and $PM_{2.5}$, model predicted ambient concentrations at each discrete receptor and at the point of maximum within the modelling domain, resulting from the eight emission source categories are presented in the form of a table. The 1-hour and 24-hour concentrations are based on the 99th percentile. In the table where dustfall rates are presented, the model predicted dustfall rates are presented at each discrete receptor and at the point of maximum within the modelling domain.

This is then followed by bar graphs which graphically illustrate the respective predicted ambient concentrations or dustfall rates at each of the discrete receptors for each source category. Below each graph is a corresponding contour plot representing the respective model predicted ambient concentrations or dustfall rates throughout the Greater Phola Airshed. Contour plots representing model predicted ambient concentrations for the Phola Airshed is only presented for the All Sources category.

5.1 PREDICTED SO_2 AMBIENT CONCENTRATIONS

5.1.1 1-HOUR SO_2

Model predicted 1-hour SO_2 ambient concentrations at discrete receptors and at the point of maximum for the seven emission source categories are presented in Table 5-1. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted 1-hour SO_2 ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-1 for the Power Generation emission source category
- Figure 5-3 for the Residential Fuel Burning emission source category
- Figure 5-5 for the Waste Burning emission source category
- Figure 5-7 for the Biomass Burning emission source category
- Figure 5-9 for the Vehicles – Paved Roads emission source category
- Figure 5-11 for the Vehicles – Unpaved Roads emission source category
- Figure 5-13 for the All Sources emission source category

Contour plots for model predicted 1-hour SO_2 ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-2 for the Power Generation emission source category
- Figure 5-4 for the Residential Fuel Burning emission source category
- Figure 5-6 for the Waste Burning emission source category
- Figure 5-8 for the Biomass Burning emission source category
- Figure 5-10 for the Vehicles – Paved Roads emission source category
- Figure 5-12 for the Vehicles – Unpaved Roads emission source category
- Figure 5-14 for the All Sources emission source category

Contour plots for model predicted 1-hour SO_2 ambient concentrations for the Phola Airshed is presented in Figure 5-15 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-1: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	89.14	586.01	2.57	1.12	0.63	0.01	593.53
Dark City	90.33	597.16	2.65	1.02	0.74	0.01	605.46
Siyabonga	91.30	215.31	0.83	0.53	1.14	0.01	230.39
Phola SP	91.05	730.02	3.35	0.71	0.93	0.01	733.72
Tycoon	91.44	275.35	1.04	0.45	1.08	0.01	286.40
Buffer Zone	94.70	297.84	0.91	0.43	1.92	0.02	305.09
Emaforumini	94.43	309.88	0.93	0.42	1.25	0.02	313.19
Vezibuhle	93.21	275.80	1.07	0.43	0.85	0.02	287.01
Oyco	94.71	291.81	0.82	0.41	1.32	0.01	295.27
Eskom Phola AQMS	89.35	612.19	2.73	0.80	0.82	0.02	616.74
Maximum	151.32	4131.70	15.37	9.74	52.98	0.05	4143.70
	NAAQS – 1-hour SO_2 (350 µg/m³)						

According to Table 5-1, model predicted 1-hour SO_2 ambient concentrations exceed the 1-hour SO_2 NAAQS of 350 µg/m³ at three discrete receptors (New Stand, Dark City, Phola SP) and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories in the Phola Airshed.

Model predicted 1-hour SO_2 ambient concentrations also exceed the 1-hour SO_2 NAAQS of 350 µg/m³ at the point of maximum for the Residential Fuel Burning and All Sources emission source categories in the Greater Phola Airshed.

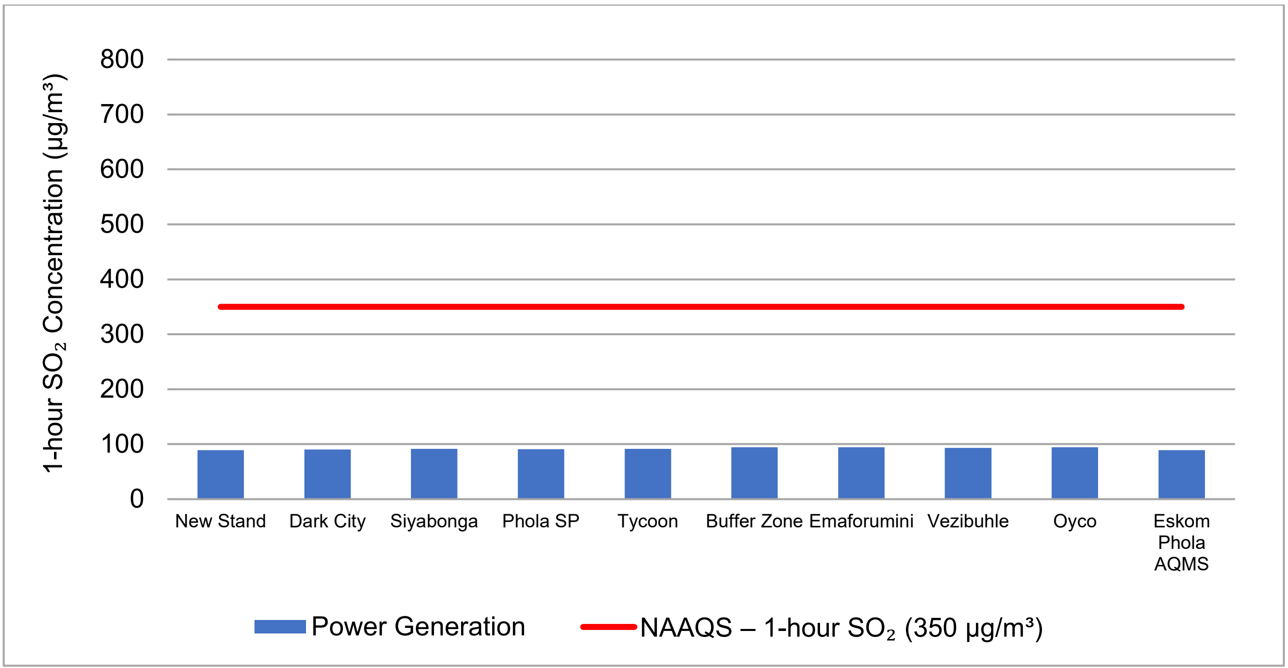


Figure 5-1: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Power Generation emission source category

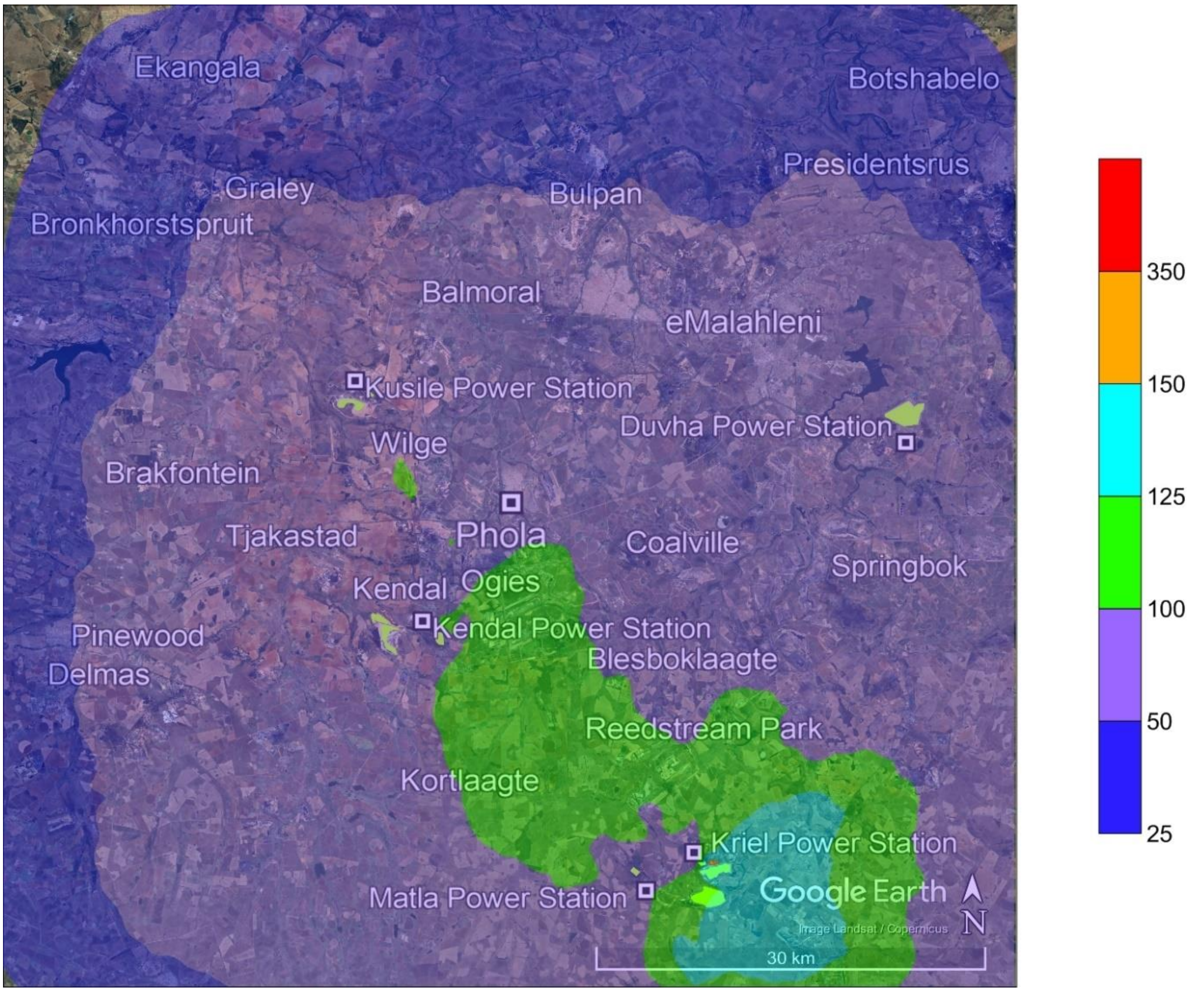


Figure 5-2: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

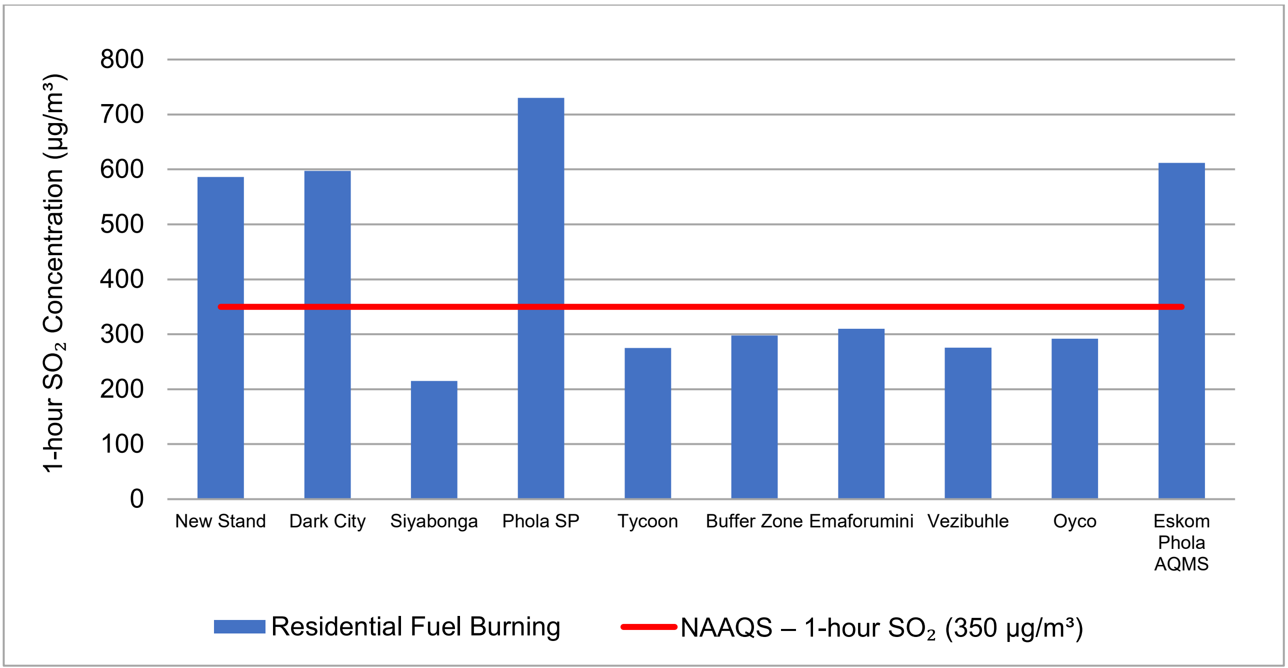


Figure 5-3: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

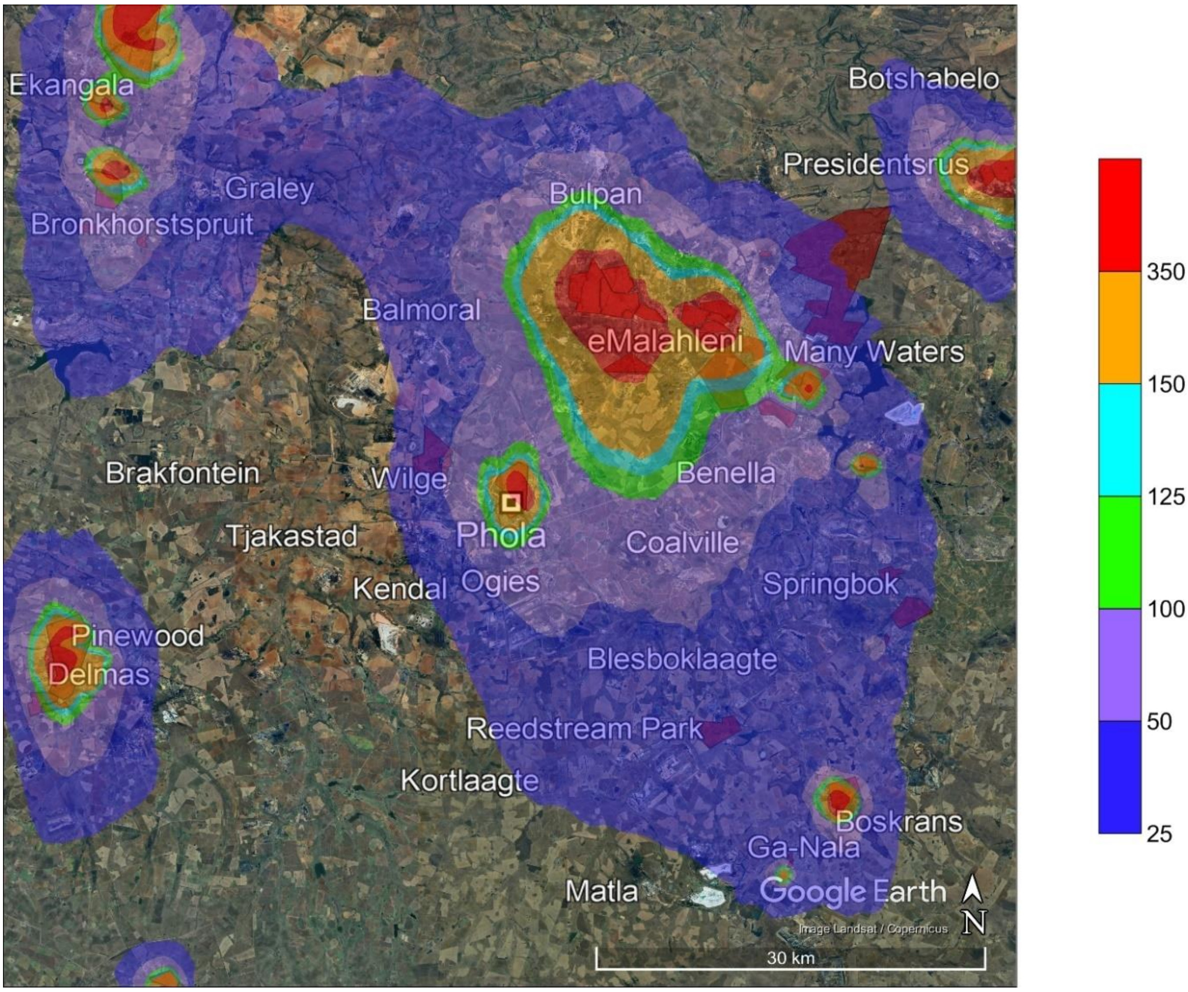


Figure 5-4: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

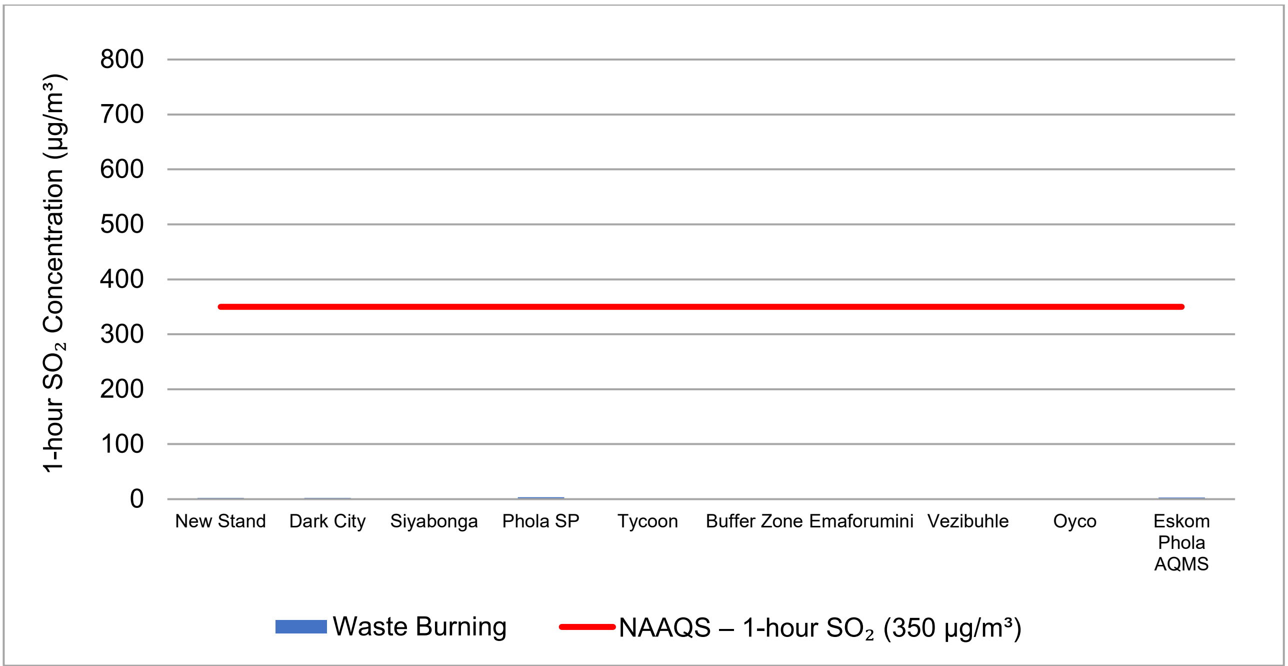


Figure 5-5: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Waste Burning emission source category

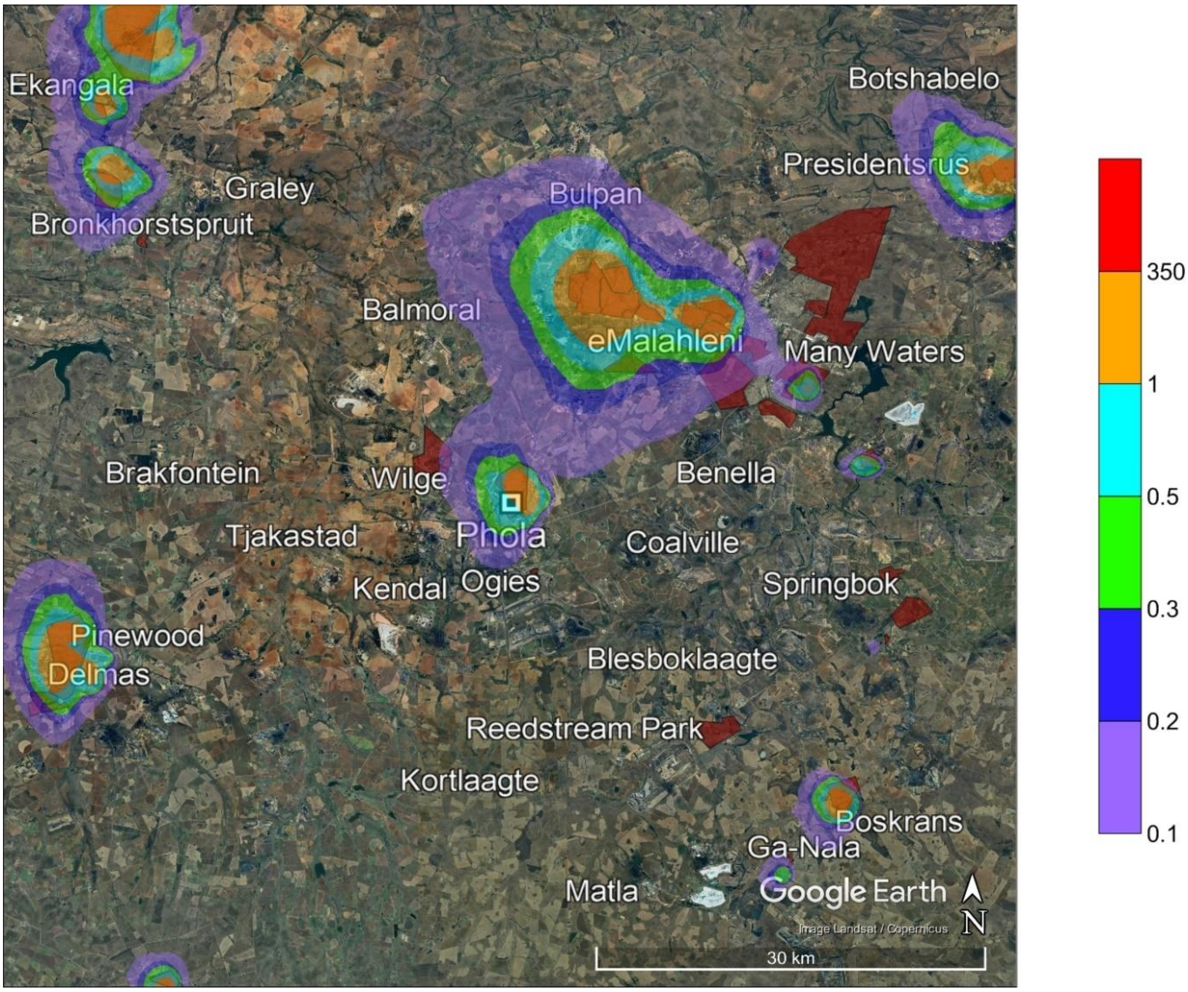


Figure 5-6: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

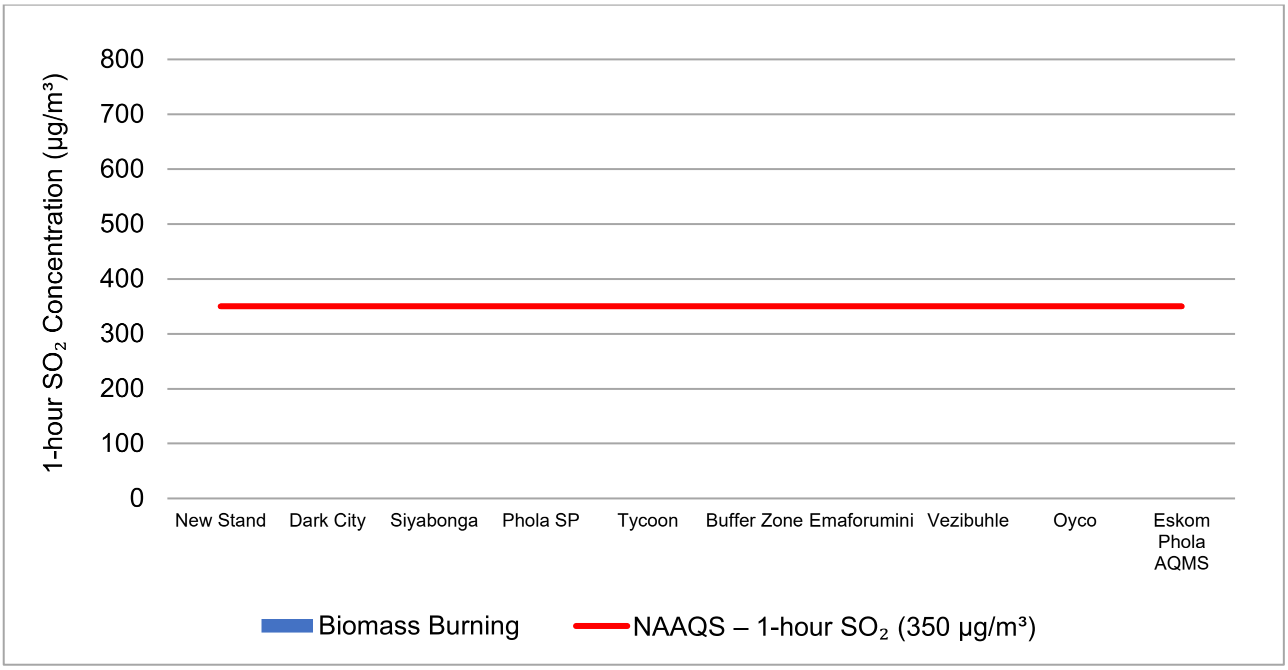


Figure 5-7: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Biomass Burning emission source category

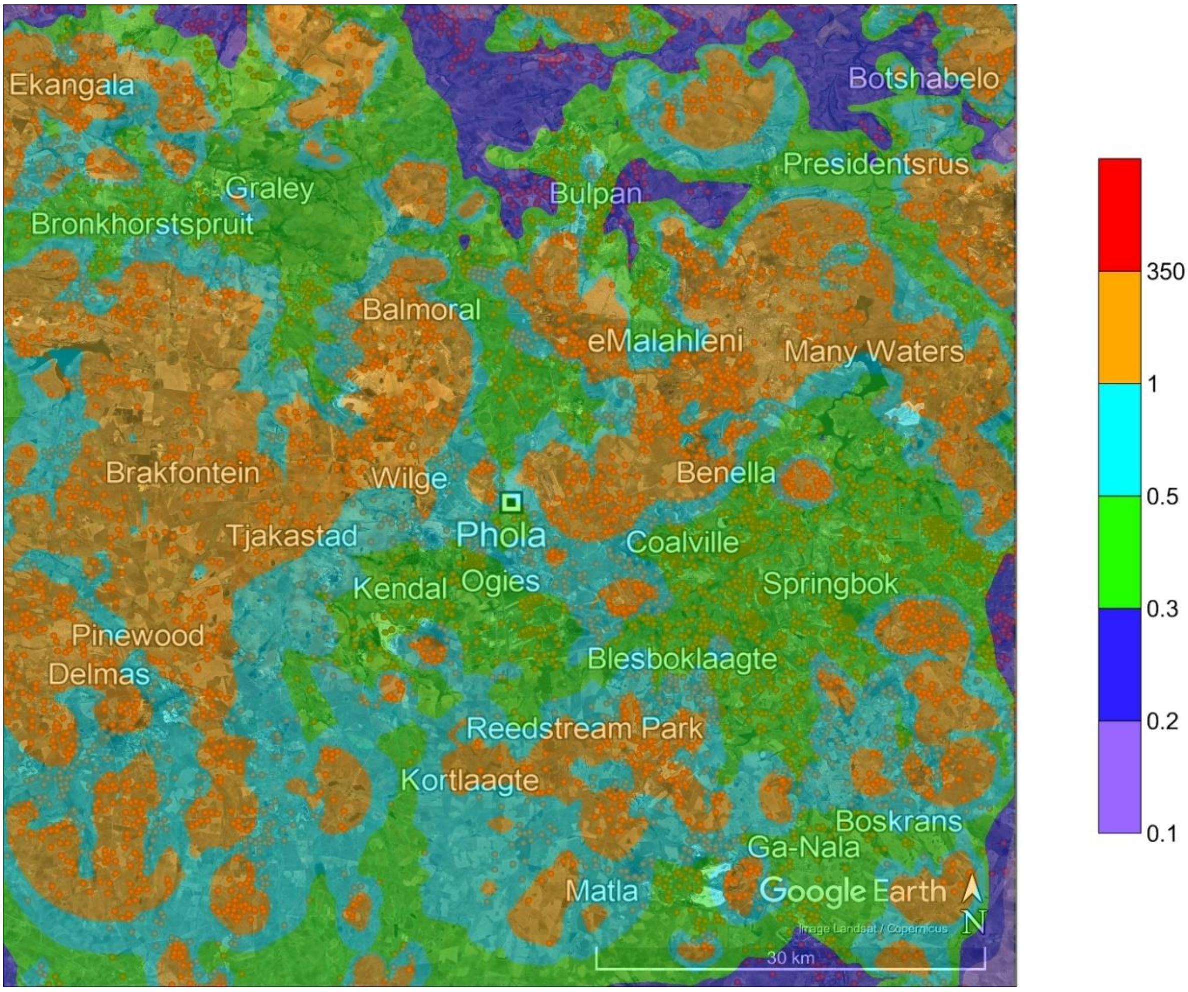


Figure 5-8: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

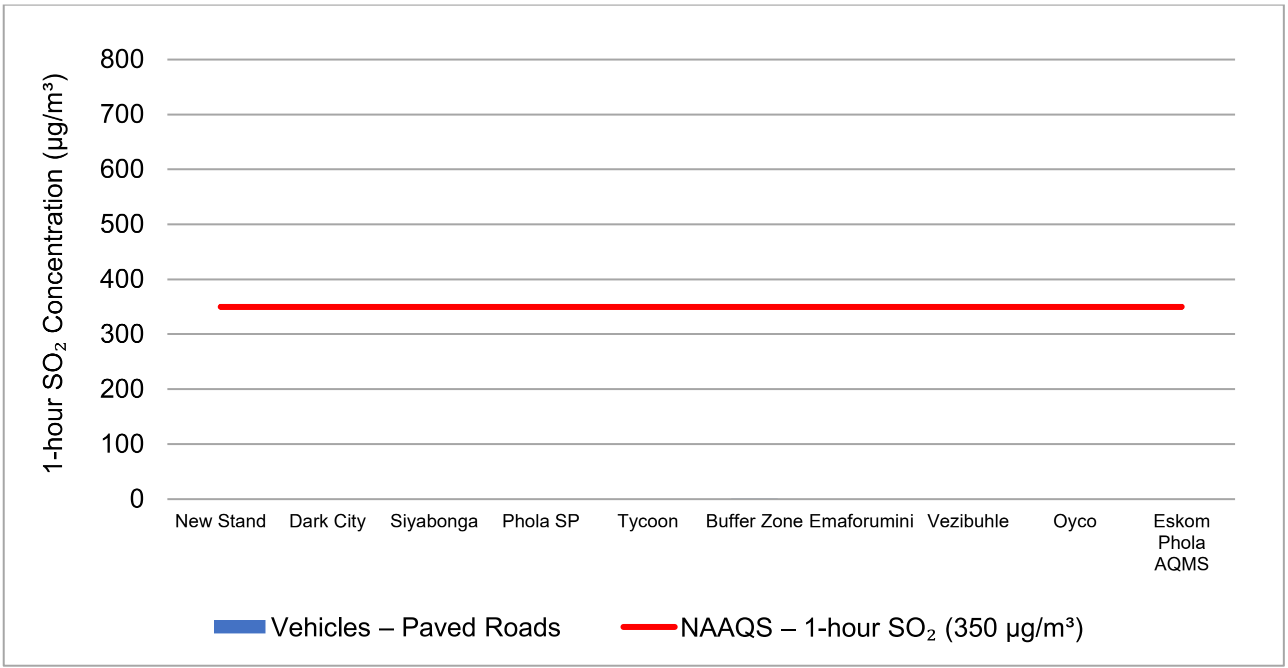


Figure 5-9: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Vehicles – Paved Roads emission source category

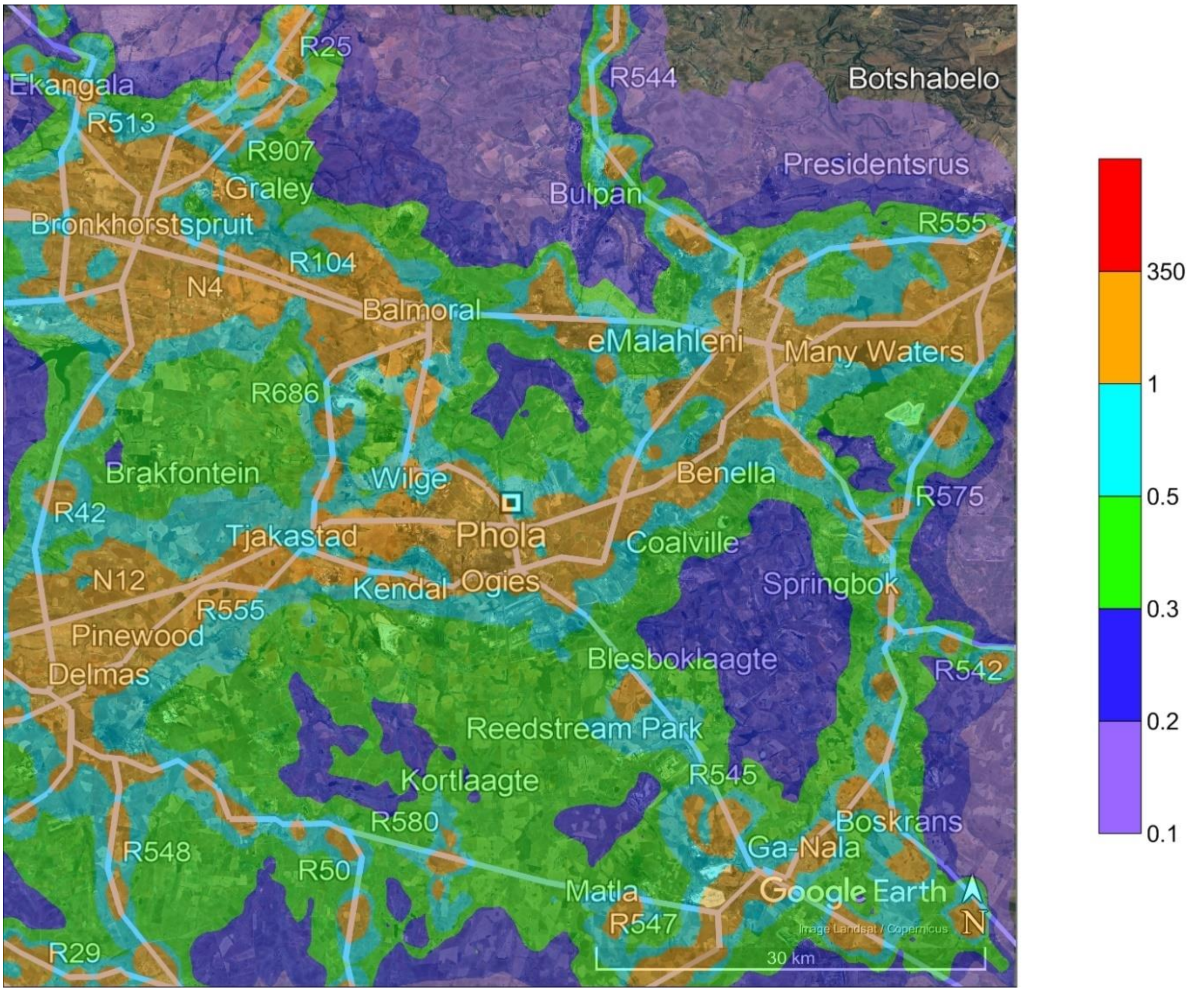


Figure 5-10: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

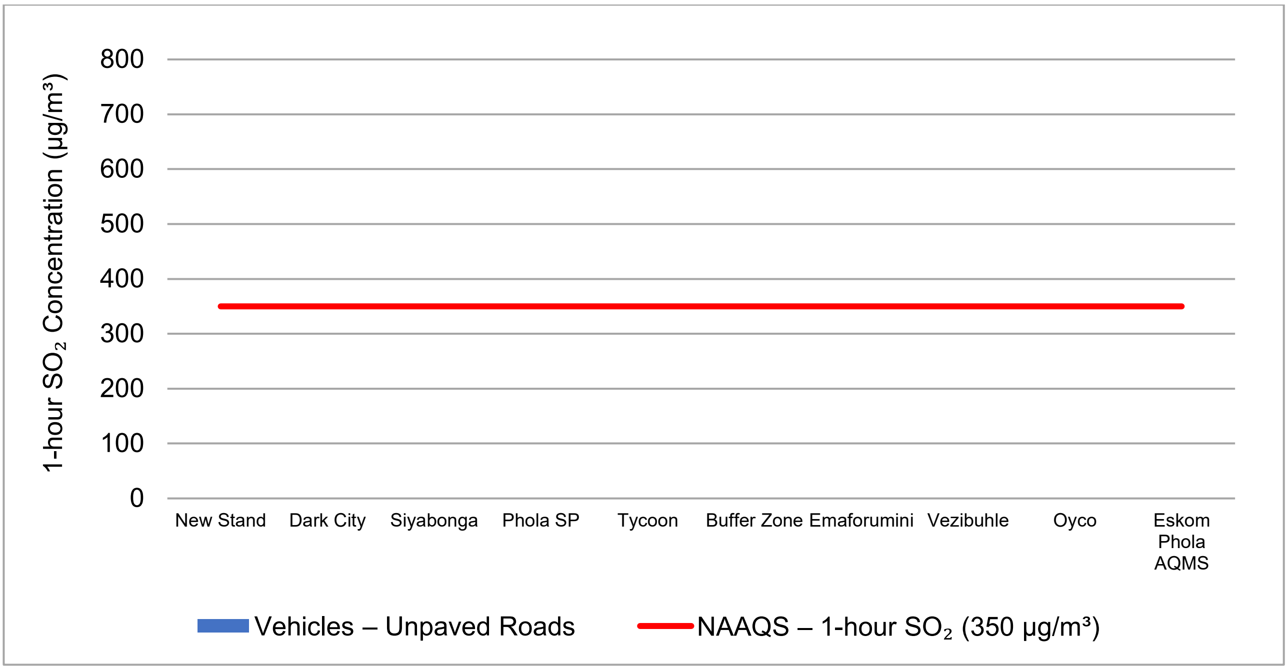


Figure 5-11: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

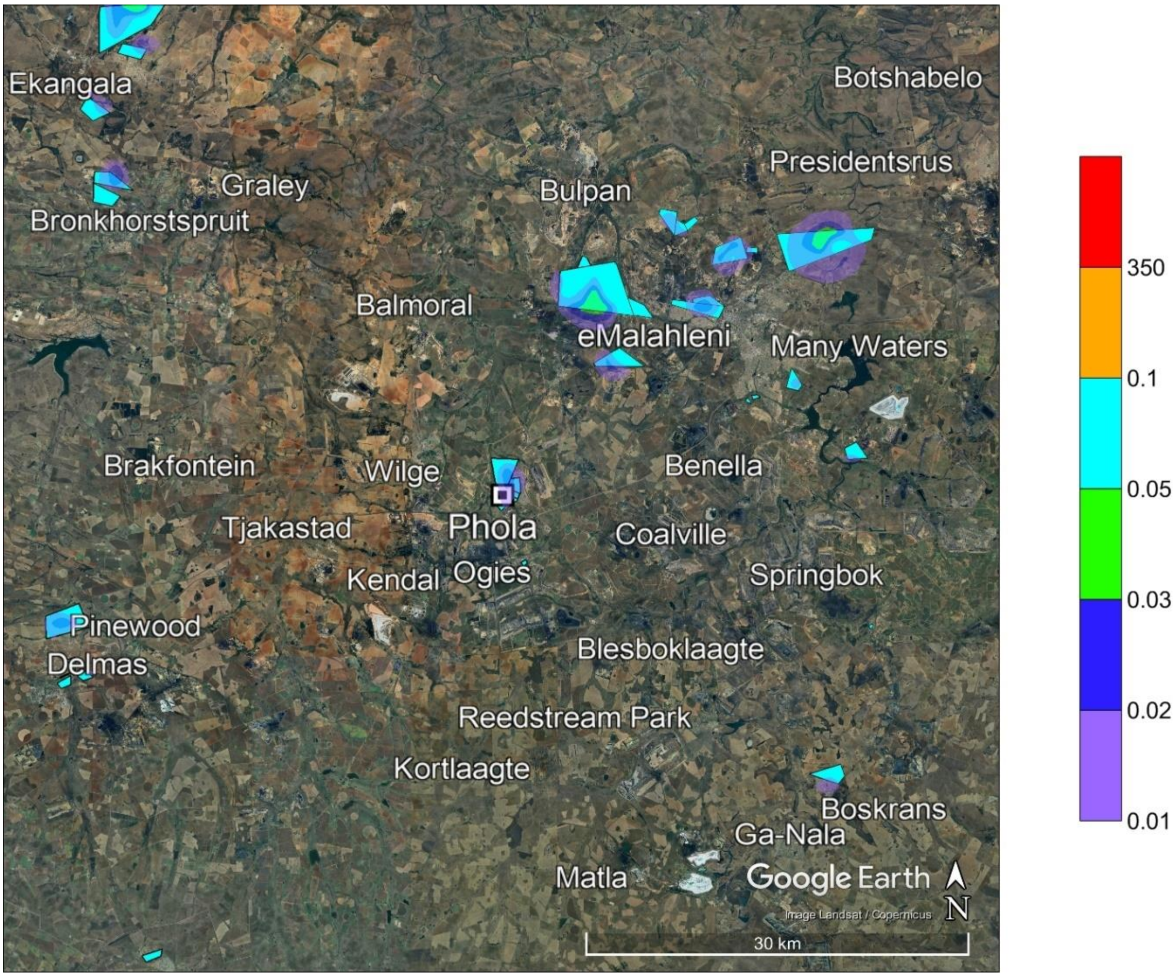


Figure 5-12: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

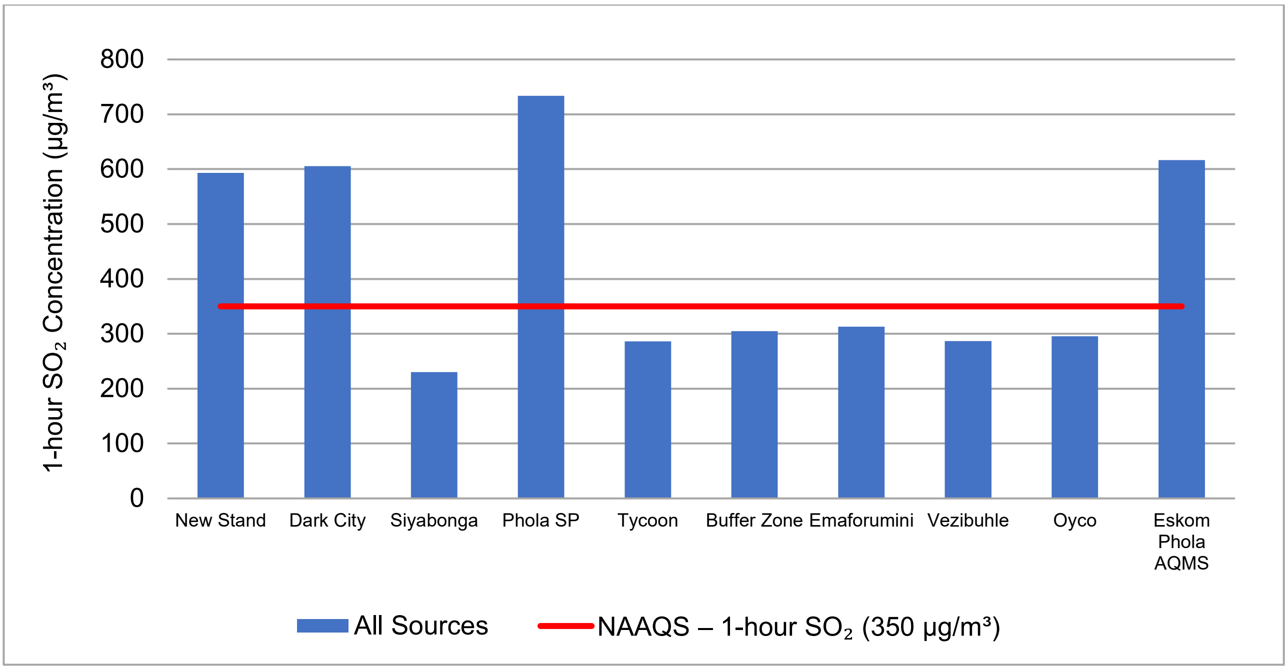


Figure 5-13: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the All Sources emission source category

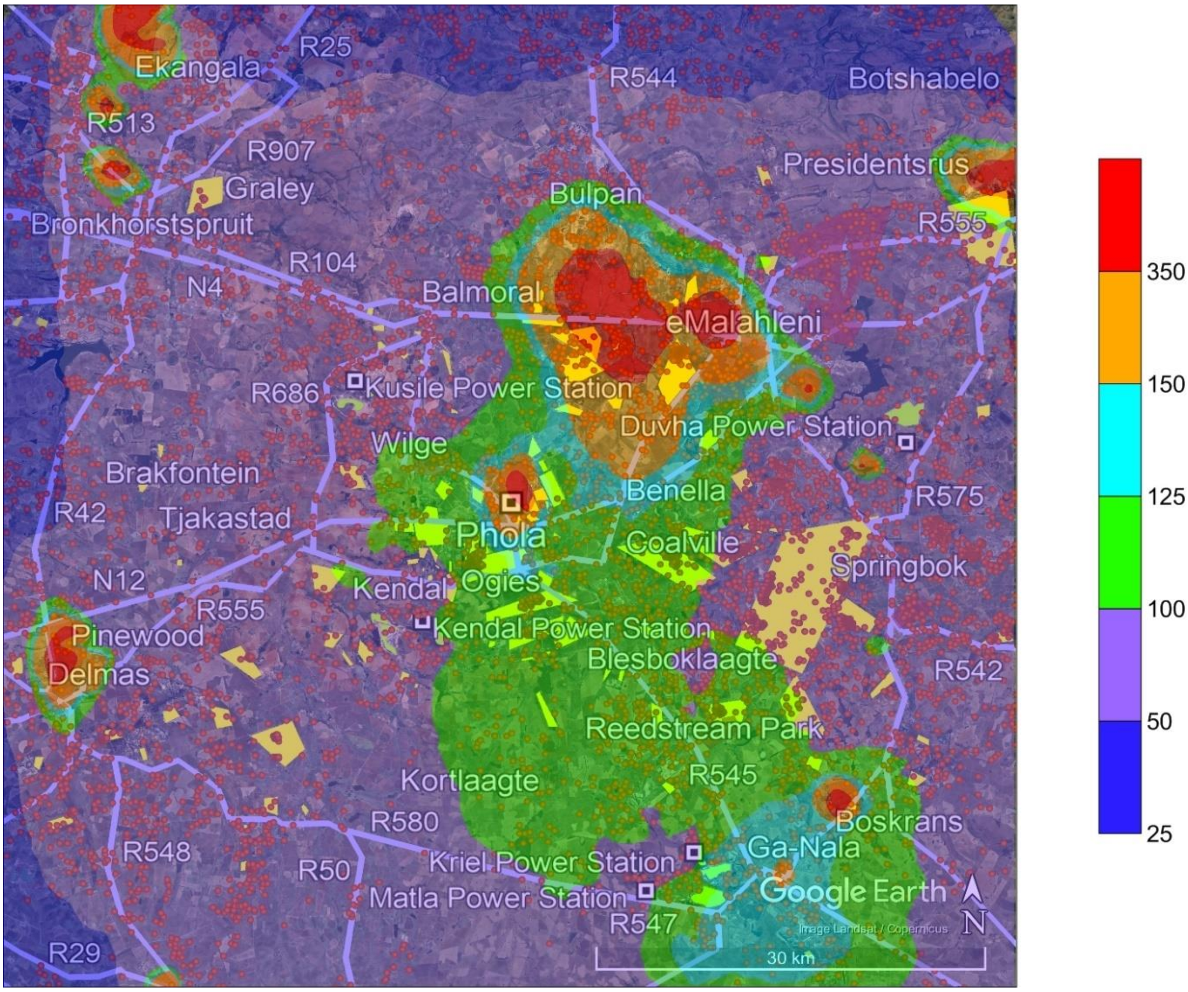


Figure 5-14: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

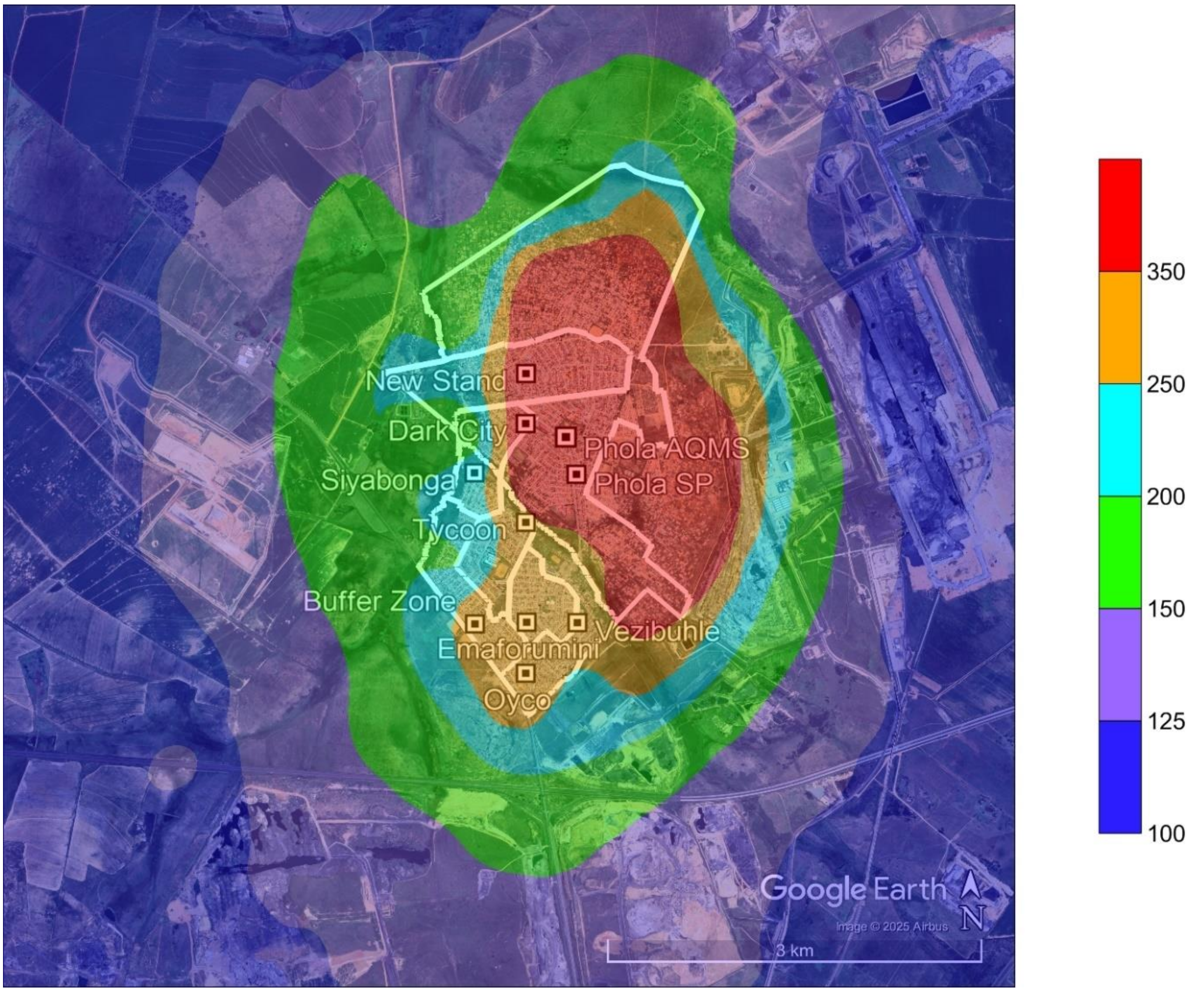


Figure 5-15: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 for the All Sources emission source category within the Phola Airshed

5.1.2 24-HOUR SO_2

Model predicted 24-hour SO_2 ambient concentrations at discrete receptors and at the point of maximum for the seven emission source categories are presented in Table 5-2. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted 24-hour SO_2 ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-16 for the Power Generation emission source category
- Figure 5-18 for the Residential Fuel Burning emission source category
- Figure 5-20 for the Waste Burning emission source category
- Figure 5-22 for the Biomass Burning emission source category
- Figure 5-24 for the Vehicles – Paved Roads emission source category
- Figure 5-26 for the Vehicles – Unpaved Roads emission source category
- Figure 5-28 for the All Sources emission source category

Contour plots for model predicted 24-hour SO_2 ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-17 for the Power Generation emission source category
- Figure 5-19 for the Residential Fuel Burning emission source category
- Figure 5-21 for the Waste Burning emission source category
- Figure 5-23 for the Biomass Burning emission source category
- Figure 5-25 for the Vehicles – Paved Roads emission source category
- Figure 5-27 for the Vehicles – Unpaved Roads emission source category
- Figure 5-29 for the All Sources emission source category

Contour plots for model predicted 24-hour SO_2 ambient concentrations for the Phola Airshed is presented in Figure 5-30 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-2: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	35.94	213.10	0.91	0.50	0.28	0.00	223.48
Dark City	36.58	202.20	0.89	0.46	0.34	0.00	219.53
Siyabonga	34.88	57.15	0.22	0.26	0.54	0.00	74.18
Phola SP	36.68	224.70	1.17	0.32	0.45	0.01	240.49
Tycoon	34.95	73.08	0.33	0.22	0.50	0.01	89.61
Buffer Zone	36.51	68.08	0.25	0.22	0.94	0.01	78.00
Emaforumini	36.01	76.00	0.27	0.21	0.55	0.01	85.56
Vezibuhle	35.26	87.59	0.38	0.20	0.36	0.01	106.15
Oyco	36.69	68.72	0.25	0.20	0.55	0.01	84.78
Eskom Phola AQMS	36.42	197.74	0.94	0.36	0.35	0.01	207.38
Maximum	79.68	1389.50	5.06	3.93	23.55	0.03	1394.10
	NAAQS – 24-hour SO_2 (125 µg/m³)						

According to Table 5-2, model predicted 24-hour SO_2 ambient concentrations exceed the 24-hour SO_2 NAAQS of 125 µg/m³ at three discrete receptors (New Stand, Dark City, Phola SP) and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories in the Phola Airshed.

Model predicted 24-hour SO_2 ambient concentrations also exceed the 24-hour SO_2 NAAQS of 125 µg/m³ at the point of maximum for the Residential Fuel Burning and All Sources emission source categories in the Greater Phola Airshed.

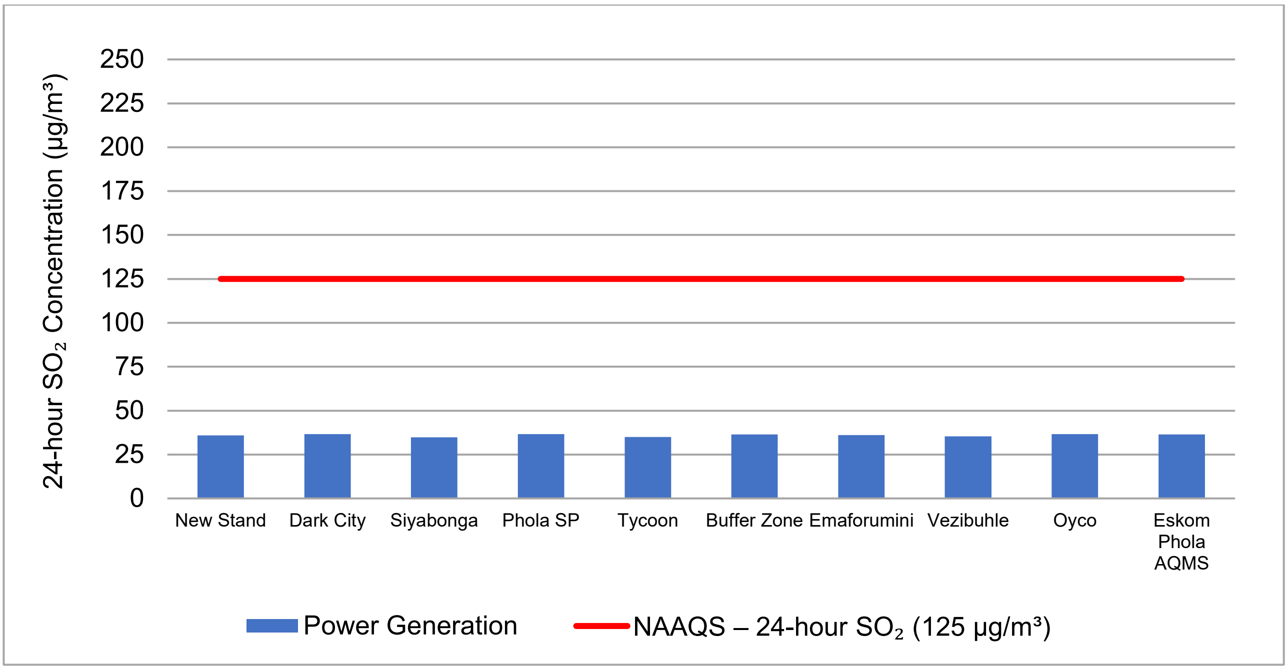


Figure 5-16: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Power Generation emission source category

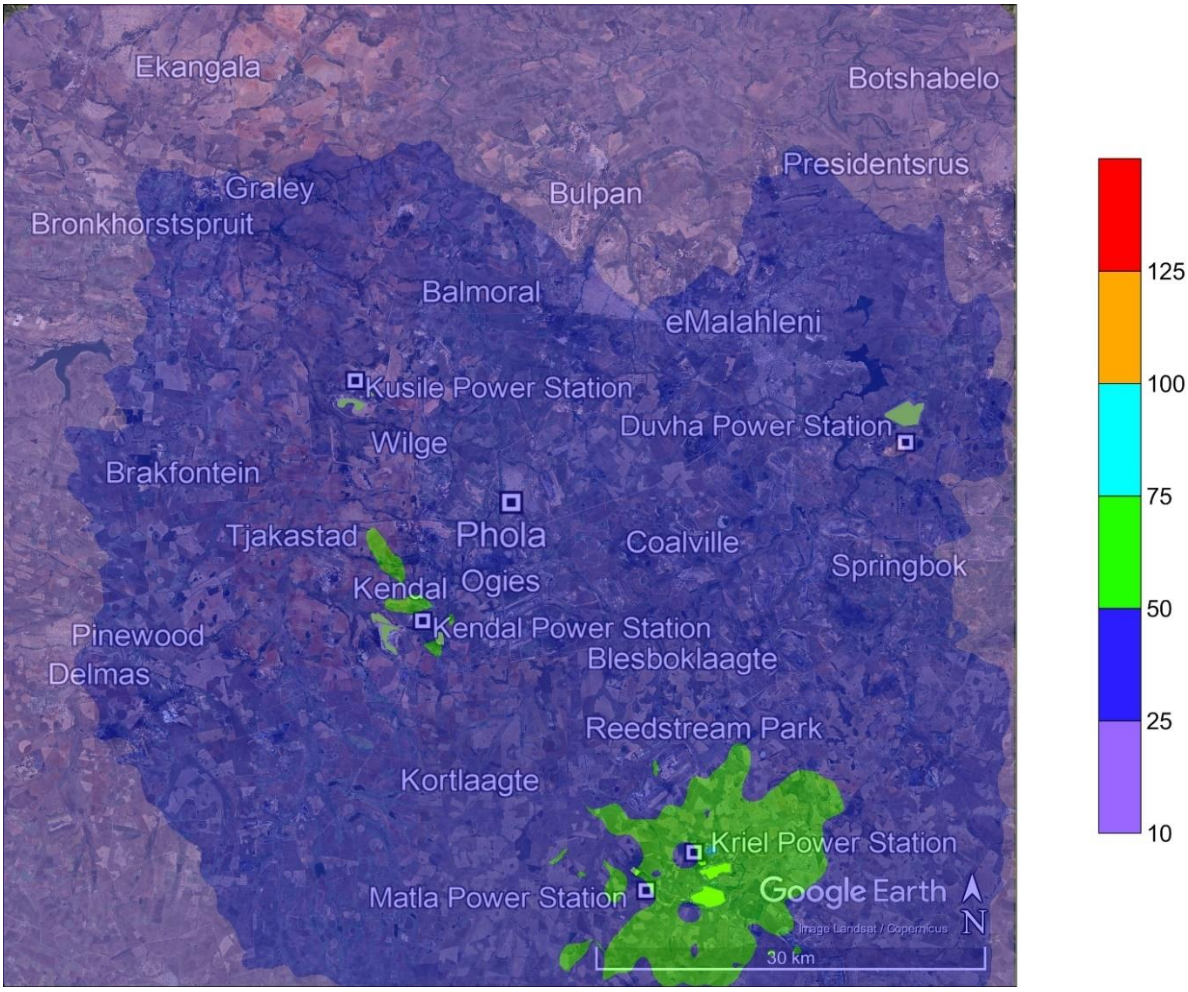


Figure 5-17: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

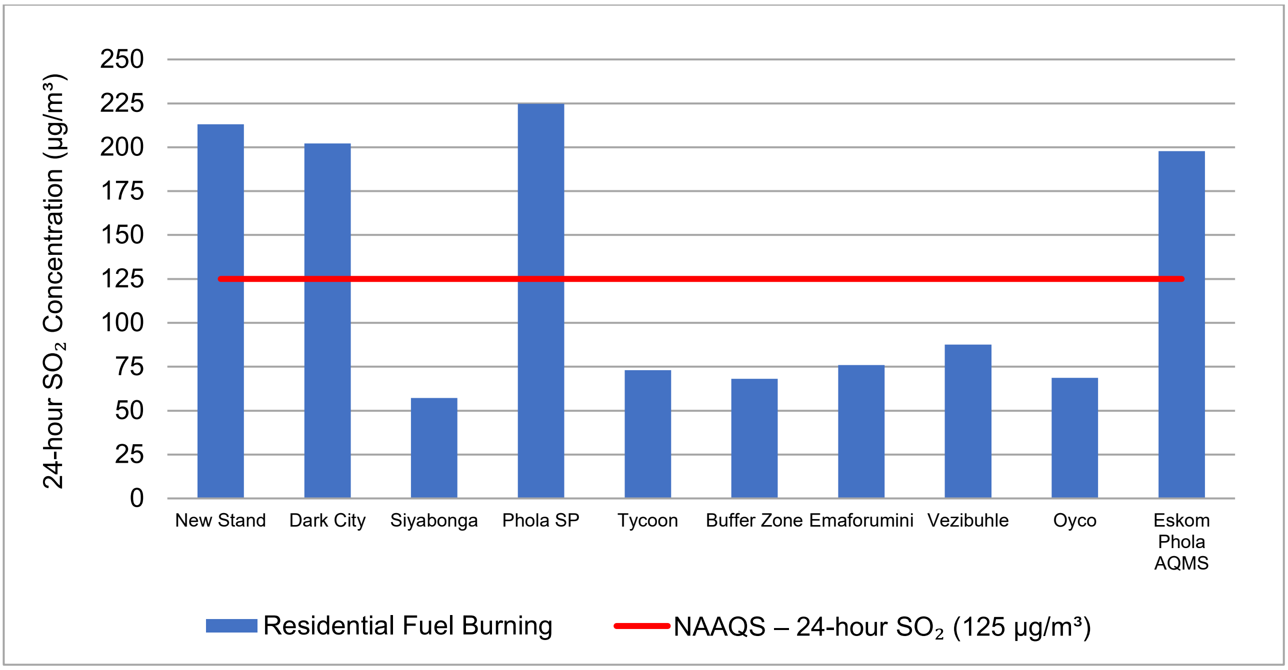


Figure 5-18: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Residential Fuel Burning emission source category

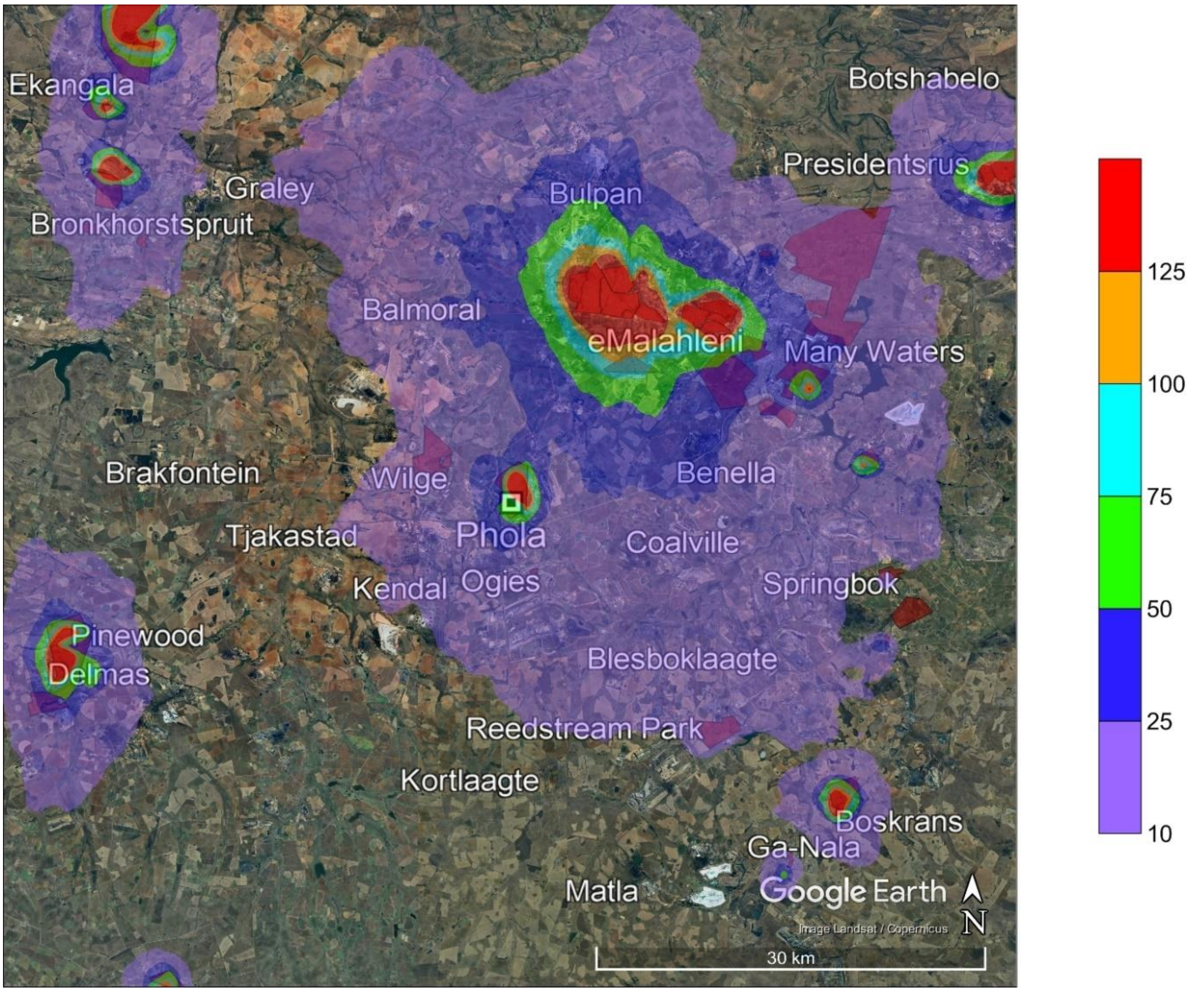


Figure 5-19: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 for the Residential Fuel Burning emission source category within the Greater Phola Airshed

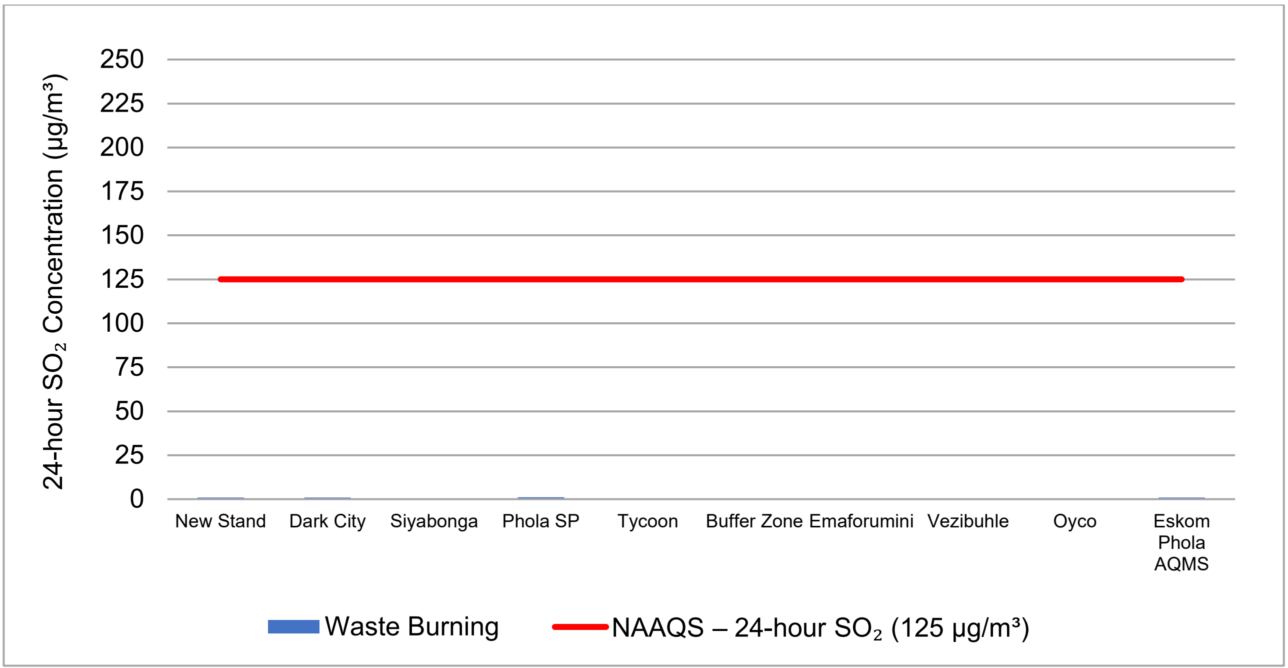


Figure 5-20: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Waste Burning emission source category

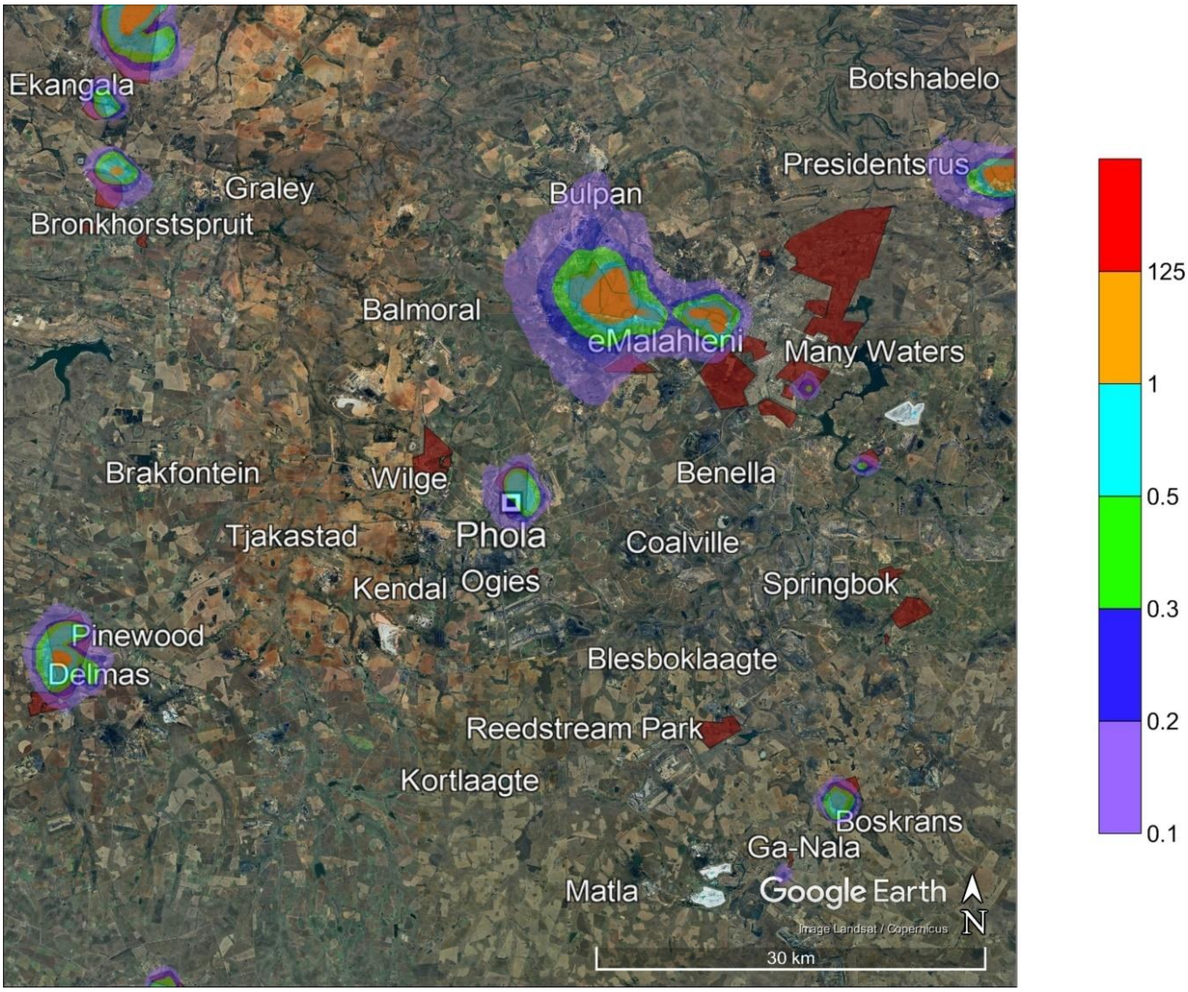


Figure 5-21: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

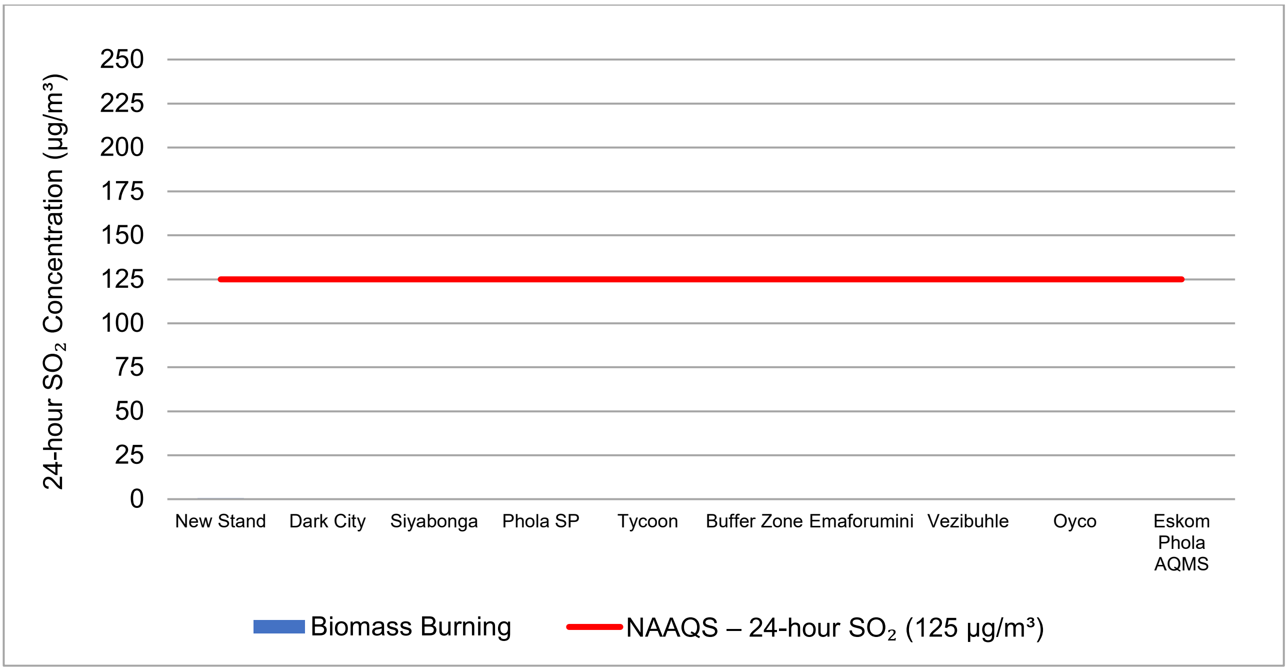


Figure 5-22: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Biomass Burning emission source category

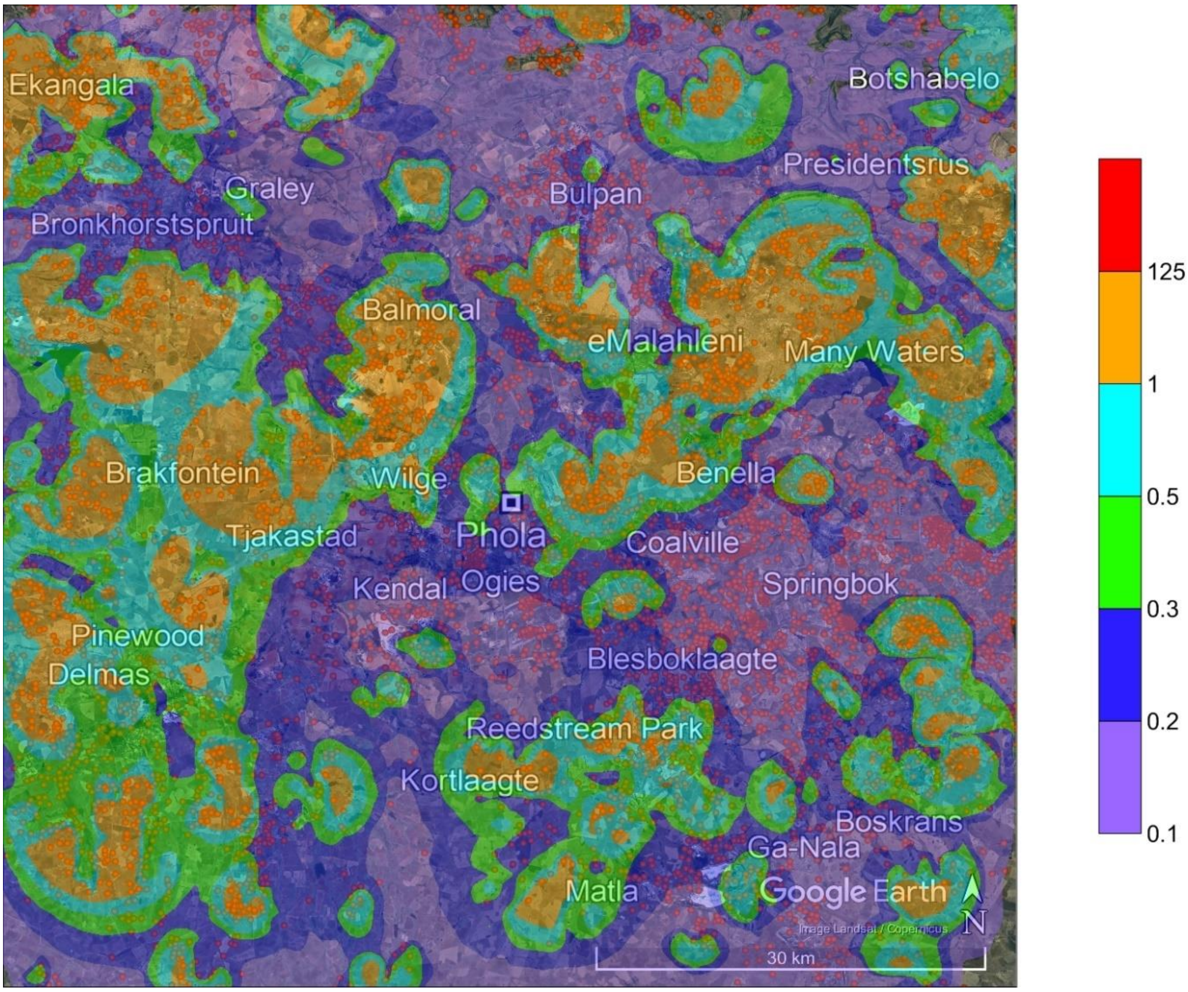


Figure 5-23: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

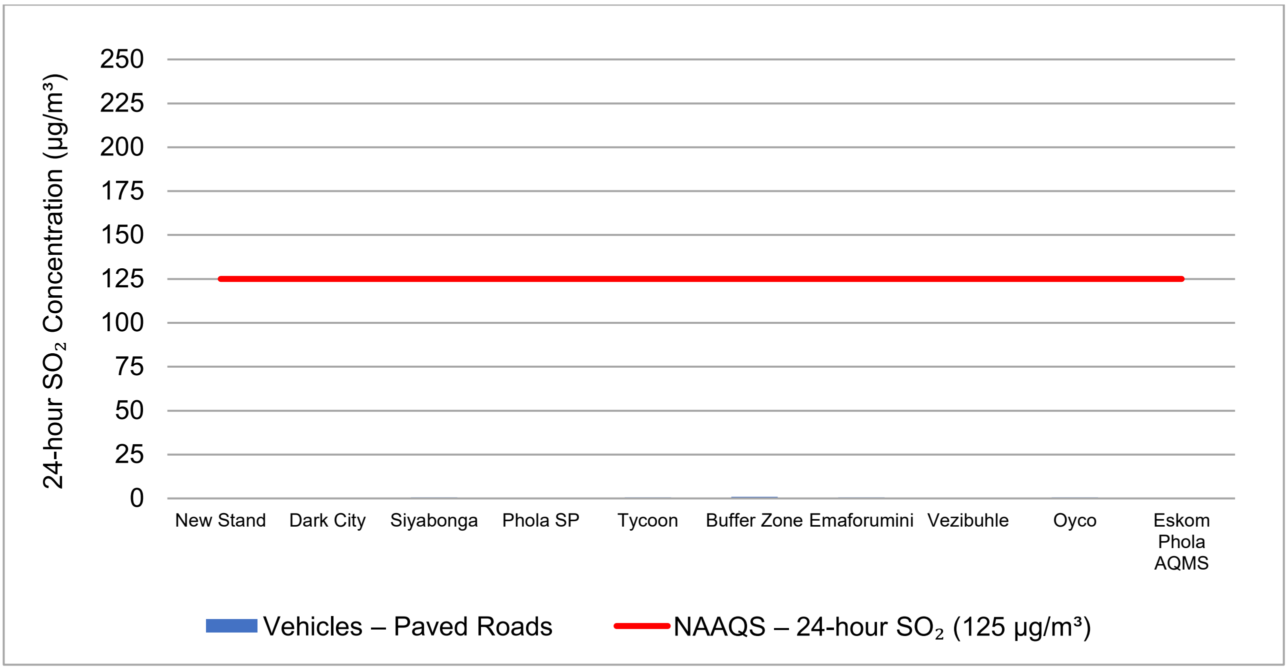


Figure 5-24: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Vehicles – Paved Roads emission source category

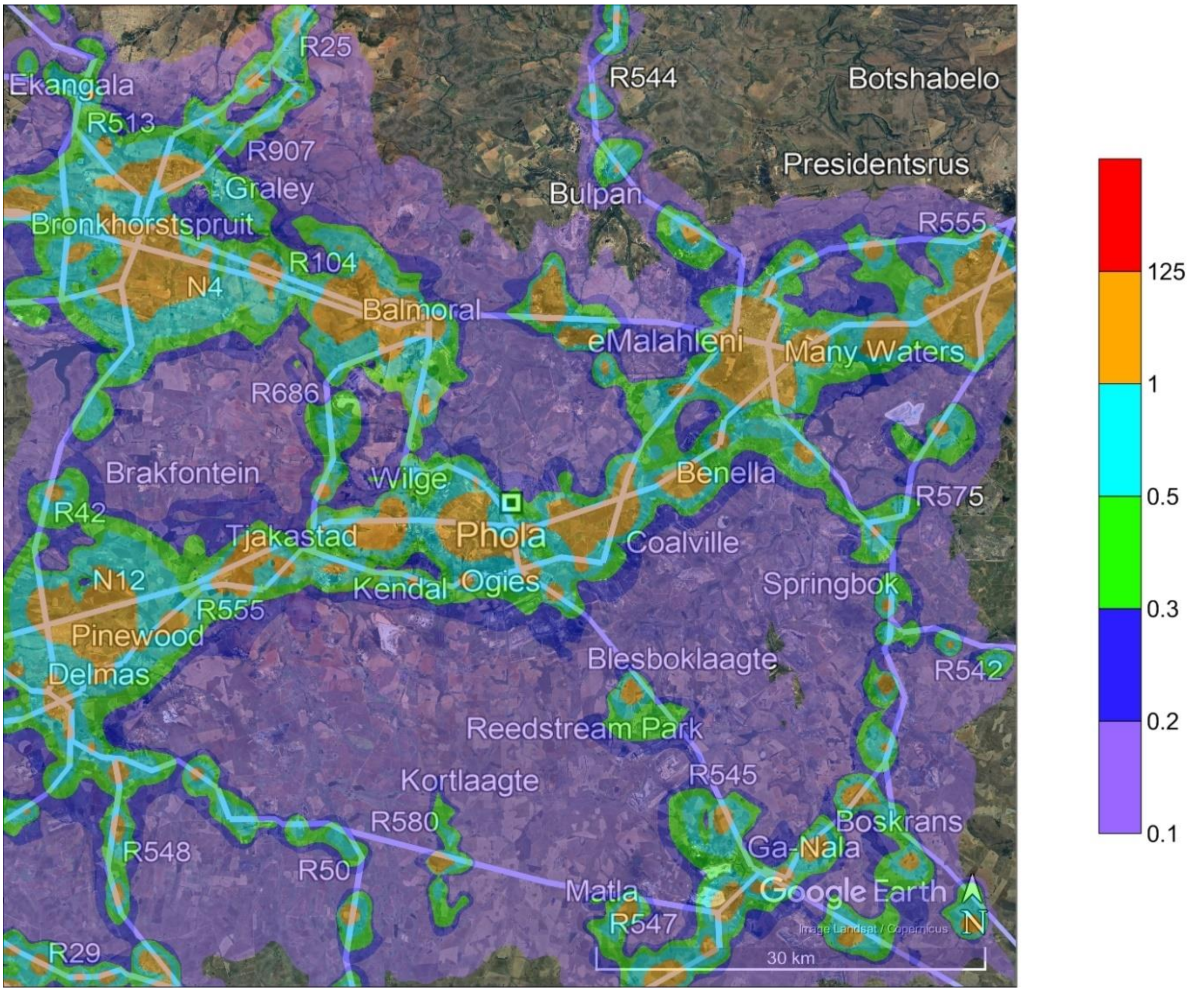


Figure 5-25: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

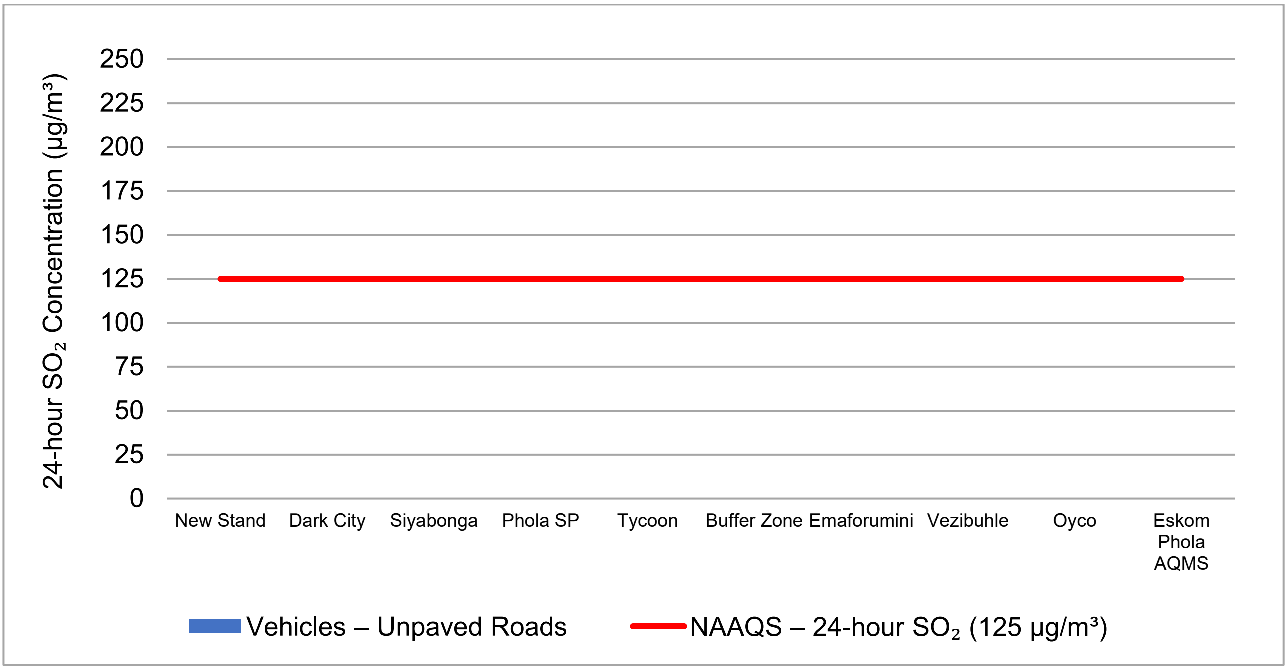


Figure 5-26: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Vehicles – Unpaved Roads emission source category

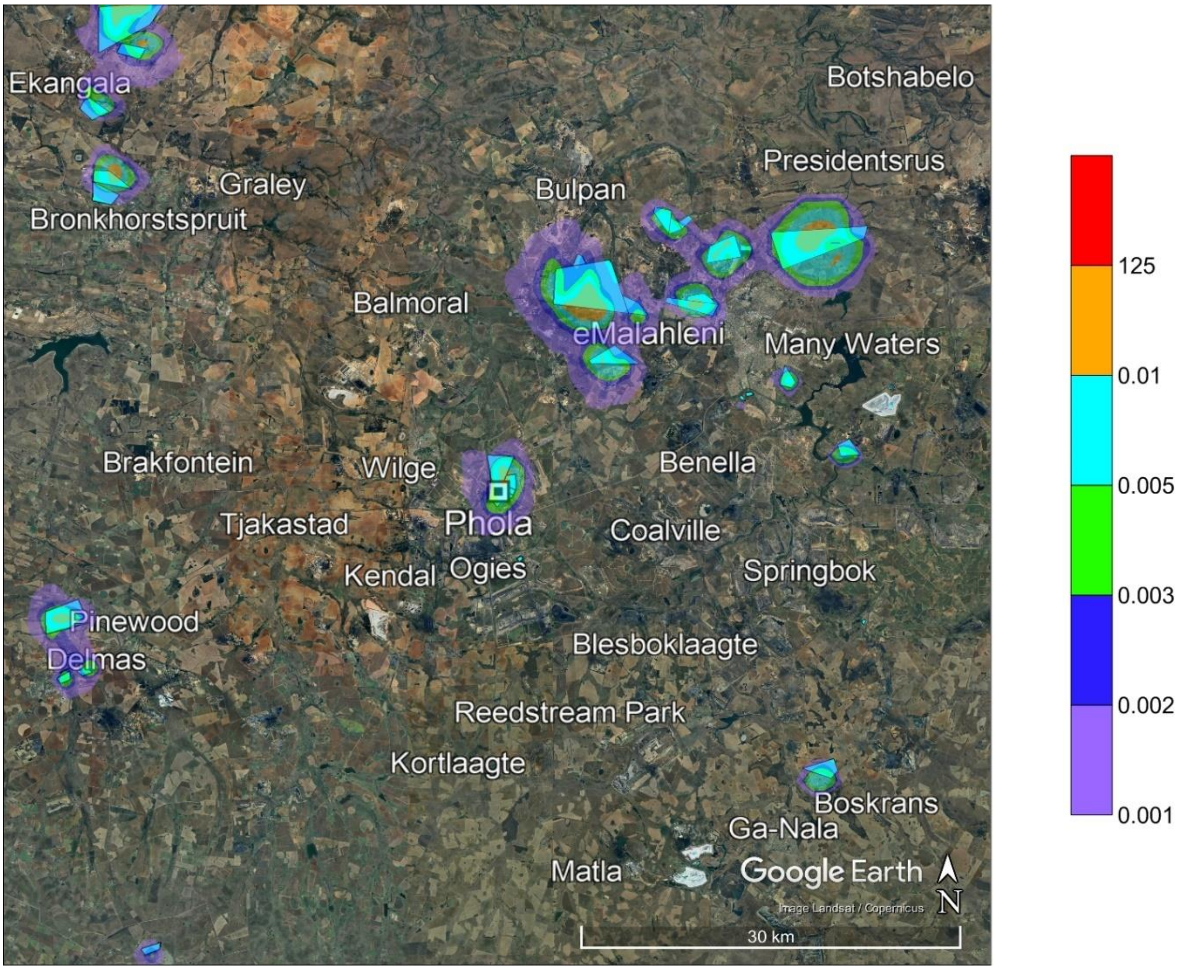


Figure 5-27: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

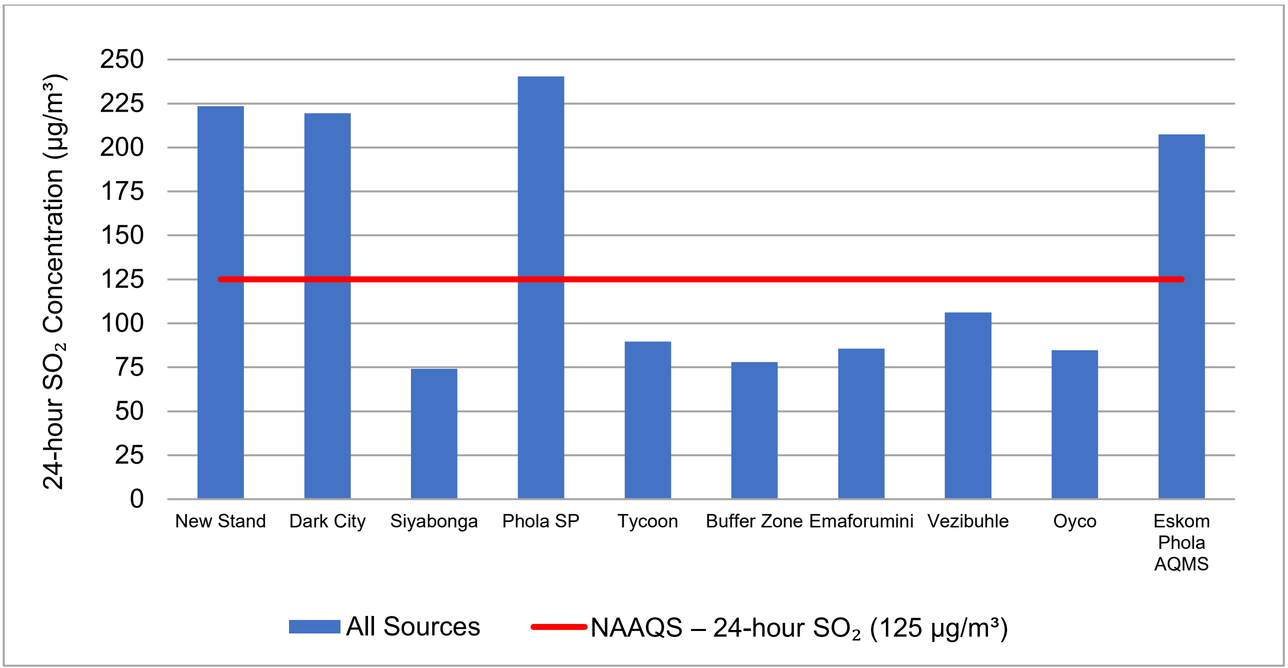


Figure 5-28: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the All Sources emission source category

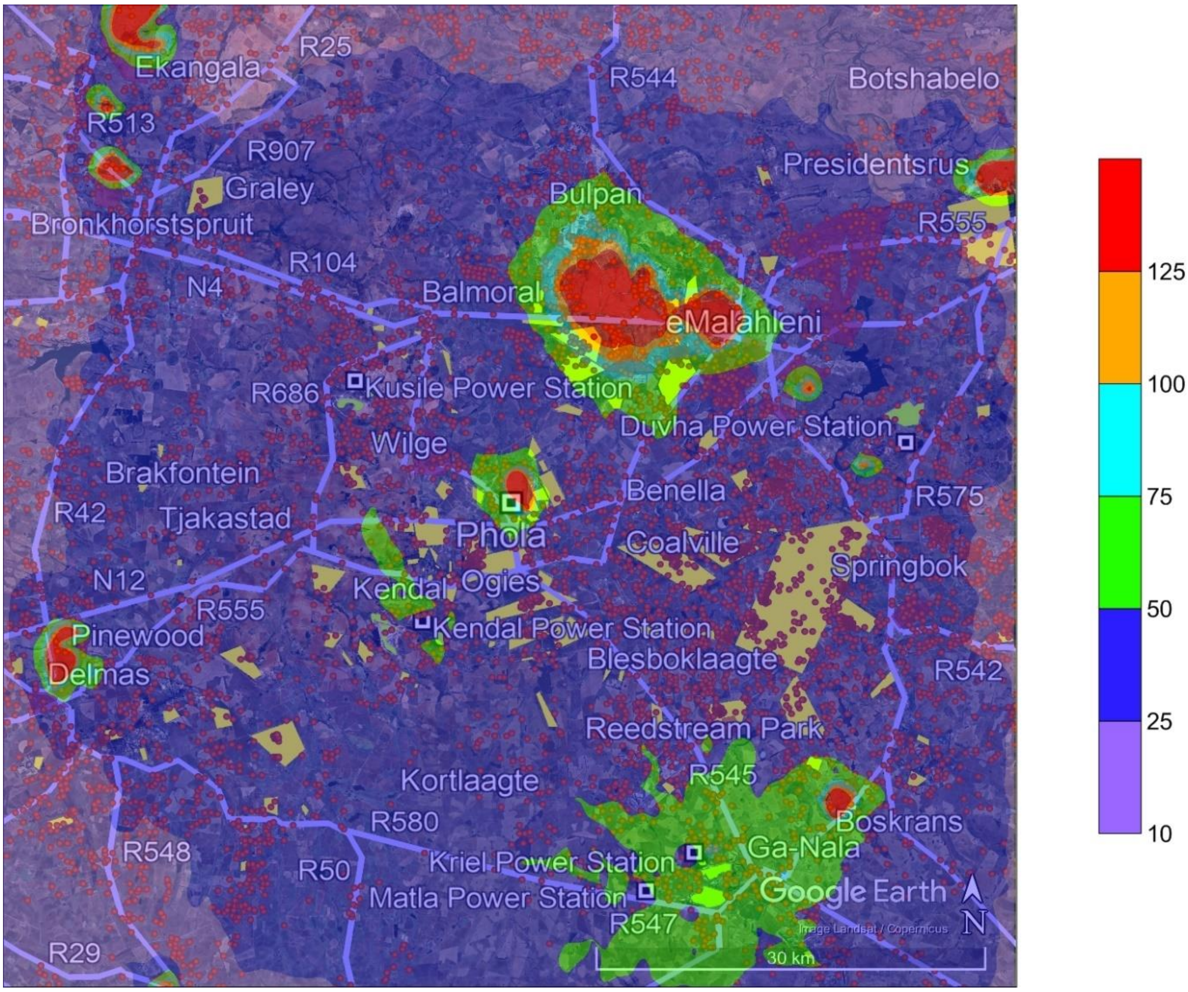


Figure 5-29: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 for the All Sources emission source category within the Greater Phola Airshed

Figure 5-30: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 for the All Sources emission source category within the Phola Airshed

5.1.3 ANNUAL SO_2

Model predicted annual SO_2 ambient concentrations at discrete receptors and at the point of maximum for the seven emission source categories are presented in Table 5-3. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted annual SO_2 ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-31 for the Power Generation emission source category
- Figure 5-33 for the Residential Fuel Burning emission source category
- Figure 5-35 for the Waste Burning emission source category
- Figure 5-37 for the Biomass Burning emission source category
- Figure 5-39 for the Vehicles – Paved Roads emission source category
- Figure 5-41 for the Vehicles – Unpaved Roads emission source category
- Figure 5-43 for the All Sources emission source category

Contour plots for model predicted annual SO_2 ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-32 for the Power Generation emission source category
- Figure 5-34 for the Residential Fuel Burning emission source category
- Figure 5-36 for the Waste Burning emission source category
- Figure 5-38 for the Biomass Burning emission source category
- Figure 5-40 for the Vehicles – Paved Roads emission source category
- Figure 5-42 for the Vehicles – Unpaved Roads emission source category
- Figure 5-44 for the All Sources emission source category

Contour plots for model predicted annual SO_2 ambient concentrations for the Phola Airshed is presented in Figure 5-45 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-3: Model predicted annual SO_2 ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	4.37	64.13	0.36	0.22	0.08	0.00	69.16
Dark City	4.42	70.61	0.38	0.19	0.11	0.00	75.72
Siyabonga	4.45	20.19	0.09	0.12	0.24	0.00	25.09
Phola SP	4.44	82.51	0.45	0.14	0.19	0.00	87.74
Tycoon	4.48	29.19	0.14	0.09	0.23	0.00	34.13
Buffer Zone	4.59	23.10	0.09	0.09	0.36	0.00	28.24
Emaforumini	4.57	25.85	0.10	0.09	0.23	0.00	30.84
Vezibuhle	4.54	31.72	0.15	0.08	0.14	0.00	36.64
Oyco	4.61	24.31	0.09	0.09	0.22	0.00	29.31
Eskom Phola AQMS	4.43	71.01	0.39	0.16	0.13	0.00	76.13
Maximum	8.07	494.01	2.35	1.59	4.56	0.01	499.53
	NAAQS – Annual SO_2 (50 µg/m³)						

According to Table 5-3, model predicted annual SO_2 ambient concentrations exceed the annual SO_2 NAAQS of 50 µg/m³ at three discrete receptors (New Stand, Dark City, Phola SP) and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories in the Phola Airshed.

Model predicted annual SO_2 ambient concentrations also exceed the annual SO_2 NAAQS of 50 µg/m³ at the point of maximum for the Residential Fuel Burning and All Sources emission source categories in the Greater Phola Airshed.

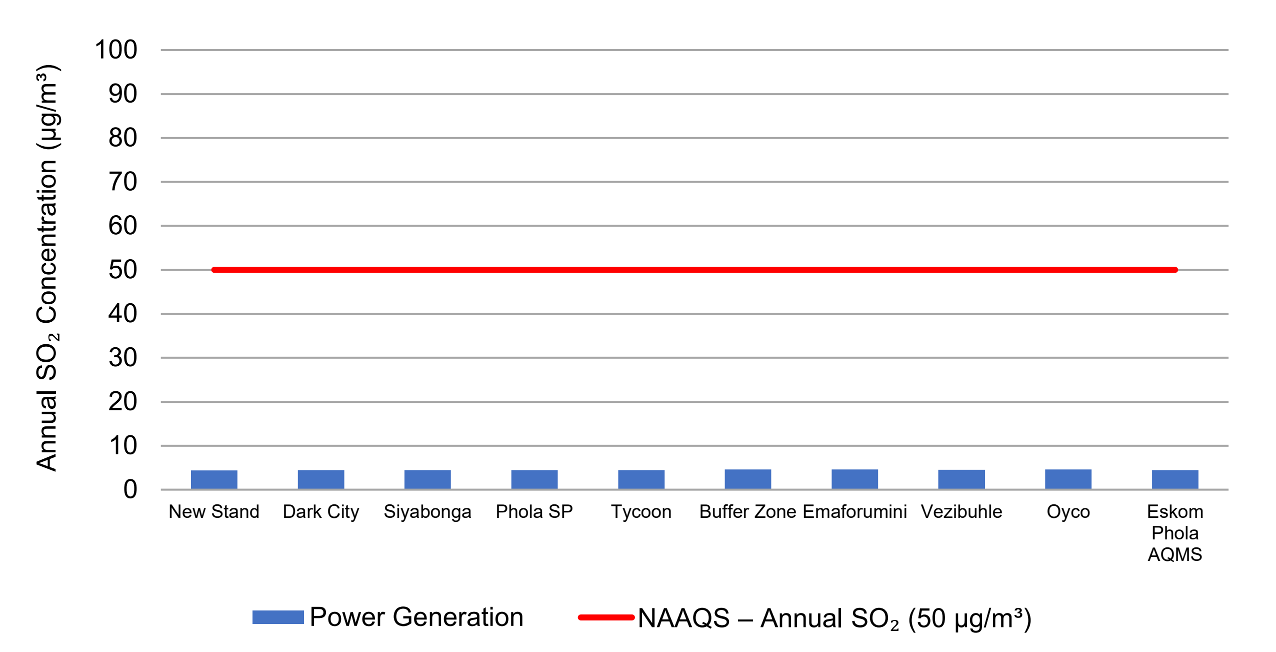


Figure 5-31: Model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the Power Generation emission source category

Figure 5-32: Model predicted annual SO_2 ambient concentrations in µg/m^3 for the Power Generation emission source category within the Greater Phola Airshed

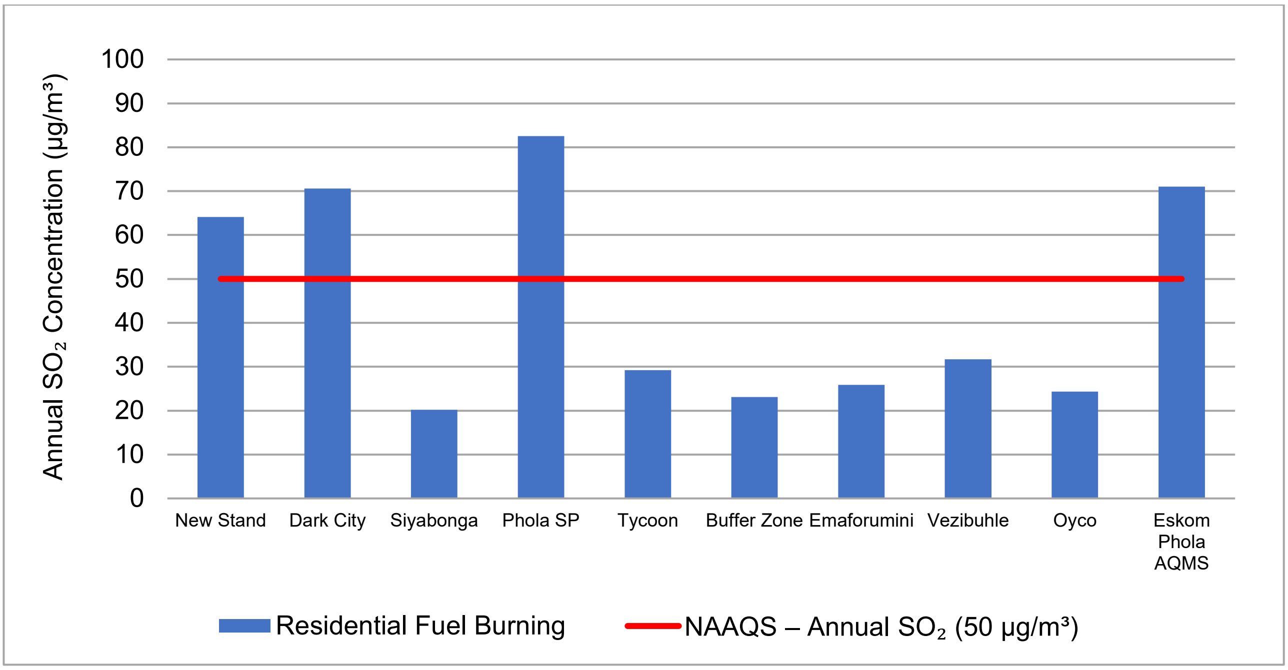


Figure 5-33: Model predicted annual SO_2 ambient concentrations in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

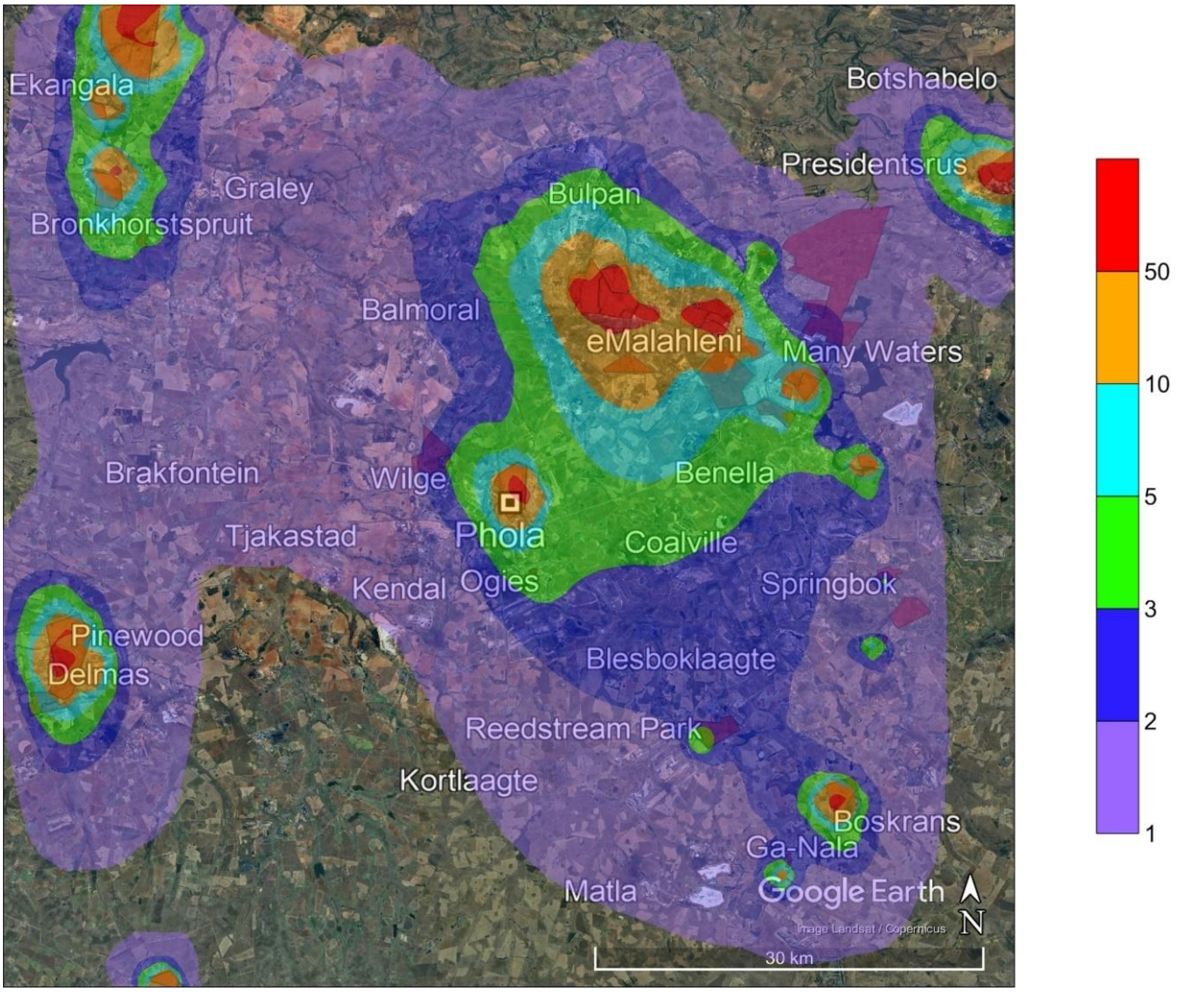


Figure 5-34: Model predicted annual SO_2 ambient concentrations in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

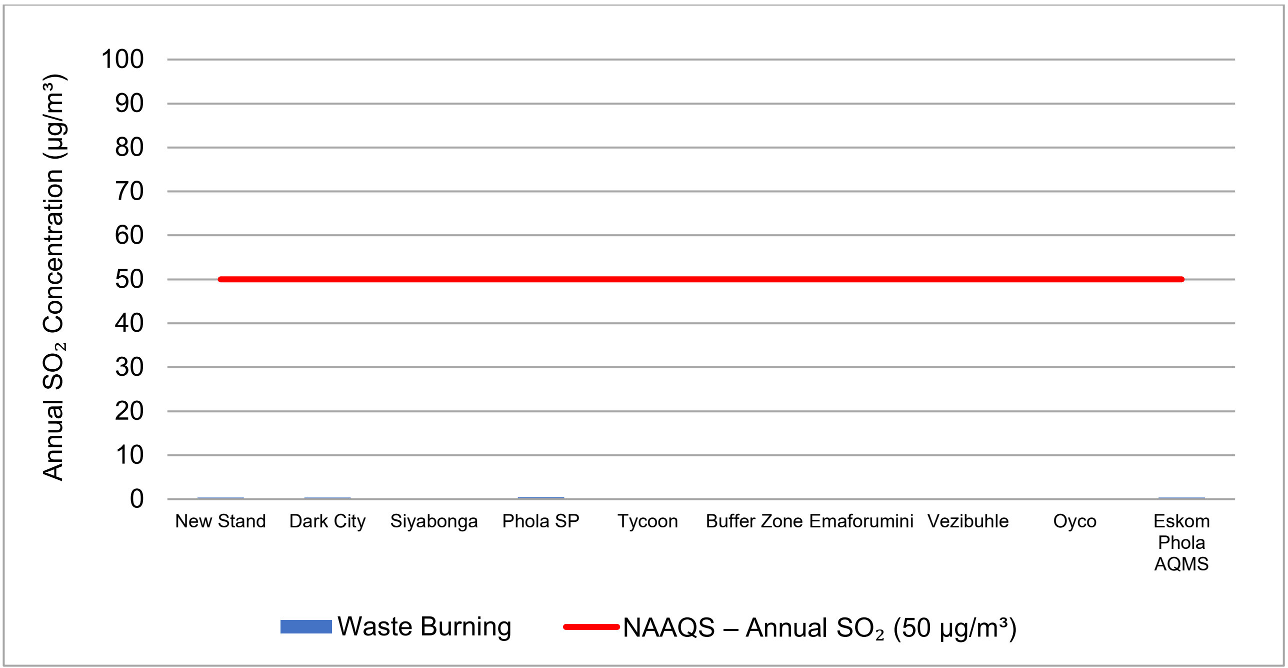


Figure 5-35: Model predicted annual SO_2 ambient concentrations in µg/m³ at discrete receptors for the Waste Burning emission source category

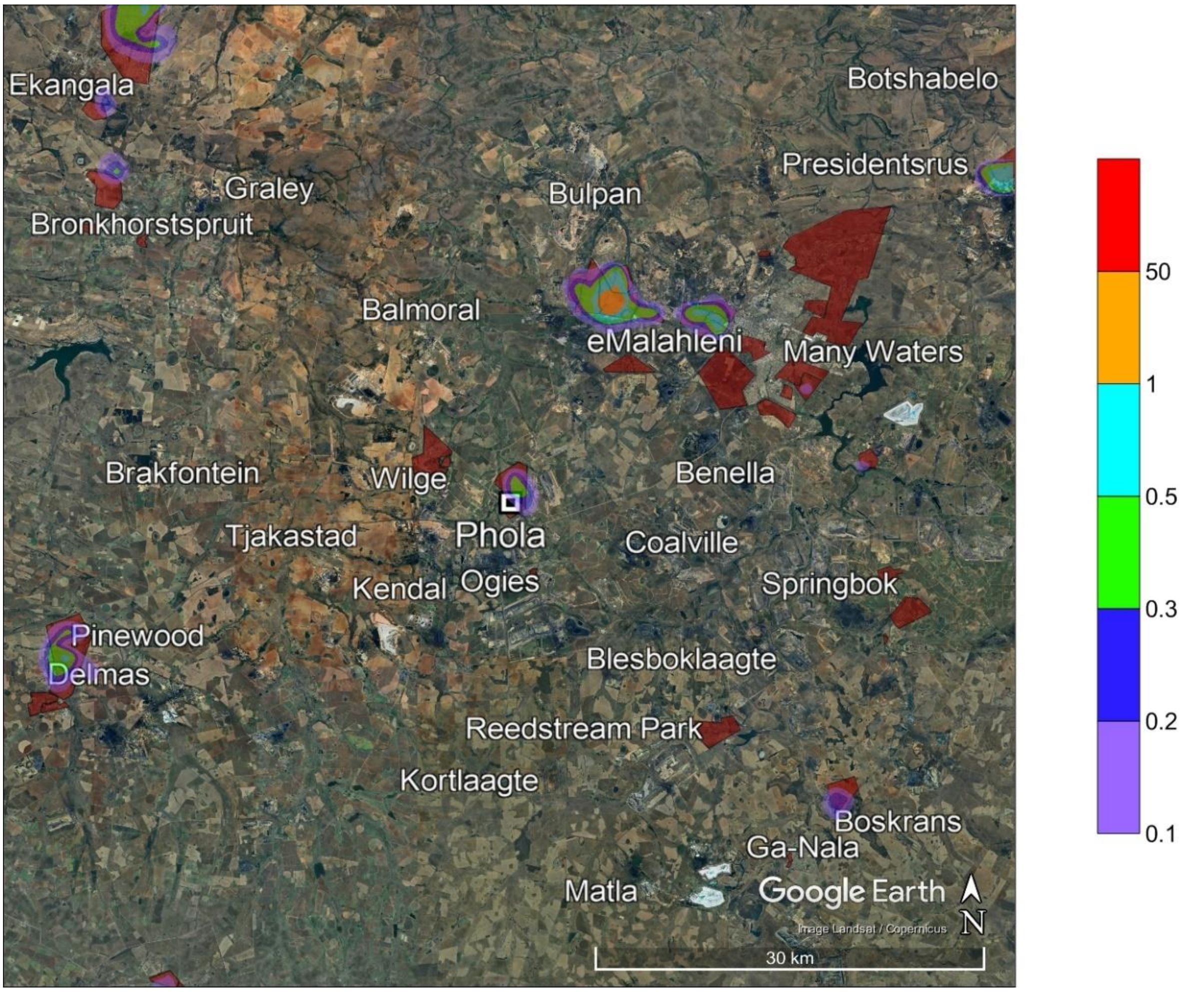


Figure 5-36: Model predicted annual SO_2 ambient concentrations in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

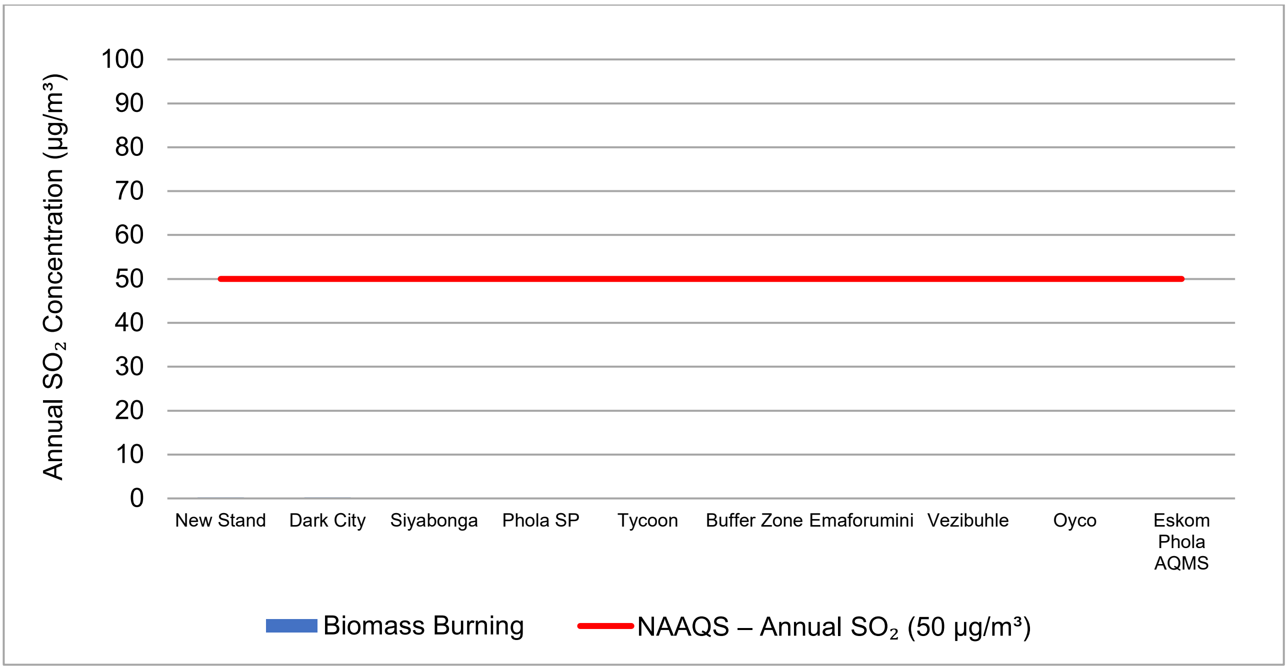


Figure 5-37: Model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the Biomass Burning emission source category

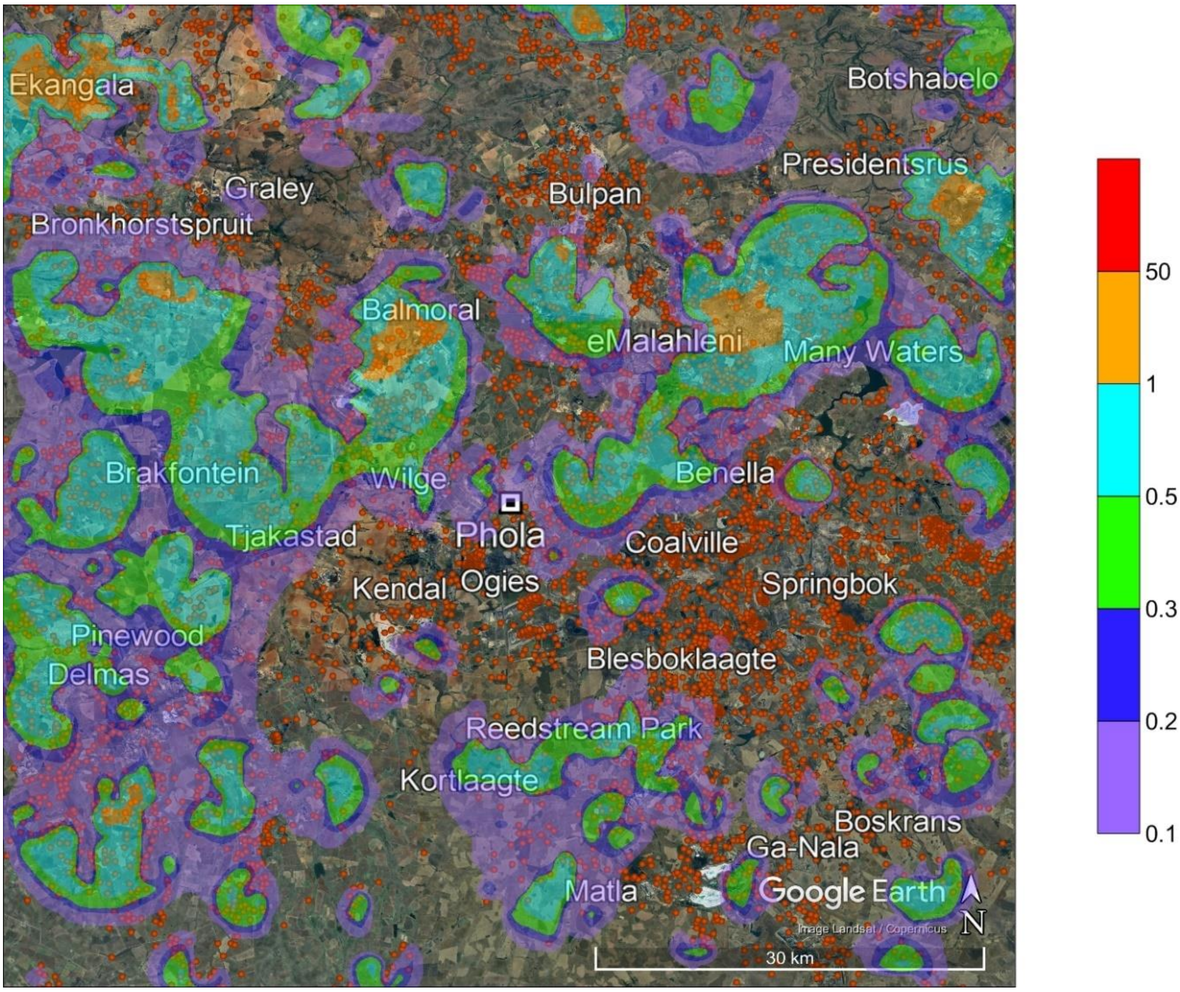


Figure 5-38: Model predicted annual SO_2 ambient concentrations in µg/m^3 for the Biomass Burning emission source category within the Greater Phola Airshed

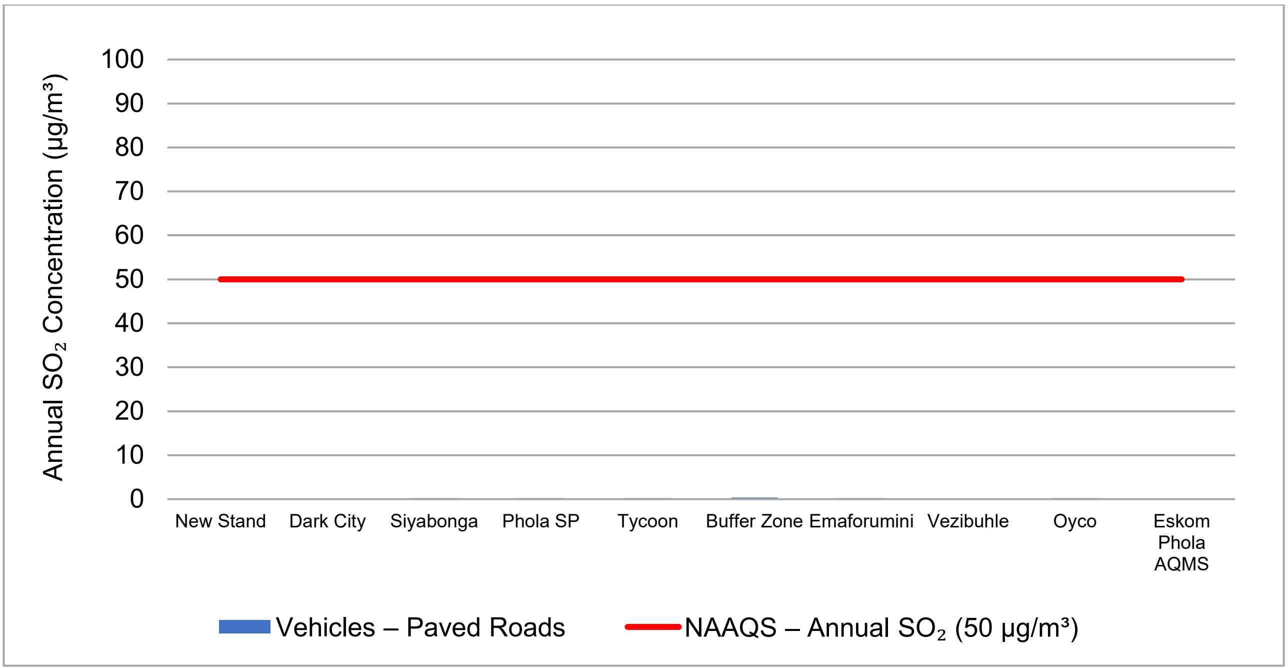


Figure 5-39: Model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the Vehicles – Paved Roads emission source category

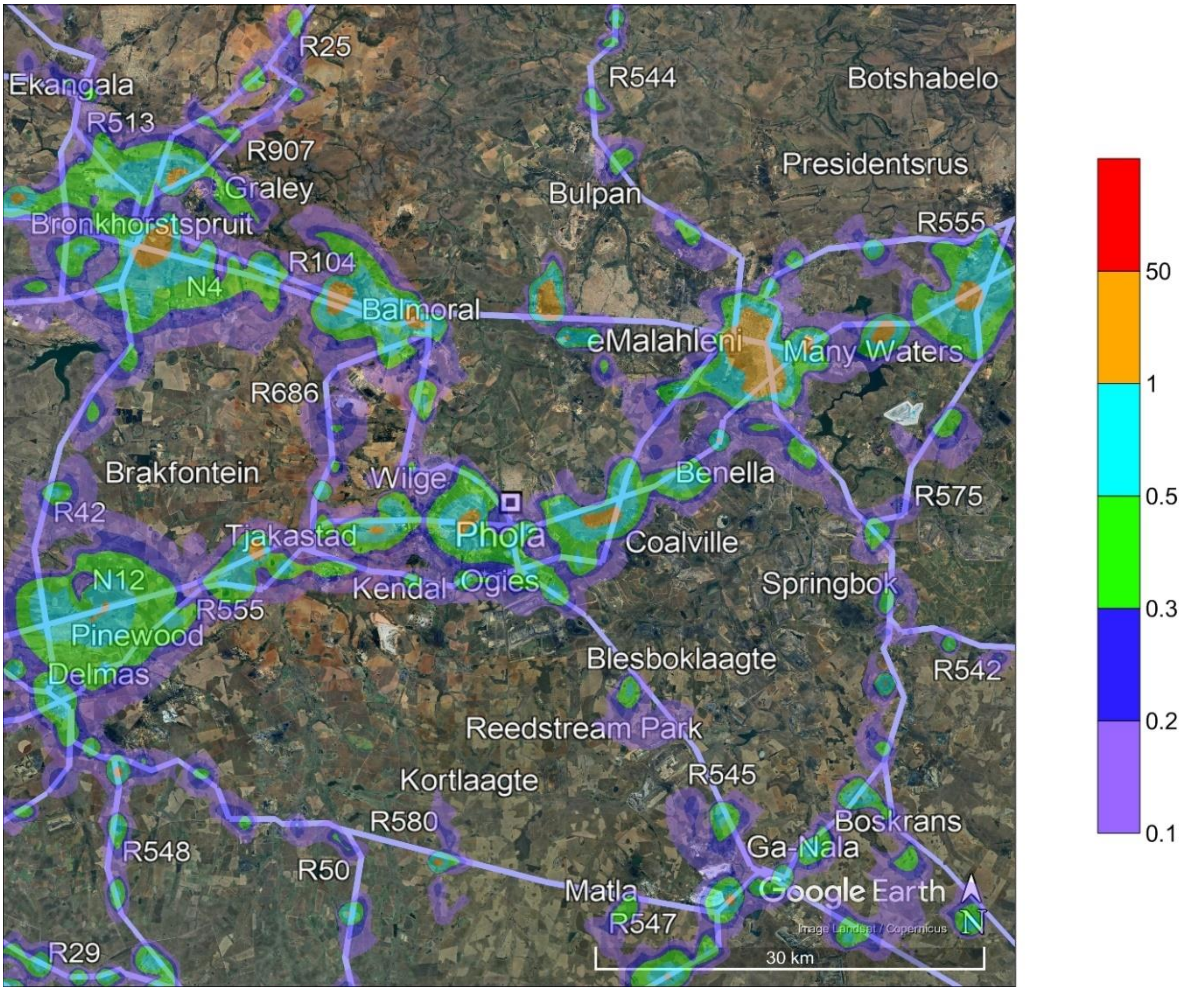


Figure 5-40: Model predicted annual SO_2 ambient concentrations in µg/m^3 for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

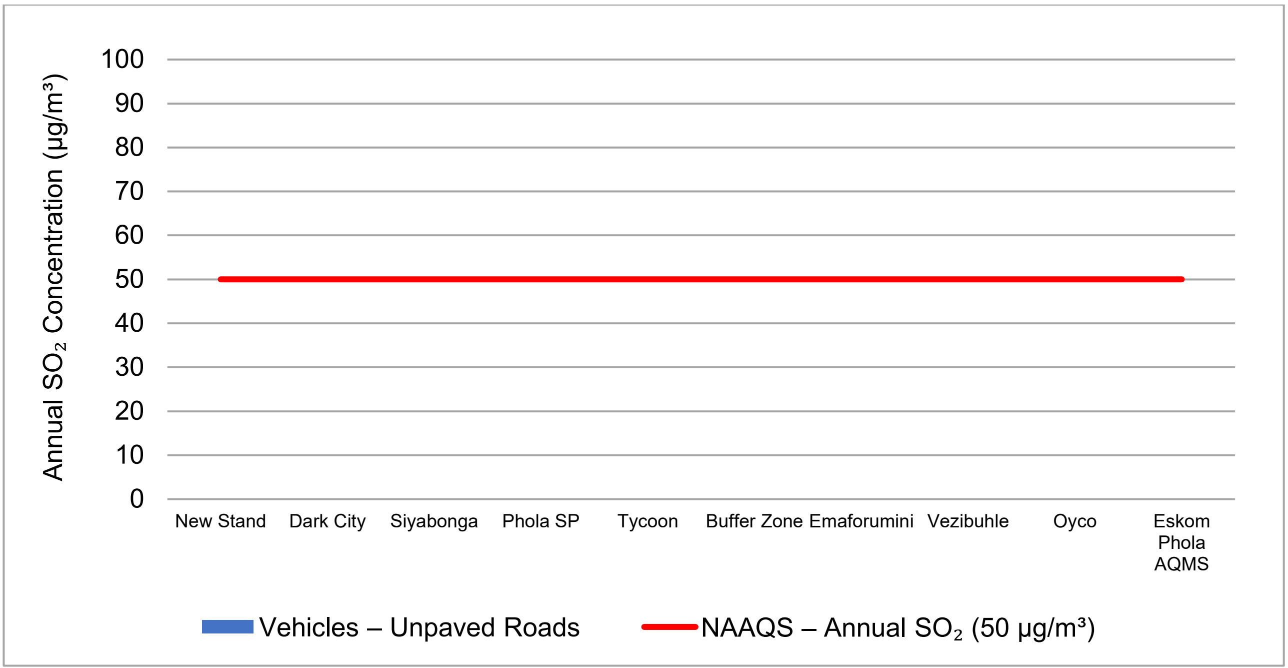


Figure 5-41: Model predicted annual SO_2 ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

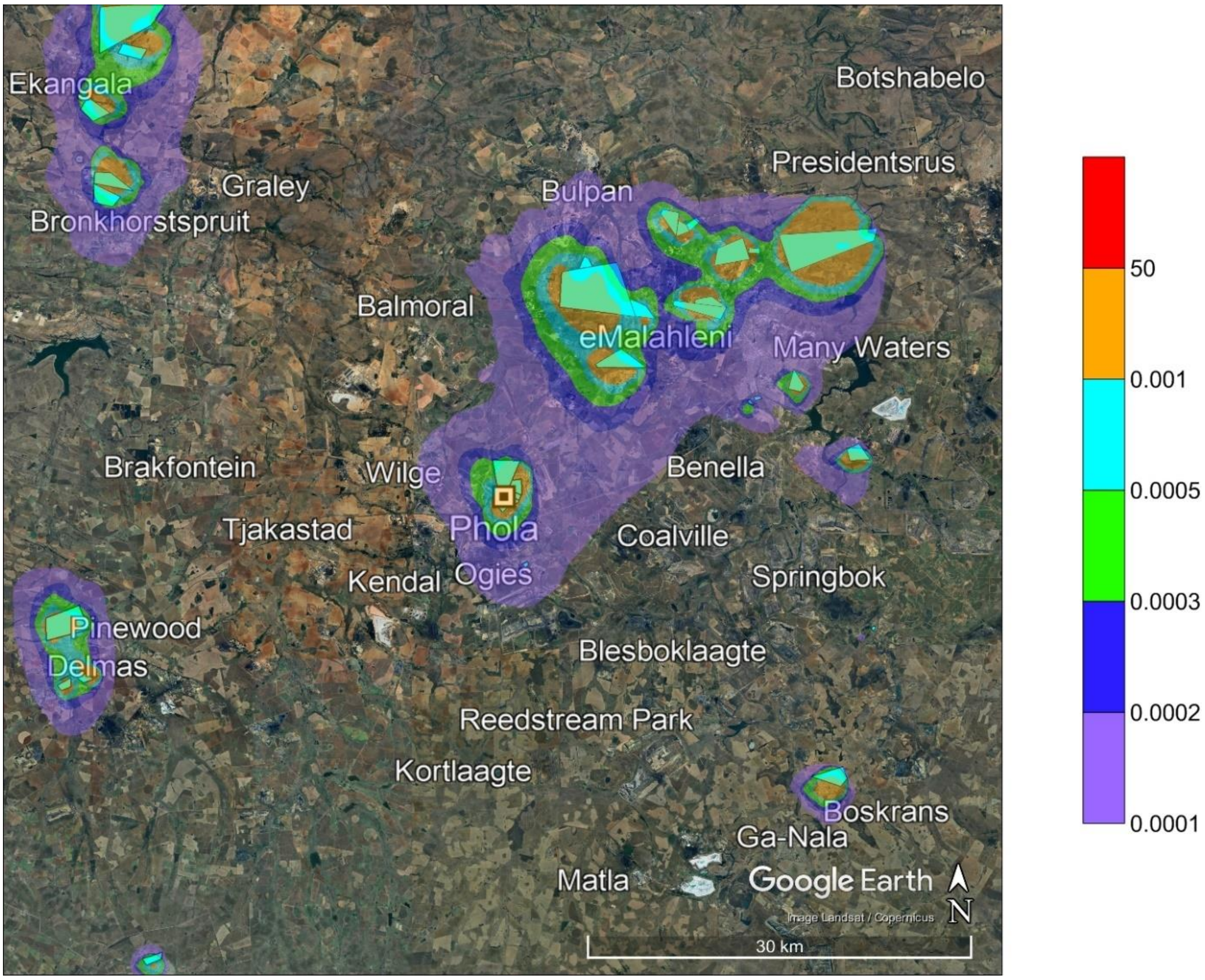


Figure 5-42: Model predicted annual SO_2 ambient concentrations in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

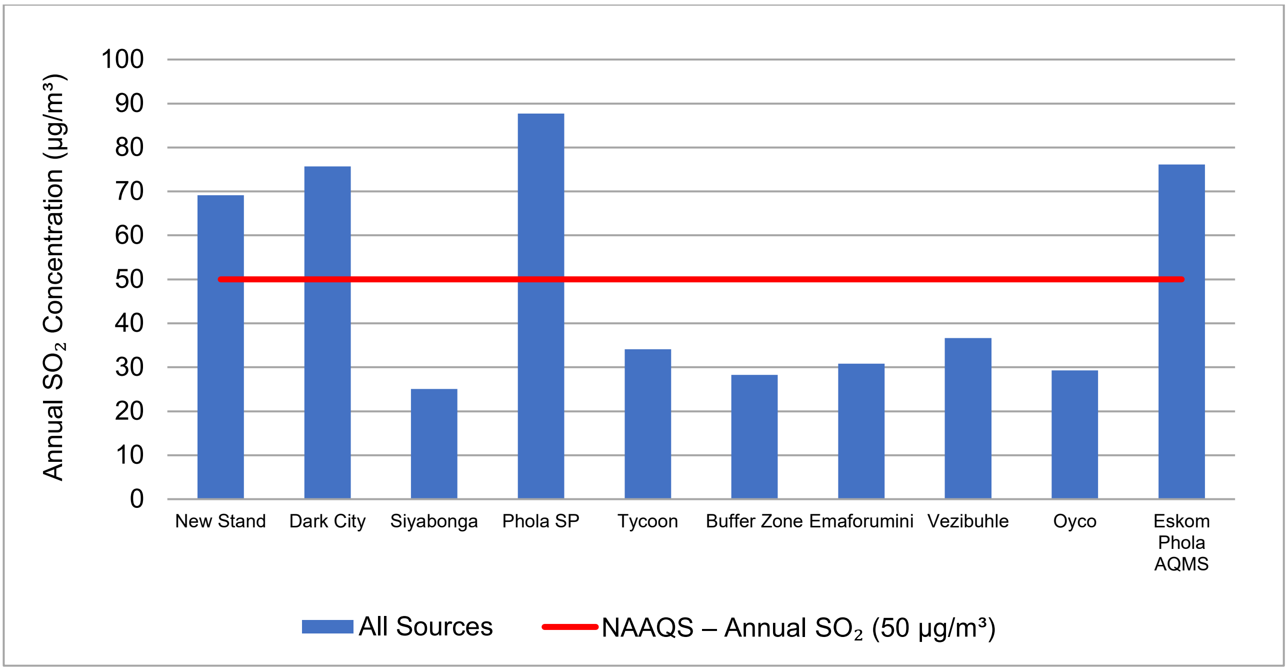


Figure 5-43: Model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the All Sources emission source category

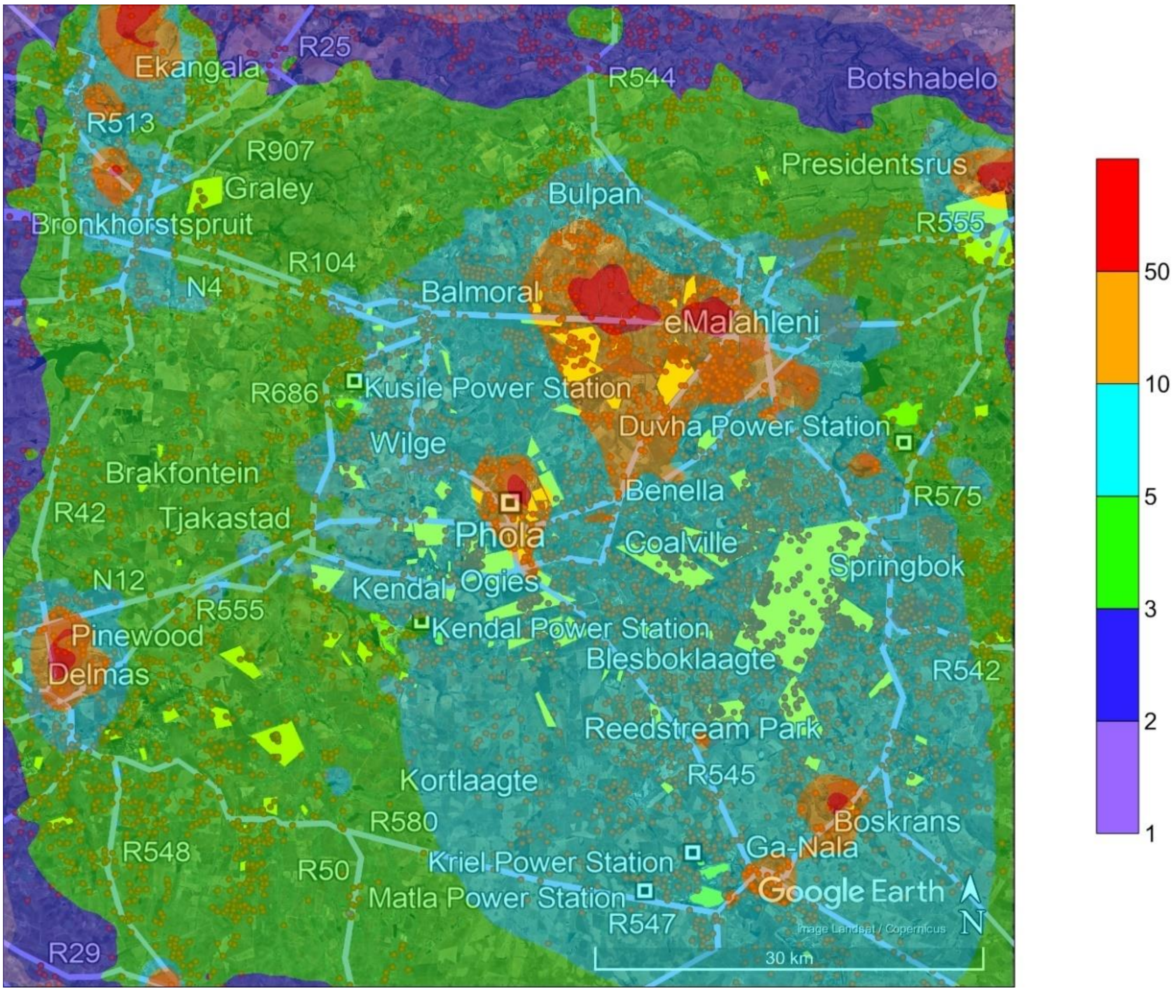


Figure 5-44: Model predicted annual SO_2 ambient concentrations in µg/m^3 for the All Sources emission source category within the Greater Phola Airshed

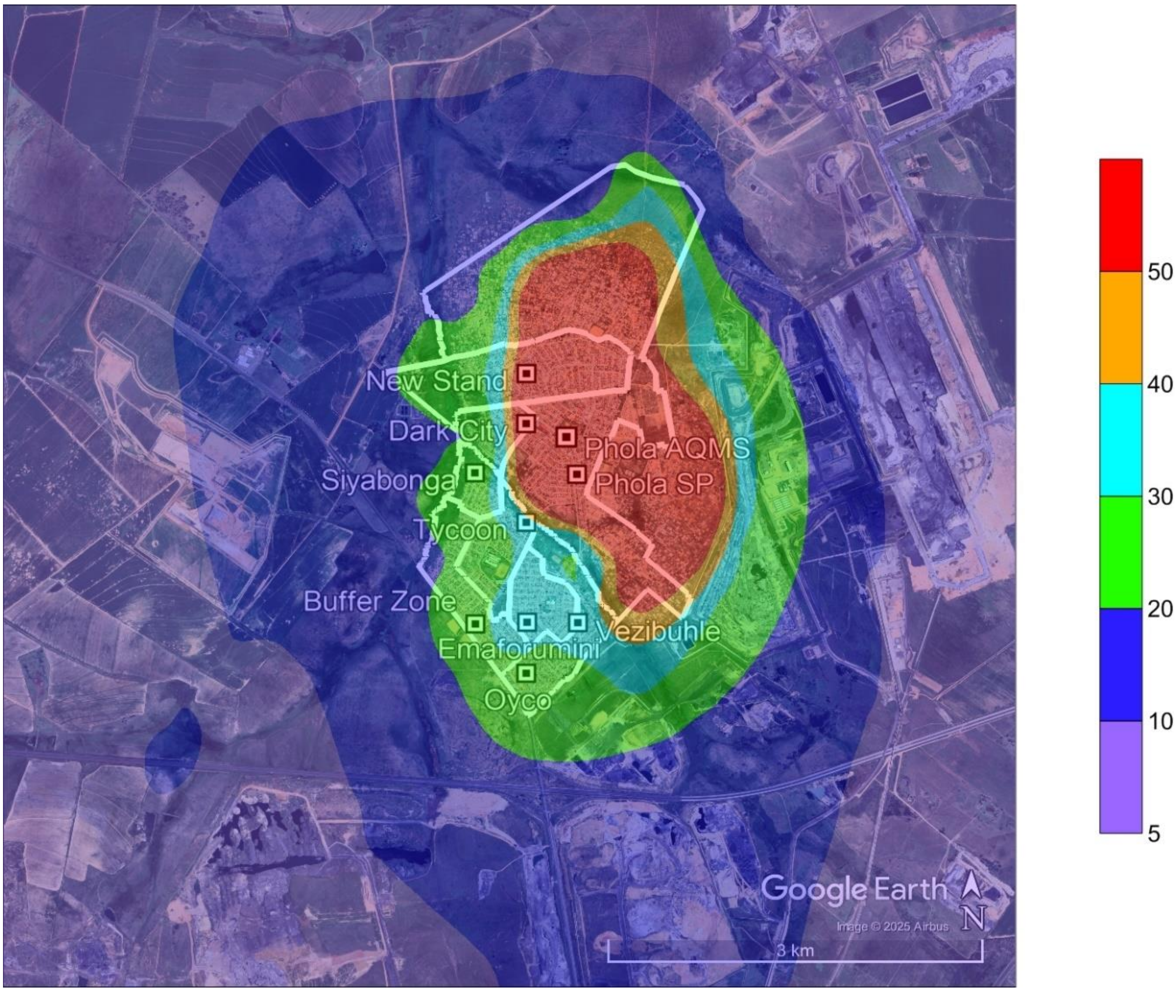


Figure 5-45: Model predicted annual SO_2 ambient concentrations in µg/m³ for the All Sources emission source category within the Phola Airshed

5.1.4 SO_2 SOURCE CONTRIBUTION ANALYSIS

In this study, the SO_2 source contribution analysis is based on model predicted annual SO_2 ambient concentrations at the discrete receptors for the six emission source categories which include power generation, residential fuel burning, waste burning, biomass burning, vehicles – paved roads and vehicles – unpaved roads (Table 5-3). Table 5-3 is used to calculate the percent contribution of SO_2 at each discrete receptor as a function of the six source categories, and is presented in Table 5-4.

Table 5-4: SO_2 source contribution (%) at discrete receptors for the six emission source categories based on model predicted annual SO_2 ambient concentrations

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	6.32	92.73	0.51	0.32	0.12	0.00	100.00
Dark City	5.84	93.25	0.51	0.26	0.14	0.00	100.00
Siyabonga	17.75	80.47	0.34	0.47	0.96	0.00	100.00
Phola SP	5.06	94.04	0.52	0.16	0.22	0.00	100.00
Tycoon	13.13	85.52	0.40	0.27	0.67	0.01	100.00
Buffer Zone	16.26	81.81	0.31	0.33	1.29	0.01	100.00
Emaforumini	14.81	83.82	0.33	0.28	0.74	0.01	100.00
Vezibuhle	12.40	86.58	0.40	0.23	0.37	0.01	100.00
Oyco	15.73	82.92	0.31	0.29	0.74	0.01	100.00
Eskom Phola AQMS	5.82	93.28	0.51	0.21	0.17	0.01	100.00

SO_2 ambient concentrations (in terms of µg/m^3) for each emission source category at each discrete receptor is presented in the form of a stacked bar graph in Figure 5-46. The total SO_2 ambient concentrations at each discrete receptor (which is made up of individual contributions representing each of the six emission source categories) represents the All Sources emission source category. The SO_2 source contribution in terms of percentages is presented in the form of a stacked bar graph in Figure 5-47. The sum of individual contributions resulting from each emission source category makes up 100%.

The source contribution analysis indicates that residential fuel burning and power generation are the main contributors to ambient SO_2 levels in the Phola Airshed. Ambient contributions from waste burning, biomass burning and vehicles on paved and unpaved roads are much smaller in comparison.

Residential fuel burning sources account for approximately 80.47-94.04% of the total SO_2 ambient concentrations at the Phola discrete receptors. This is expected as these sources are in close proximity to the receptors.

Power generation sources account for approximately 5.06-17.75% of the total SO_2 ambient concentrations at the Phola discrete receptors. This is expected as the Eskom Power Stations are located relatively far away from Phola.

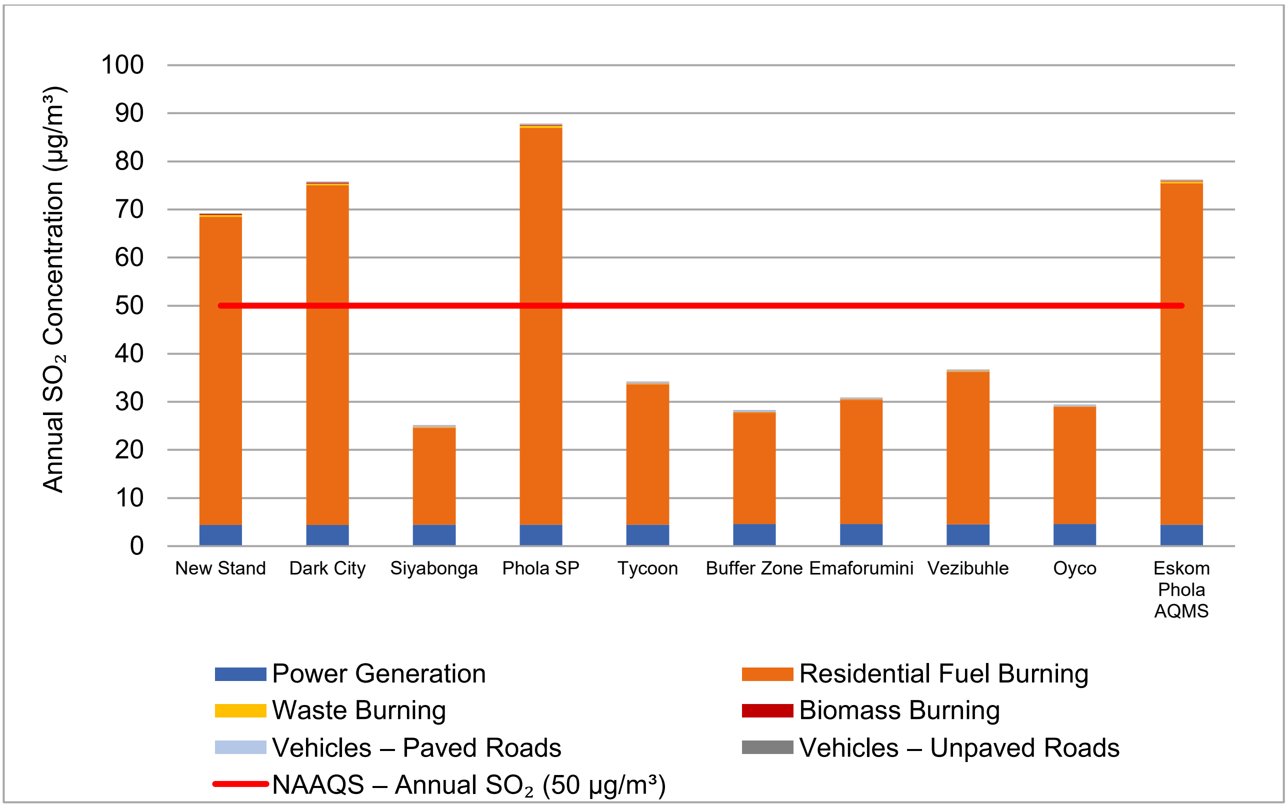


Figure 5-46: Stacked bar graph representing model predicted annual SO_2 ambient concentrations in µg/m^3 at discrete receptors for the six emission source categories

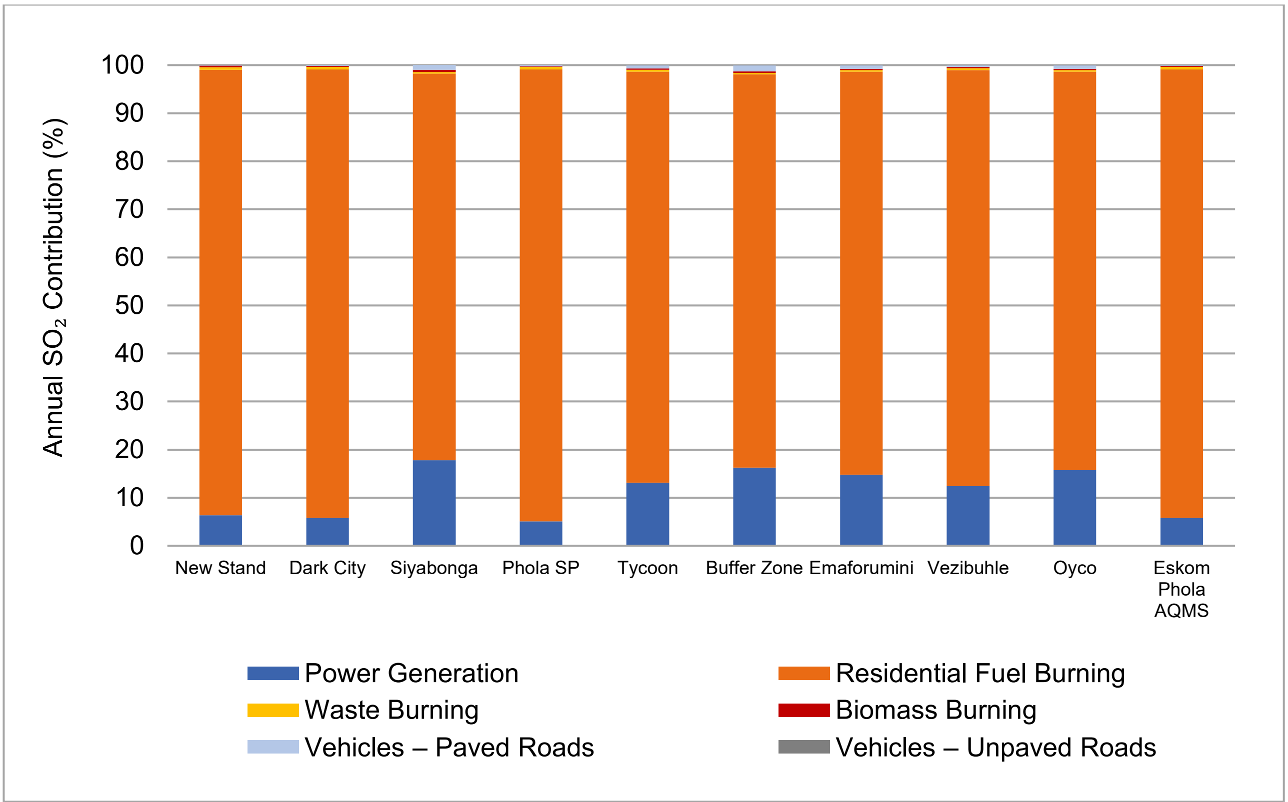


Figure 5-47: Stacked bar graph representing the percent contribution of SO_2 ambient concentrations at discrete receptors as a function of source category

5.2 PREDICTED NO_2 AMBIENT CONCENTRATIONS

5.2.1 1-HOUR NO_2

Model predicted 1-hour NO_2 ambient concentrations at discrete receptors and at the point of maximum for the seven emission source categories are presented in Table 5-5. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted 1-hour NO_2 ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-48 for the Power Generation emission source category
- Figure 5-50 for the Residential Fuel Burning emission source category
- Figure 5-52 for the Waste Burning emission source category
- Figure 5-54 for the Biomass Burning emission source category
- Figure 5-56 for the Vehicles – Paved Roads emission source category
- Figure 5-58 for the Vehicles – Unpaved Roads emission source category
- Figure 5-60 for the All Sources emission source category

Contour plots for model predicted 1-hour NO_2 ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-49 for the Power Generation emission source category
- Figure 5-51 for the Residential Fuel Burning emission source category
- Figure 5-53 for the Waste Burning emission source category
- Figure 5-55 for the Biomass Burning emission source category
- Figure 5-57 for the Vehicles – Paved Roads emission source category
- Figure 5-59 for the Vehicles – Unpaved Roads emission source category
- Figure 5-61 for the All Sources emission source category

Contour plots for model predicted 1-hour NO_2 ambient concentrations for the Phola Airshed is presented in Figure 5-62 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-5: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	31.99	213.01	9.89	0.19	32.58	1.30	227.11
Dark City	32.37	216.91	10.22	0.17	37.41	1.33	233.05
Siyabonga	32.79	78.10	3.29	0.09	58.73	1.31	116.81
Phola SP	32.39	265.47	12.69	0.12	48.15	3.02	294.55
Tycoon	33.12	100.42	4.05	0.07	55.46	2.89	135.78
Buffer Zone	34.08	108.53	3.60	0.07	100.04	3.87	157.98
Emaforumini	33.31	112.98	3.74	0.07	63.94	3.64	139.97
Vezibuhle	33.46	100.54	4.17	0.07	43.68	3.30	120.30
Oyco	33.51	106.50	3.18	0.06	68.77	2.54	130.05
Eskom Phola AQMS	32.32	223.08	10.44	0.13	42.79	4.85	243.67
Maximum	108.58	1512.10	61.14	1.66	2914.50	10.90	2922.00
	NAAQS – 1-hour NO_2 (200 µg/m³)						

According to Table 5-5, model predicted 1-hour NO_2 ambient concentrations exceed the 1-hour NO_2 NAAQS of 200 µg/m³ at three discrete receptors (New Stand, Dark City, Phola SP) and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories in the Phola Airshed.

Model predicted 1-hour NO_2 ambient concentrations also exceed the 1-hour NO_2 NAAQS of 200 µg/m³ at the point of maximum for the Residential Fuel Burning, Vehicles – Paved Roads and All Sources emission source categories in the Greater Phola Airshed.

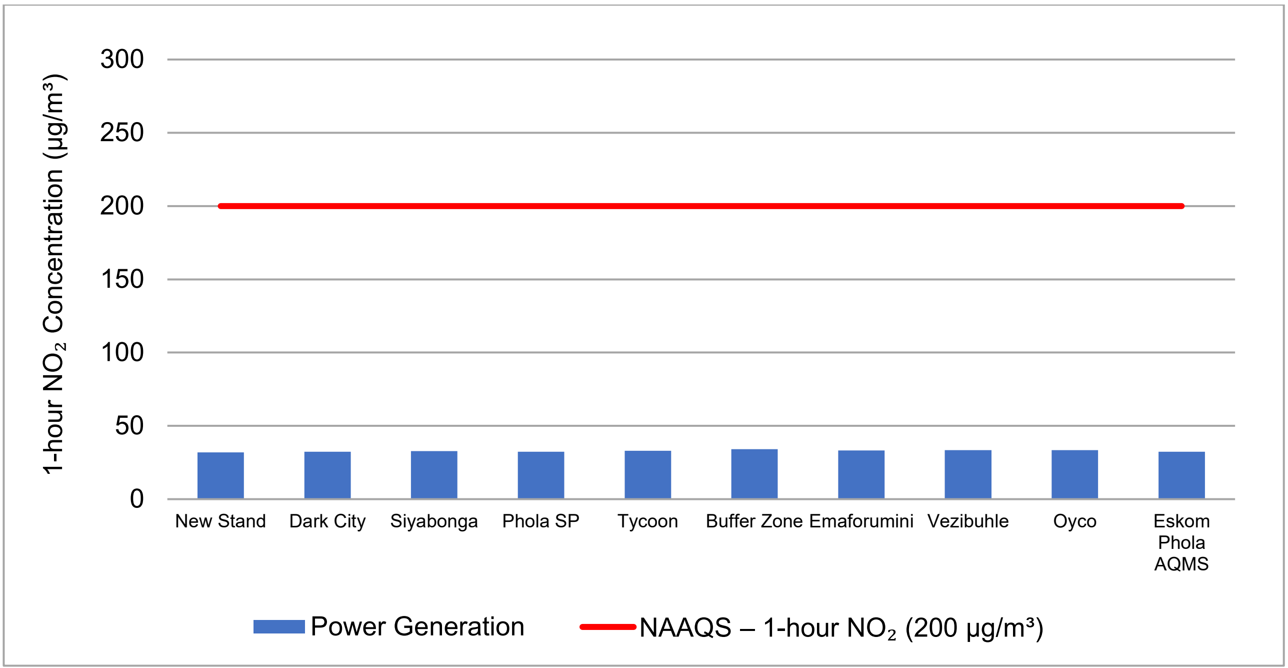


Figure 5-48: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Power Generation emission source category

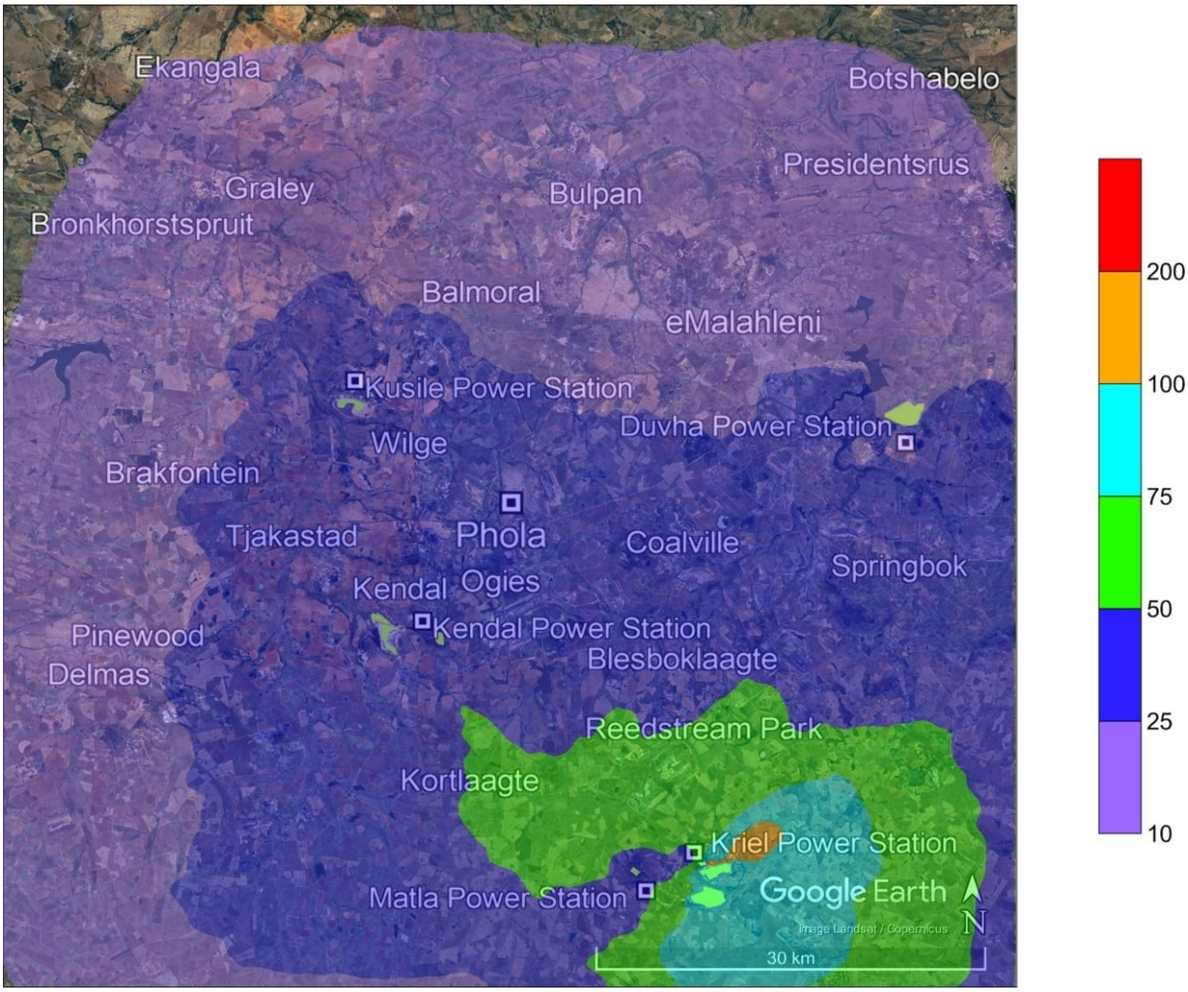


Figure 5-49: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

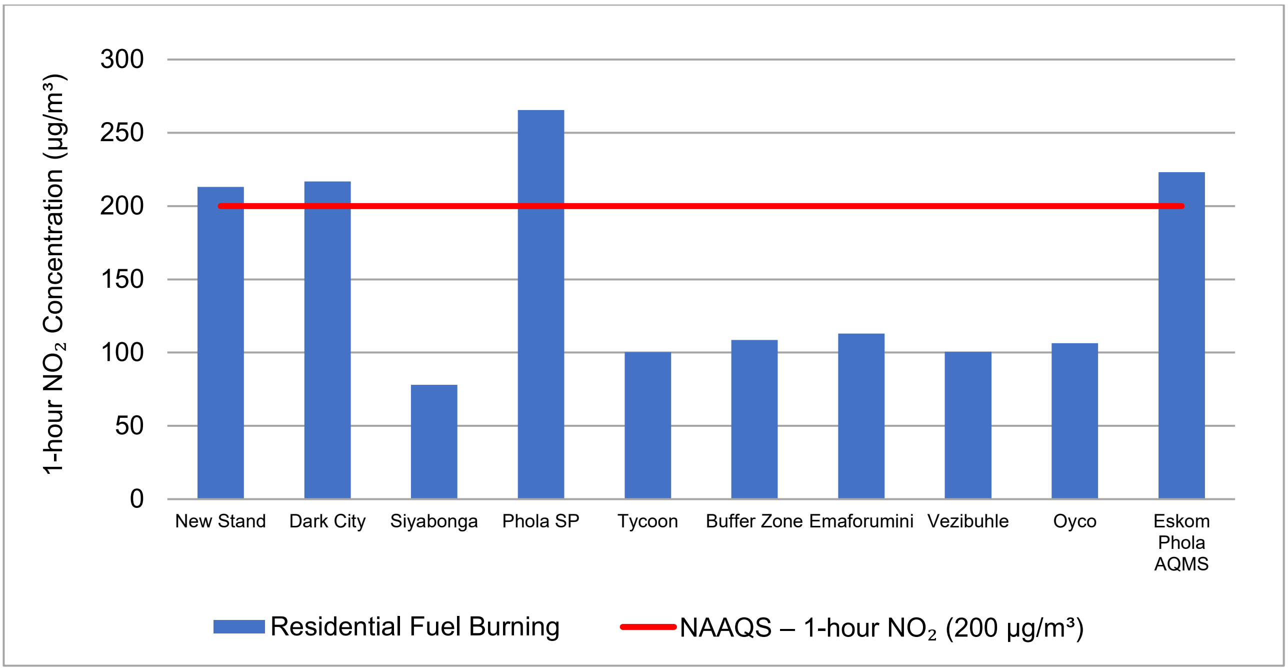


Figure 5-50: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

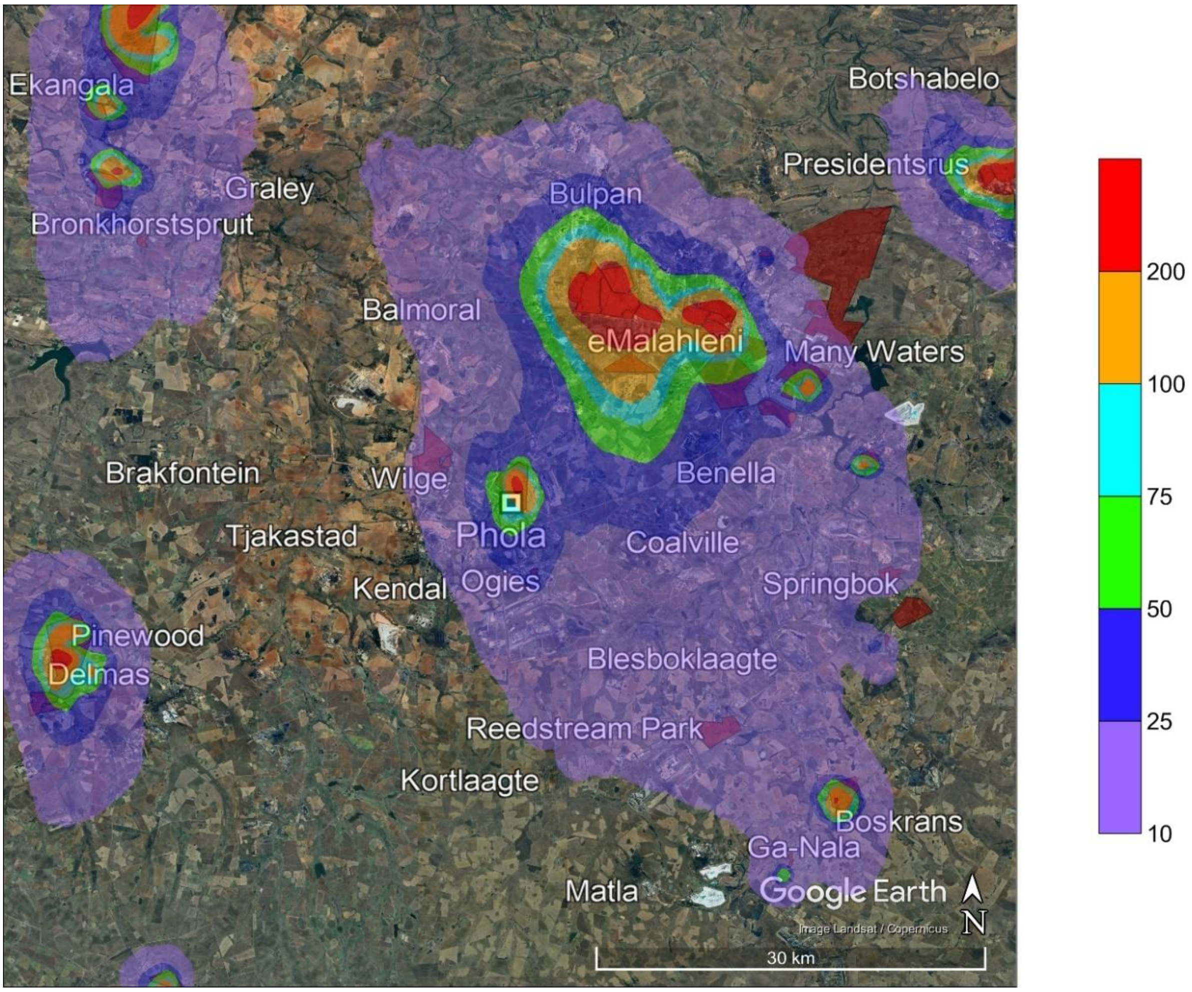


Figure 5-51: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

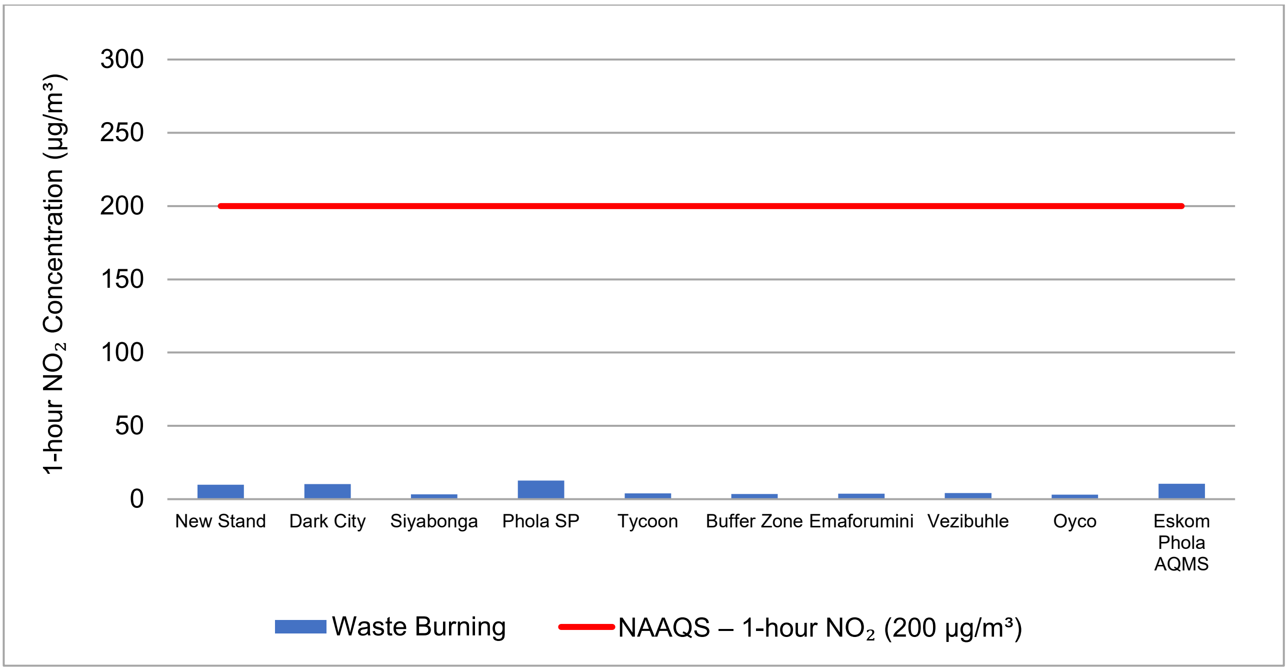


Figure 5-52: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Waste Burning emission source category

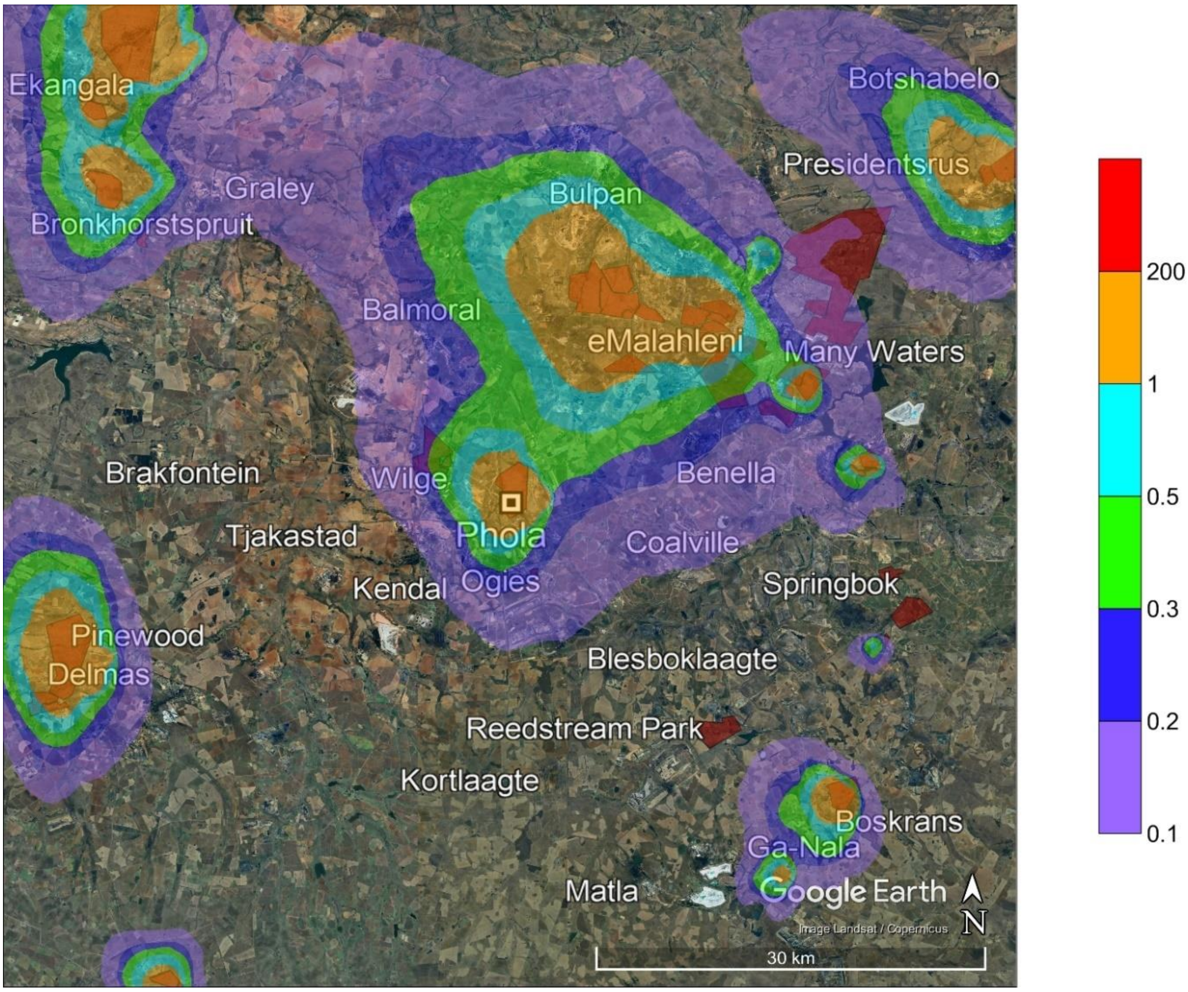


Figure 5-53: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m^3 for the Waste Burning emission source category within the Greater Phola Airshed

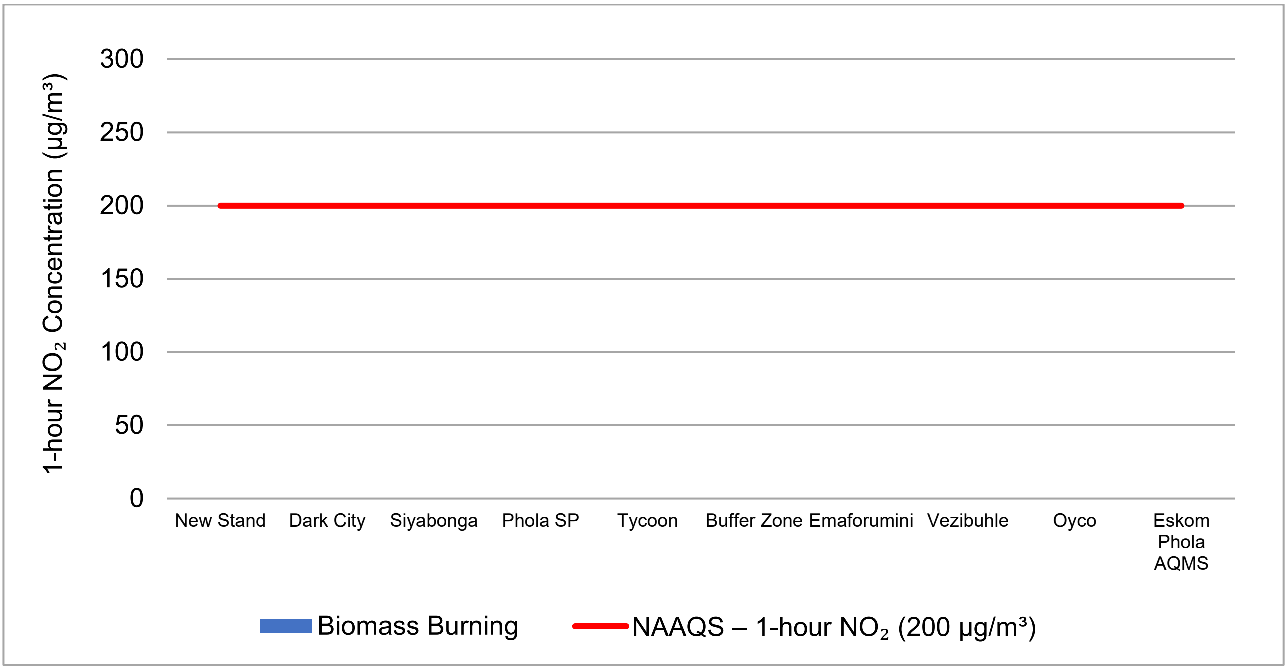


Figure 5-54: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Biomass Burning emission source category

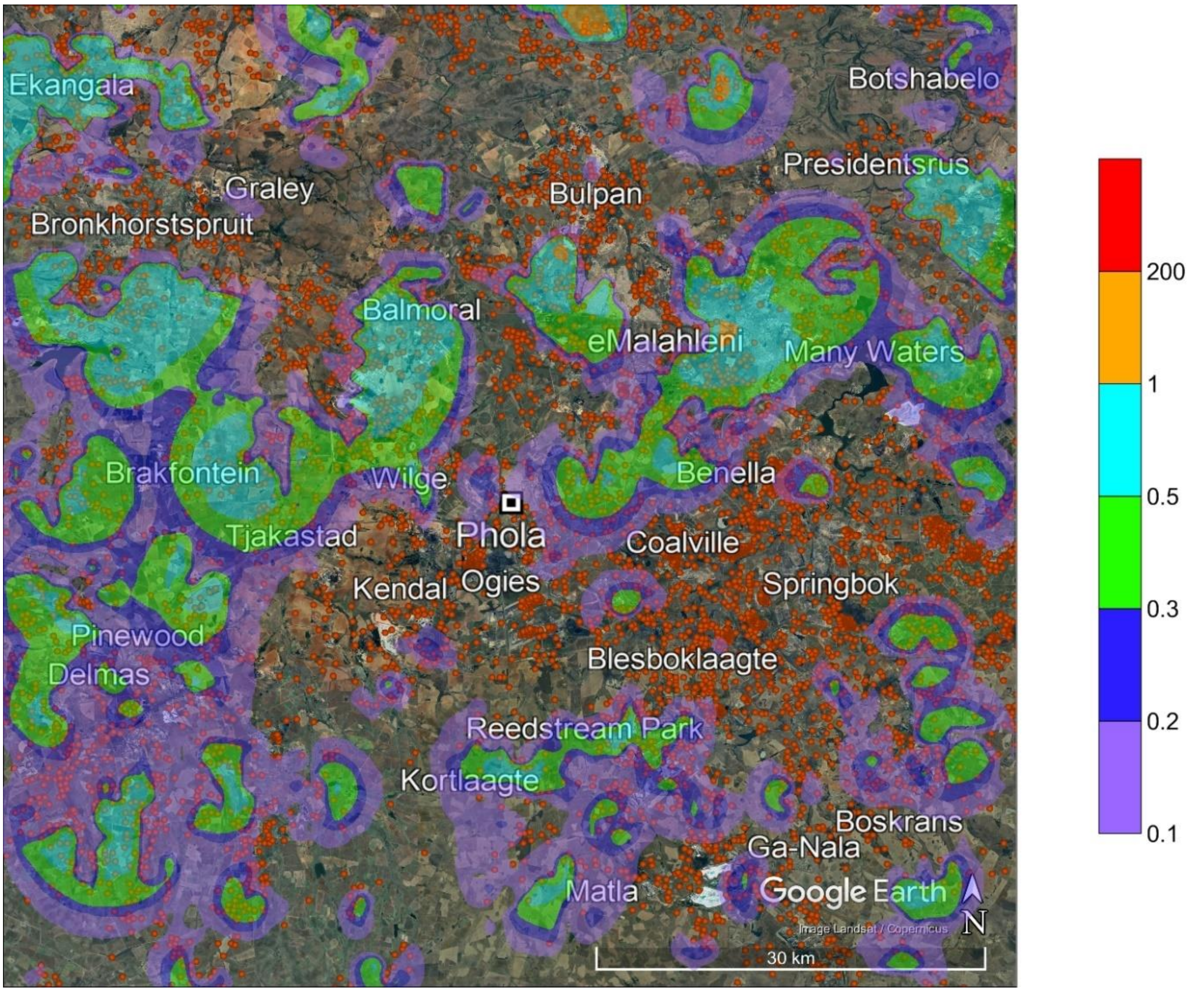


Figure 5-55: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

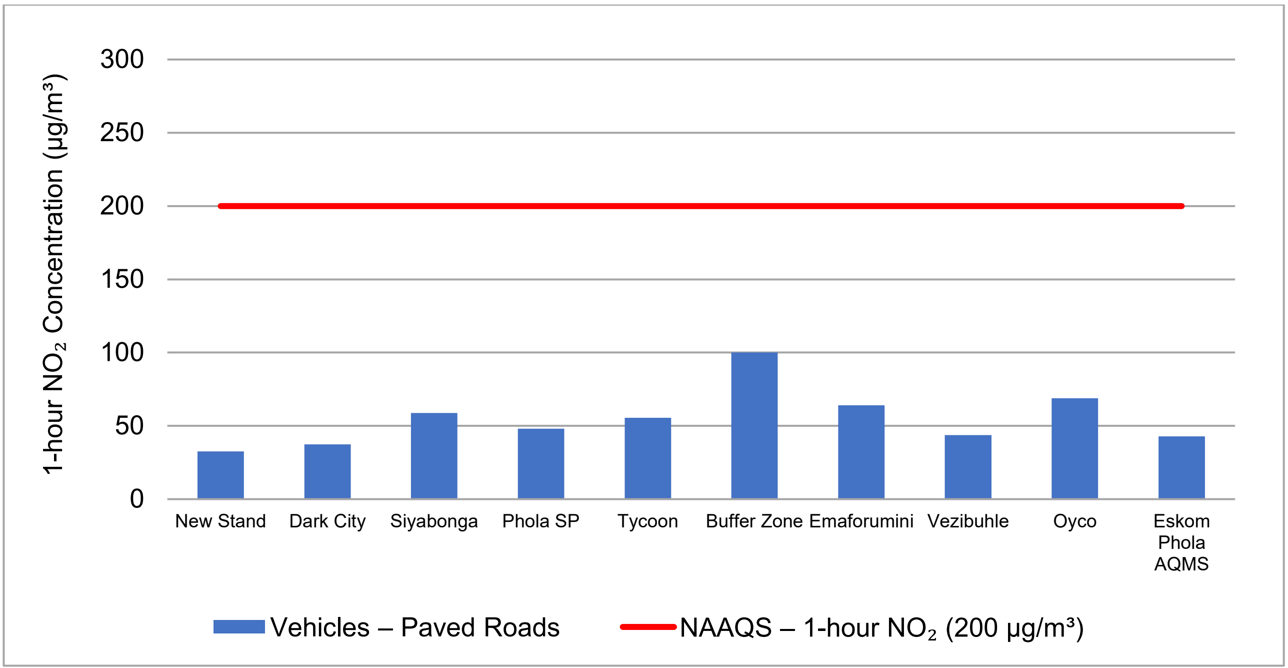


Figure 5-56: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Vehicles – Paved Roads emission source category

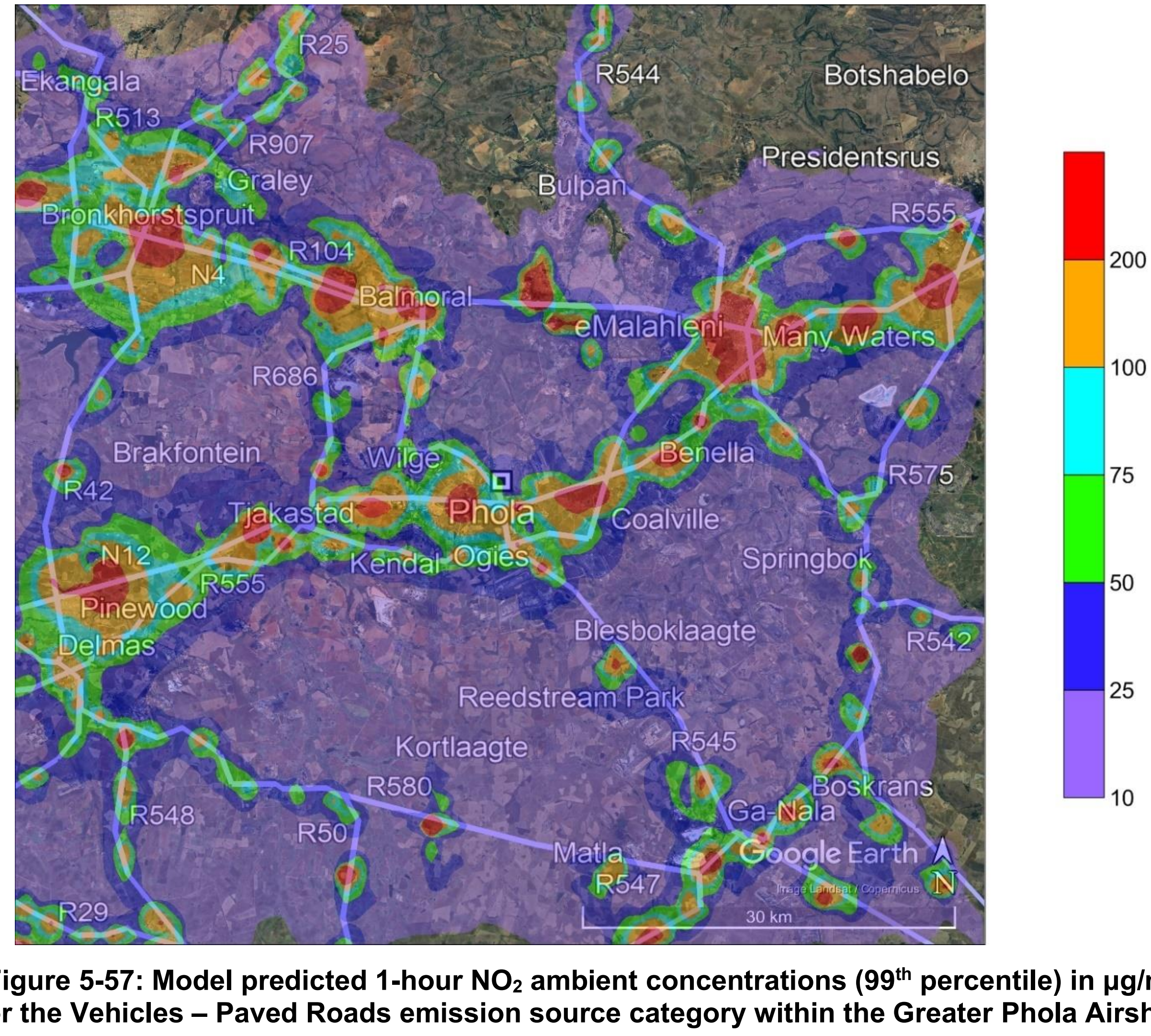


Figure 5-57: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

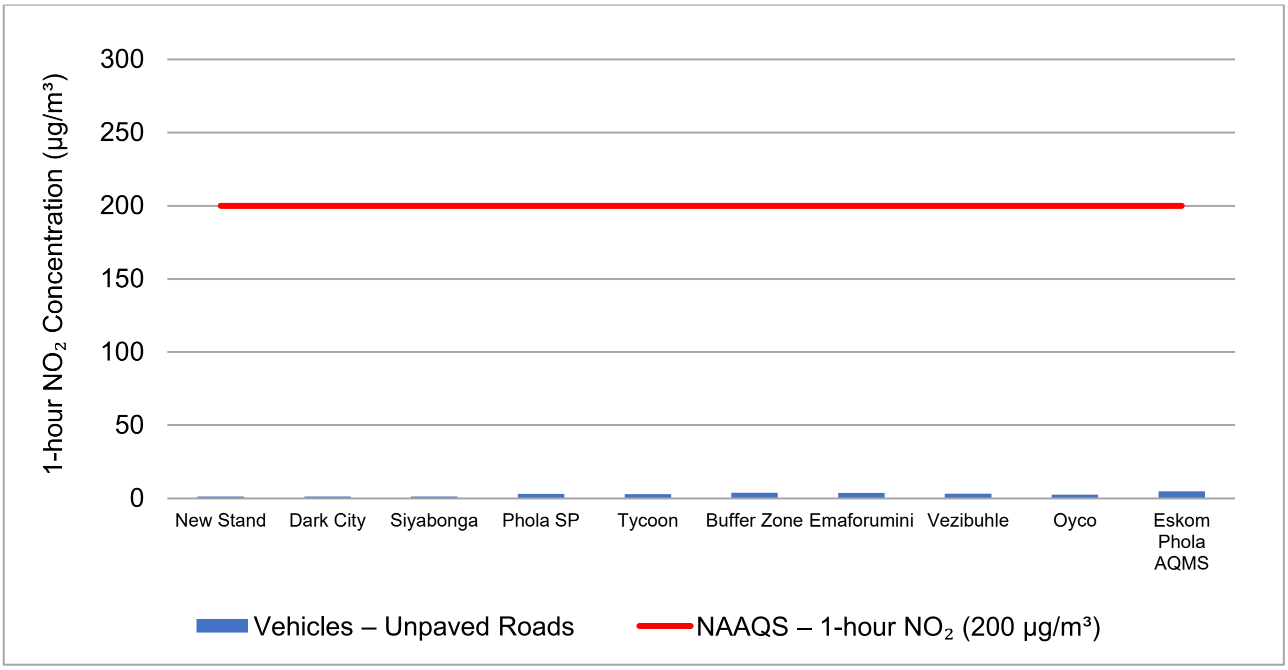


Figure 5-58: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

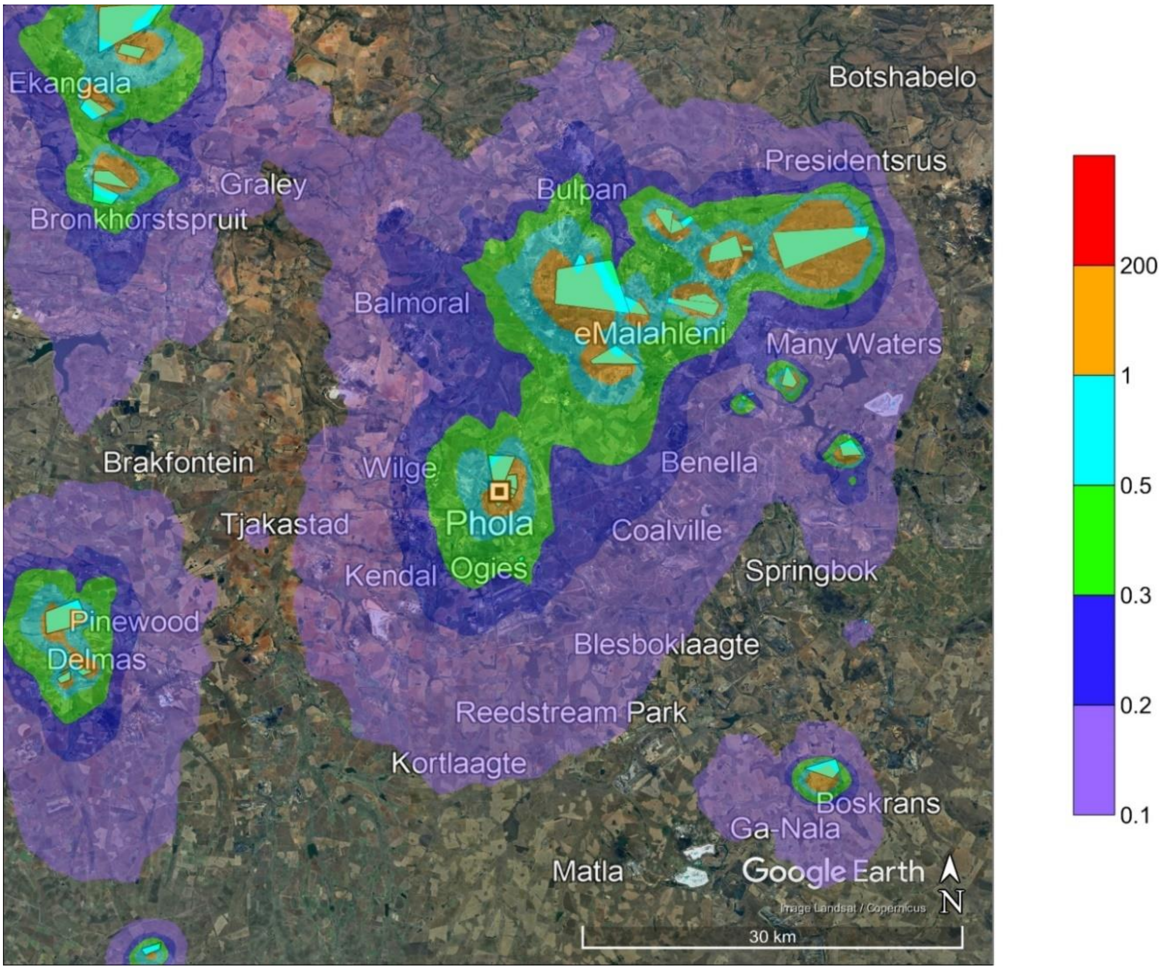


Figure 5-59: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

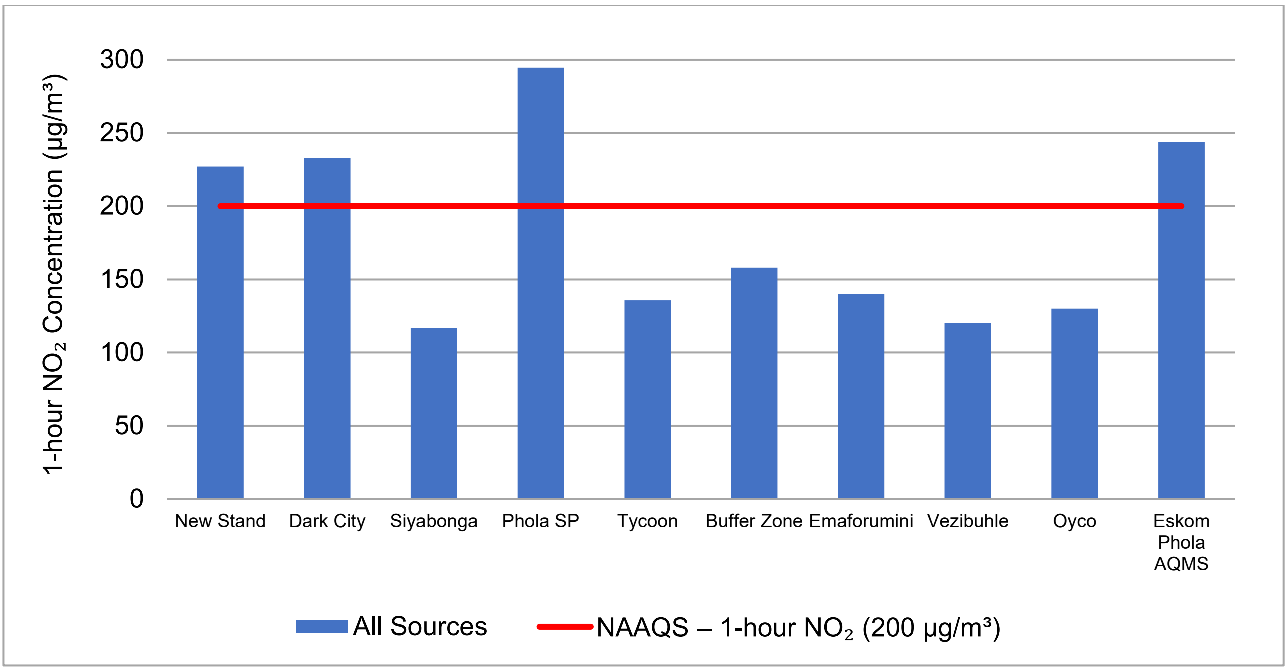


Figure 5-60: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the All Sources emission source category

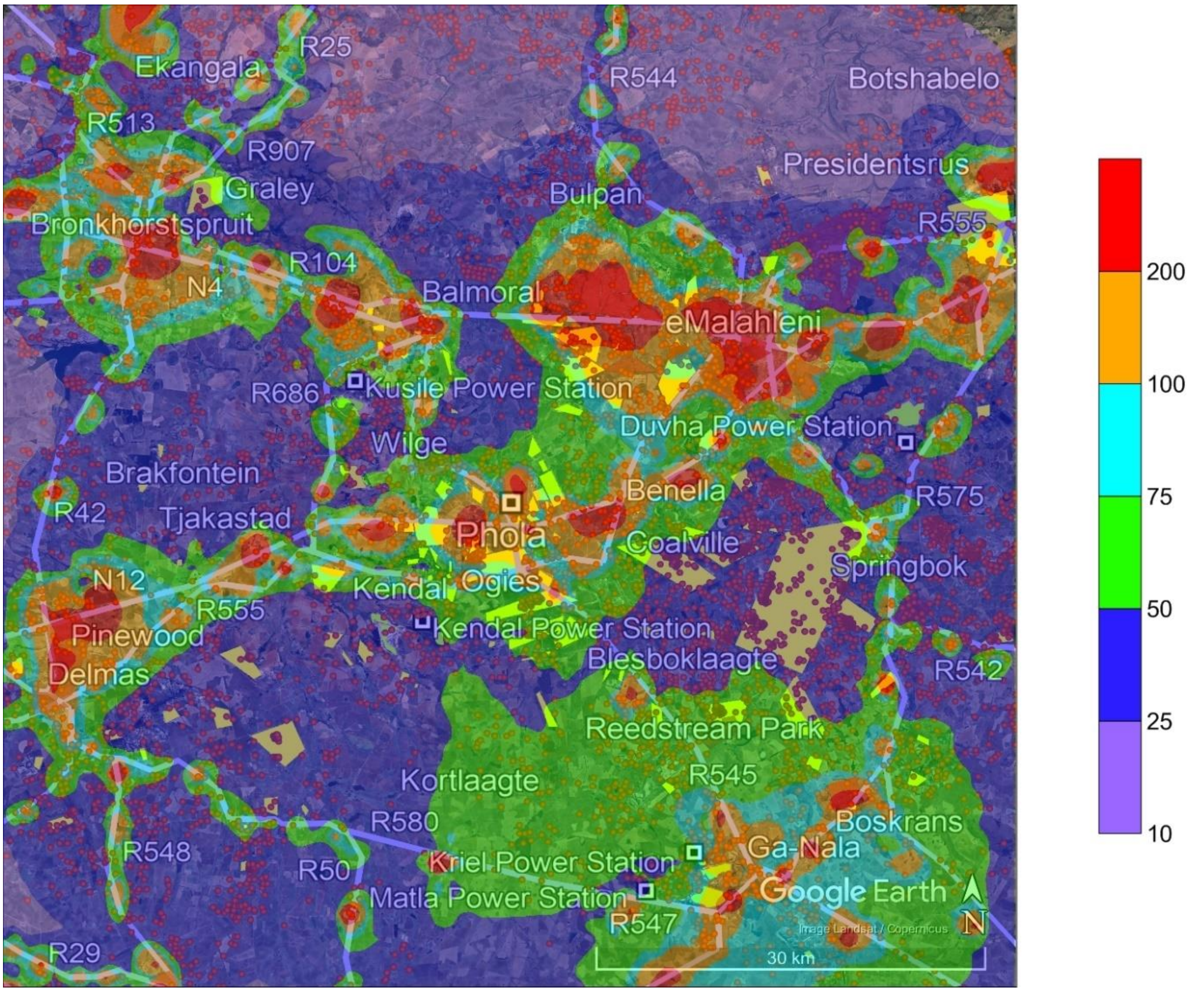


Figure 5-61: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

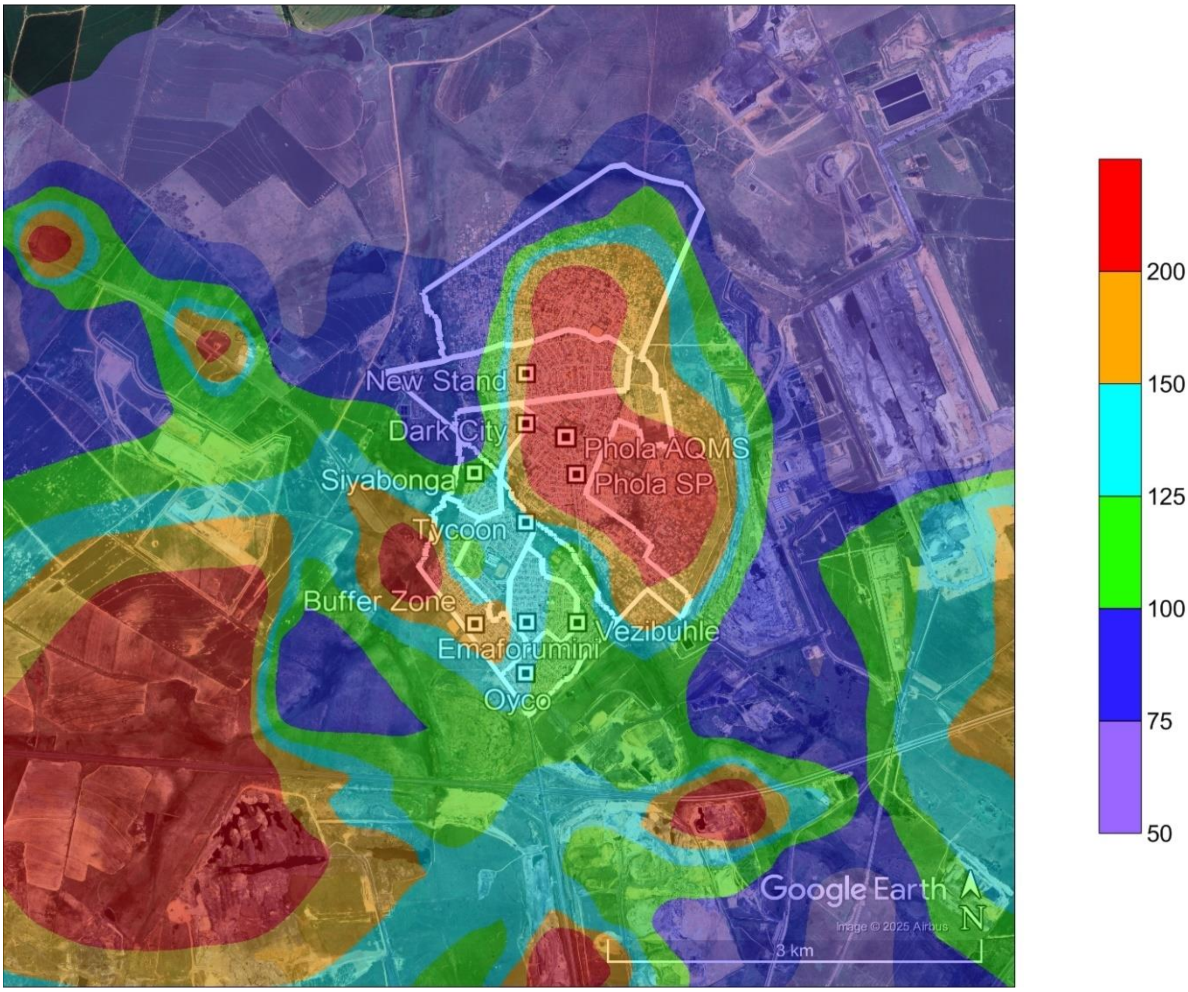


Figure 5-62: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Phola Airshed

5.2.2 ANNUAL NO_2

Model predicted annual NO_2 ambient concentrations at discrete receptors and at the point of maximum for the seven emission source categories are presented in Table 5-6. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted annual NO_2 ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-63 for the Power Generation emission source category
- Figure 5-65 for the Residential Fuel Burning emission source category
- Figure 5-67 for the Waste Burning emission source category
- Figure 5-69 for the Biomass Burning emission source category
- Figure 5-71 for the Vehicles – Paved Roads emission source category
- Figure 5-73 for the Vehicles – Unpaved Roads emission source category
- Figure 5-75 for the All Sources emission source category

Contour plots for model predicted annual NO_2 ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-64 for the Power Generation emission source category
- Figure 5-66 for the Residential Fuel Burning emission source category
- Figure 5-68 for the Waste Burning emission source category
- Figure 5-70 for the Biomass Burning emission source category
- Figure 5-72 for the Vehicles – Paved Roads emission source category
- Figure 5-74 for the Vehicles – Unpaved Roads emission source category
- Figure 5-76 for the All Sources emission source category

Contour plots for model predicted annual NO_2 ambient concentrations for the Phola Airshed is presented in Figure 5-77 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-6: Model predicted annual NO_2 ambient concentrations in µg/m^3 at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	1.71	23.19	1.39	0.04	4.18	0.30	30.81
Dark City	1.73	25.56	1.50	0.03	5.54	0.28	34.63
Siyabonga	1.73	7.23	0.33	0.02	12.40	0.26	21.97
Phola SP	1.73	29.85	1.76	0.02	9.88	0.67	43.92
Tycoon	1.74	10.49	0.53	0.01	11.65	0.75	25.17
Buffer Zone	1.77	8.29	0.34	0.01	18.76	0.84	30.01
Emaforumini	1.76	9.28	0.39	0.01	11.74	0.92	24.11
Vezibuhle	1.76	11.41	0.56	0.01	6.96	0.76	21.47
Oyco	1.77	8.72	0.35	0.01	11.12	0.59	22.56
Eskom Phola AQMS	1.73	25.69	1.50	0.03	6.82	0.96	36.73
Maximum	4.76	180.46	9.33	0.27	247.17	2.74	255.80
	NAAQS – Annual NO_2 (40 µg/m³)						

According to Table 5-6, model predicted annual NO_2 ambient concentrations exceed the annual NO_2 NAAQS of 40 µg/m³ at one discrete receptors (Phola SP) for the All Sources emission source category in the Phola Airshed.

Model predicted annual NO_2 ambient concentrations also exceed the annual NO_2 NAAQS of 40 µg/m³ at the point of maximum for the Residential Fuel Burning, Vehicles – Paved Roads and All Sources emission source categories in the Greater Phola Airshed.

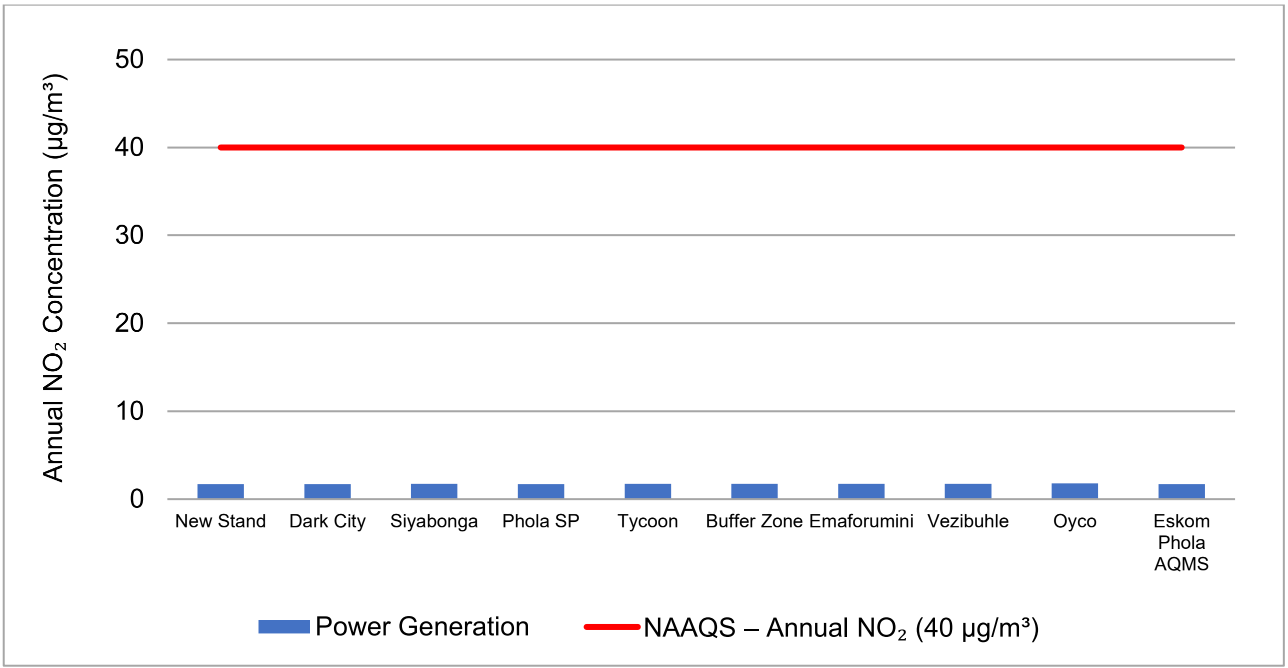


Figure 5-63: Model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the Power Generation emission source category

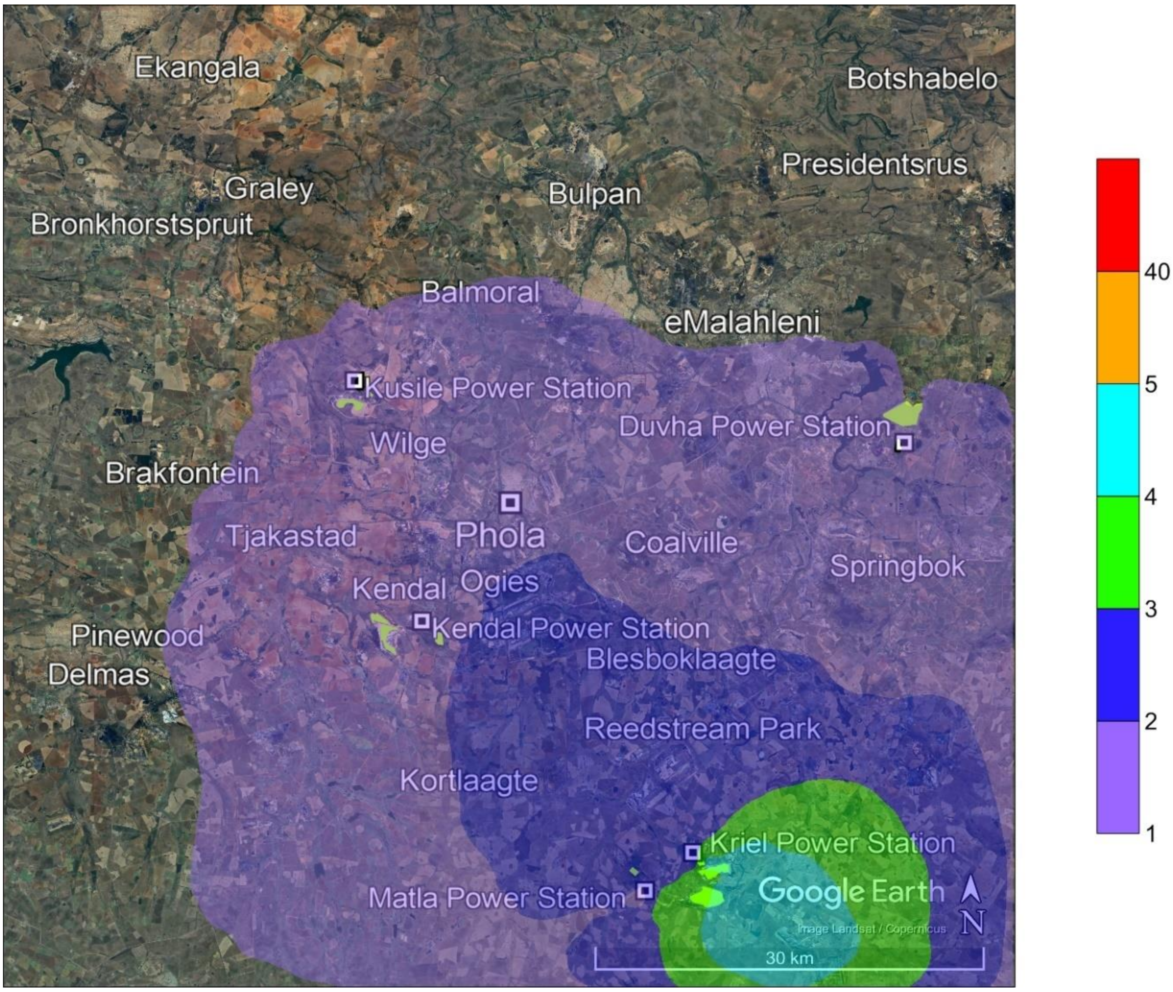


Figure 5-64: Model predicted annual NO_2 ambient concentrations in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

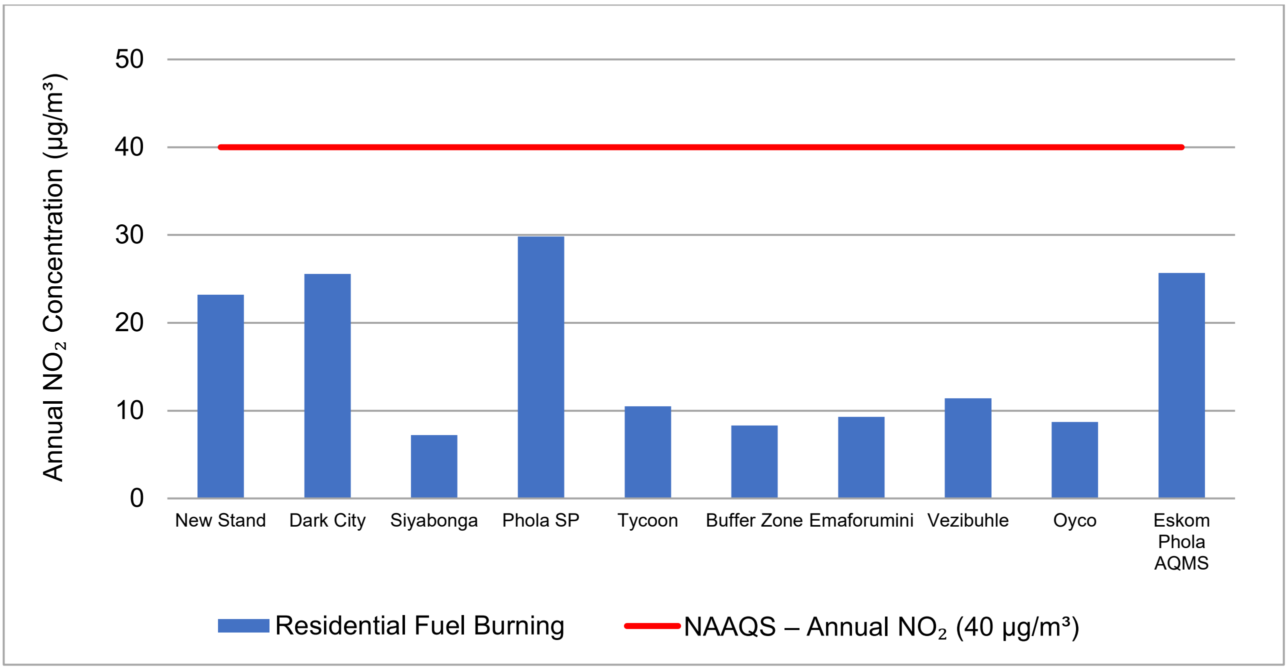


Figure 5-65: Model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

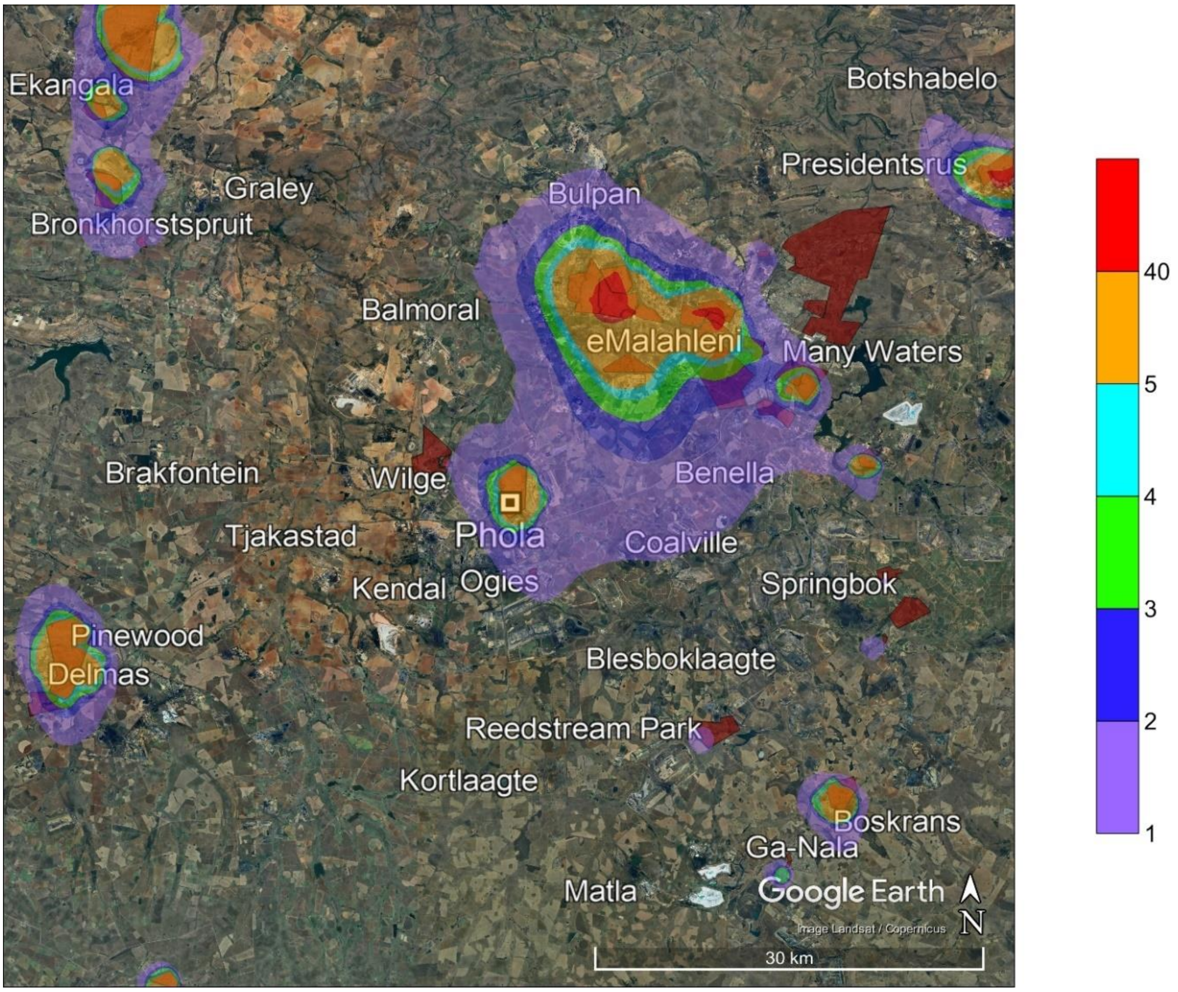


Figure 5-66: Model predicted annual NO_2 ambient concentrations in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

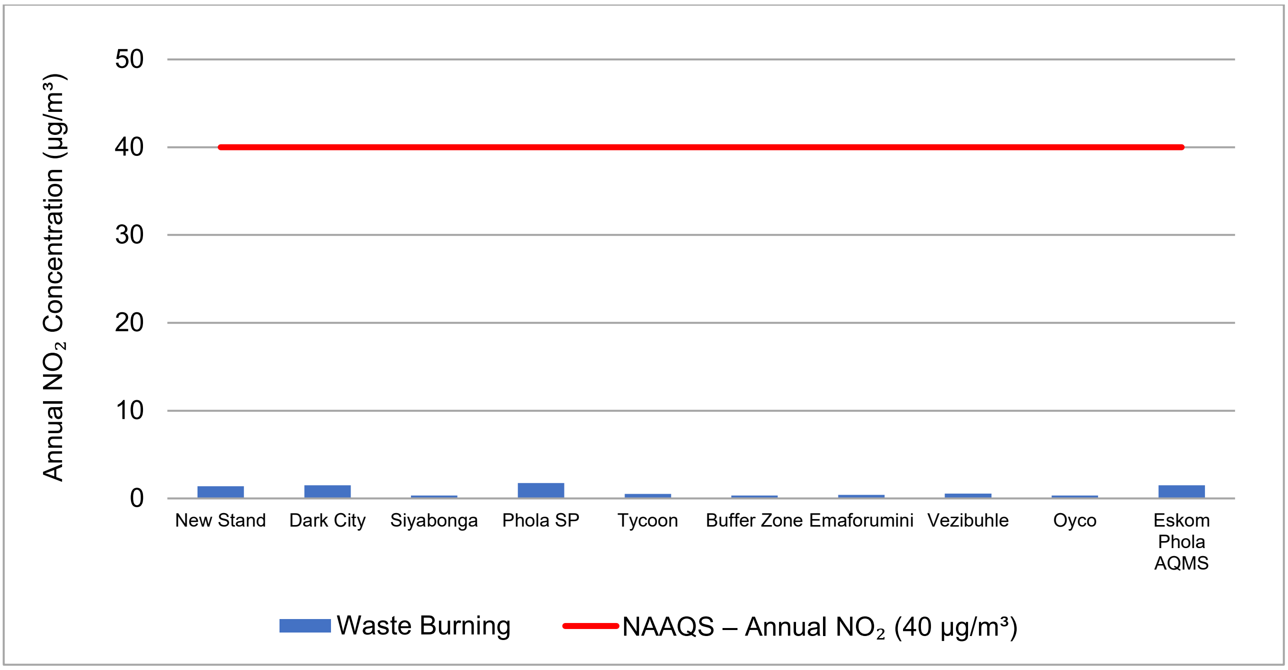


Figure 5-67: Model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the Waste Burning emission source category

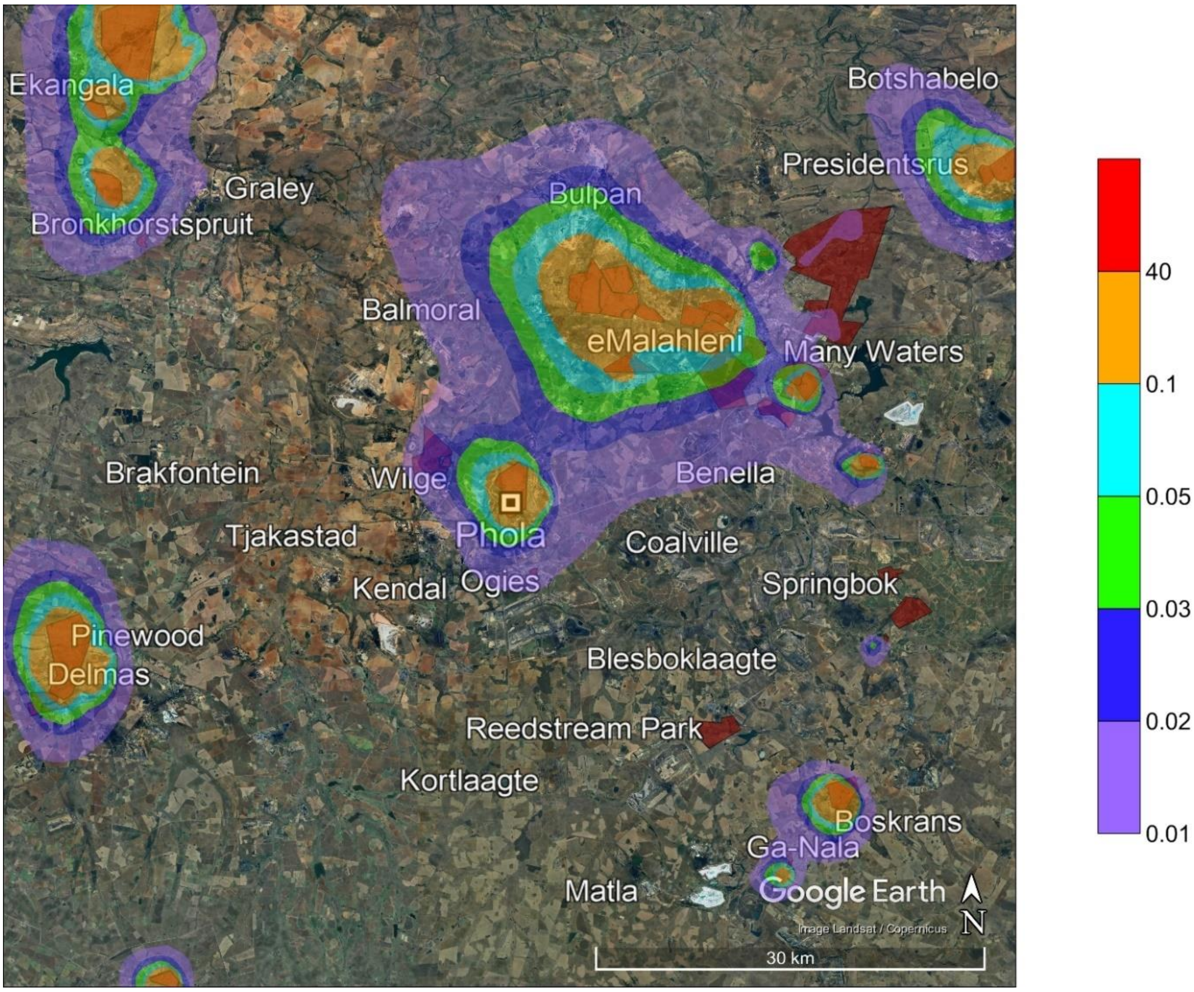


Figure 5-68: Model predicted annual NO_2 ambient concentrations in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

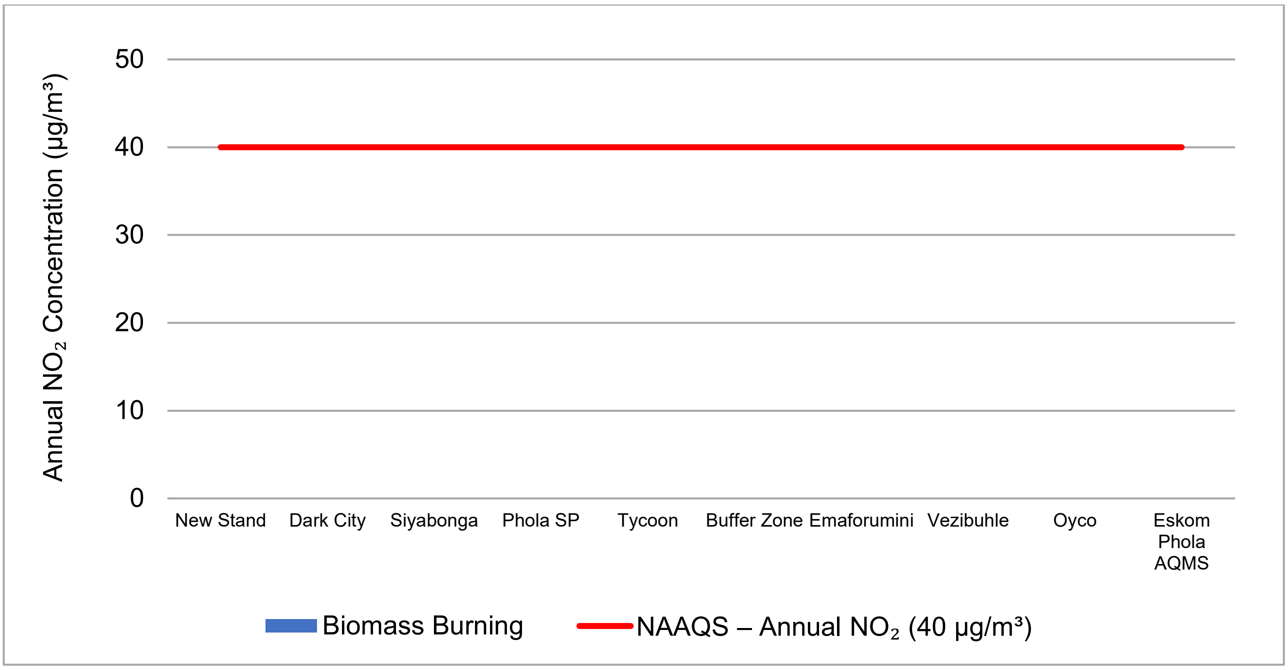


Figure 5-69: Model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the Biomass Burning emission source category

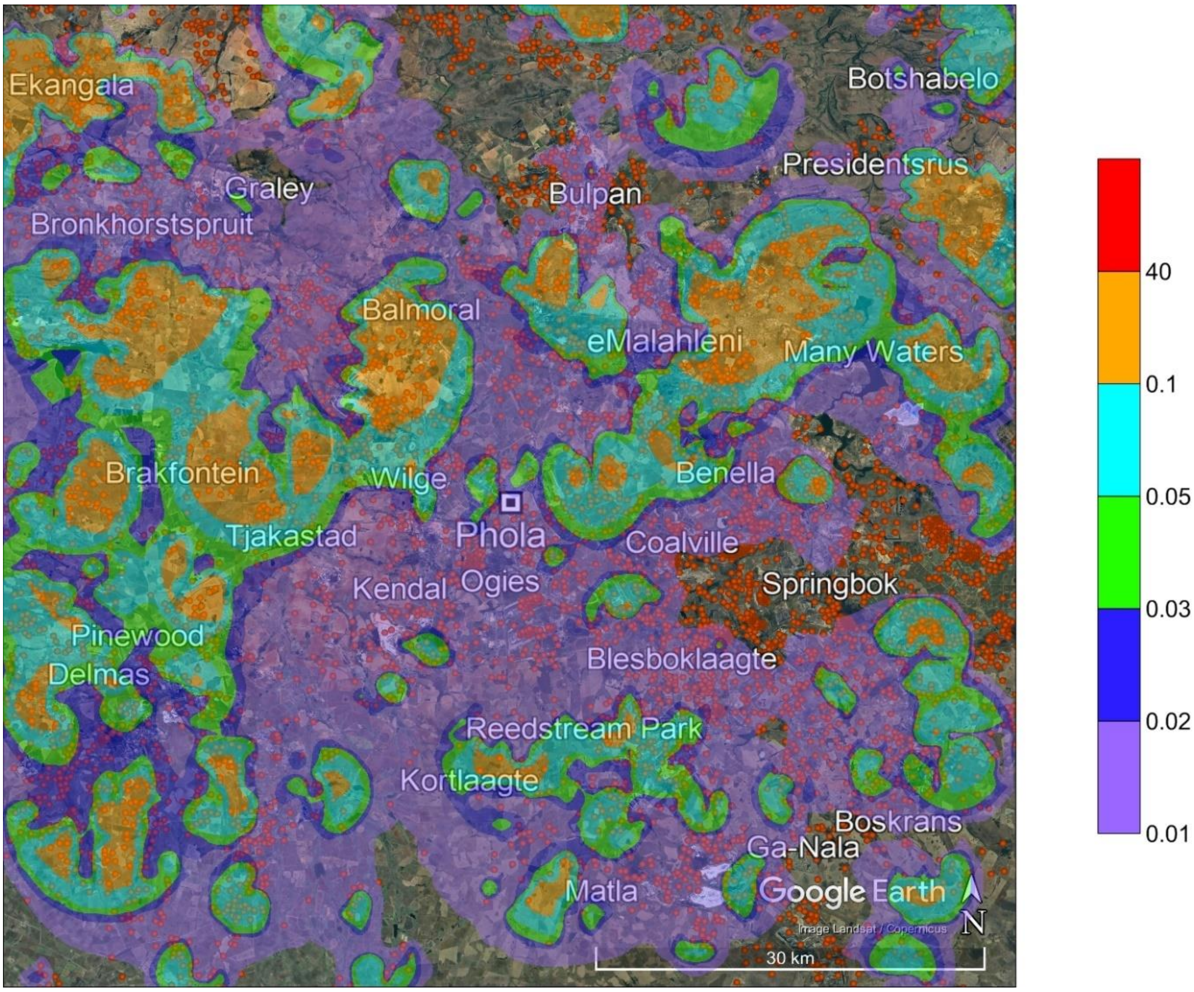


Figure 5-70: Model predicted annual NO_2 ambient concentrations in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

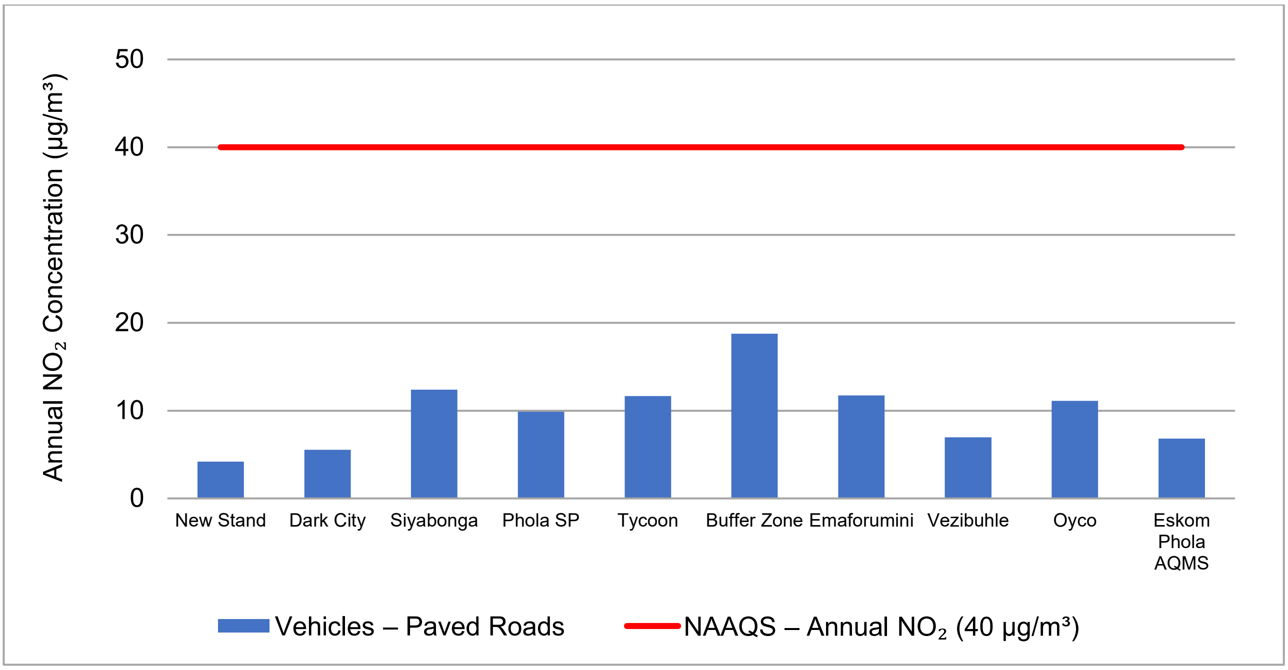


Figure 5-71: Model predicted annual NO_2 ambient concentrations in µg/m^3 at discrete receptors for the Vehicles – Paved Roads emission source category

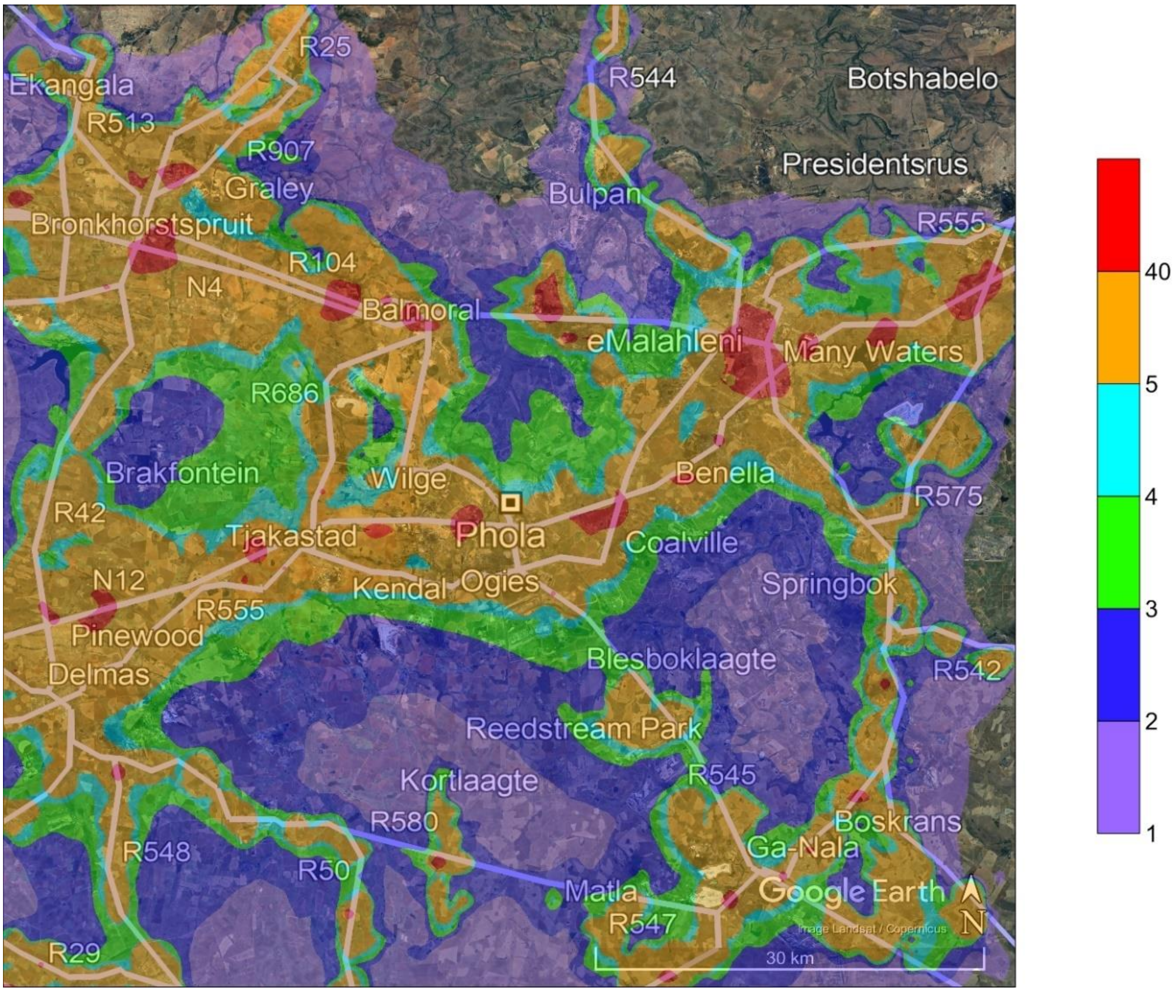


Figure 5-72: Model predicted annual NO_2 ambient concentrations in µg/m^3 for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

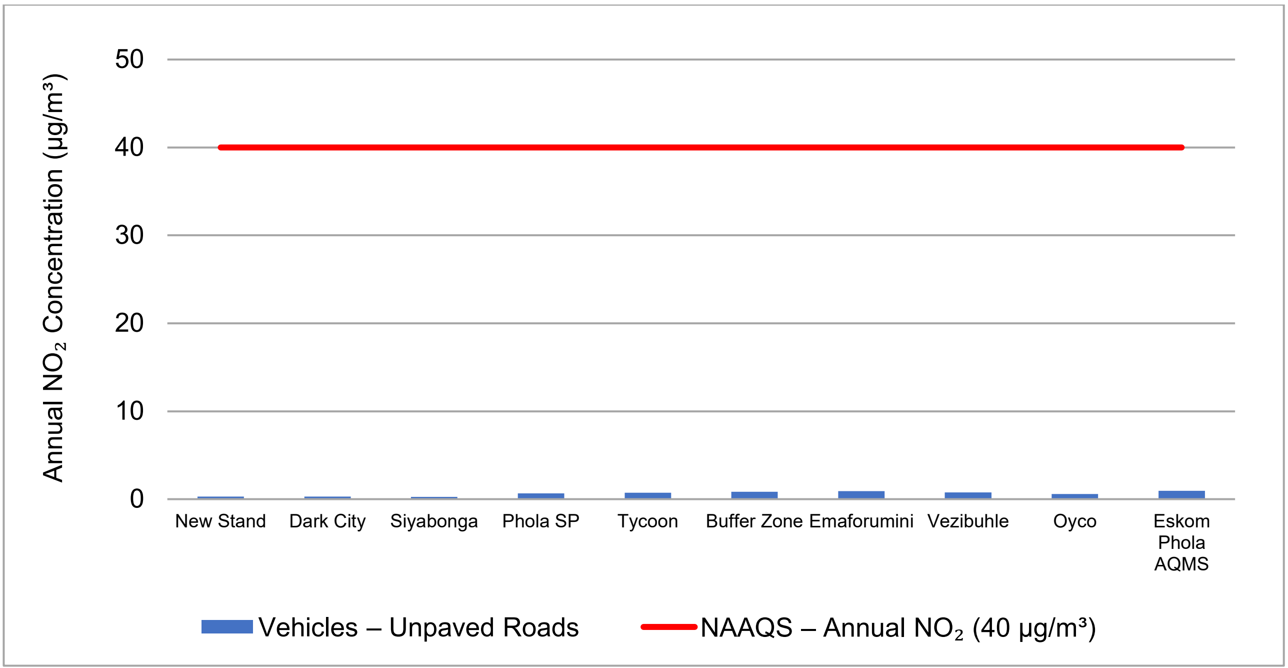


Figure 5-73: Model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

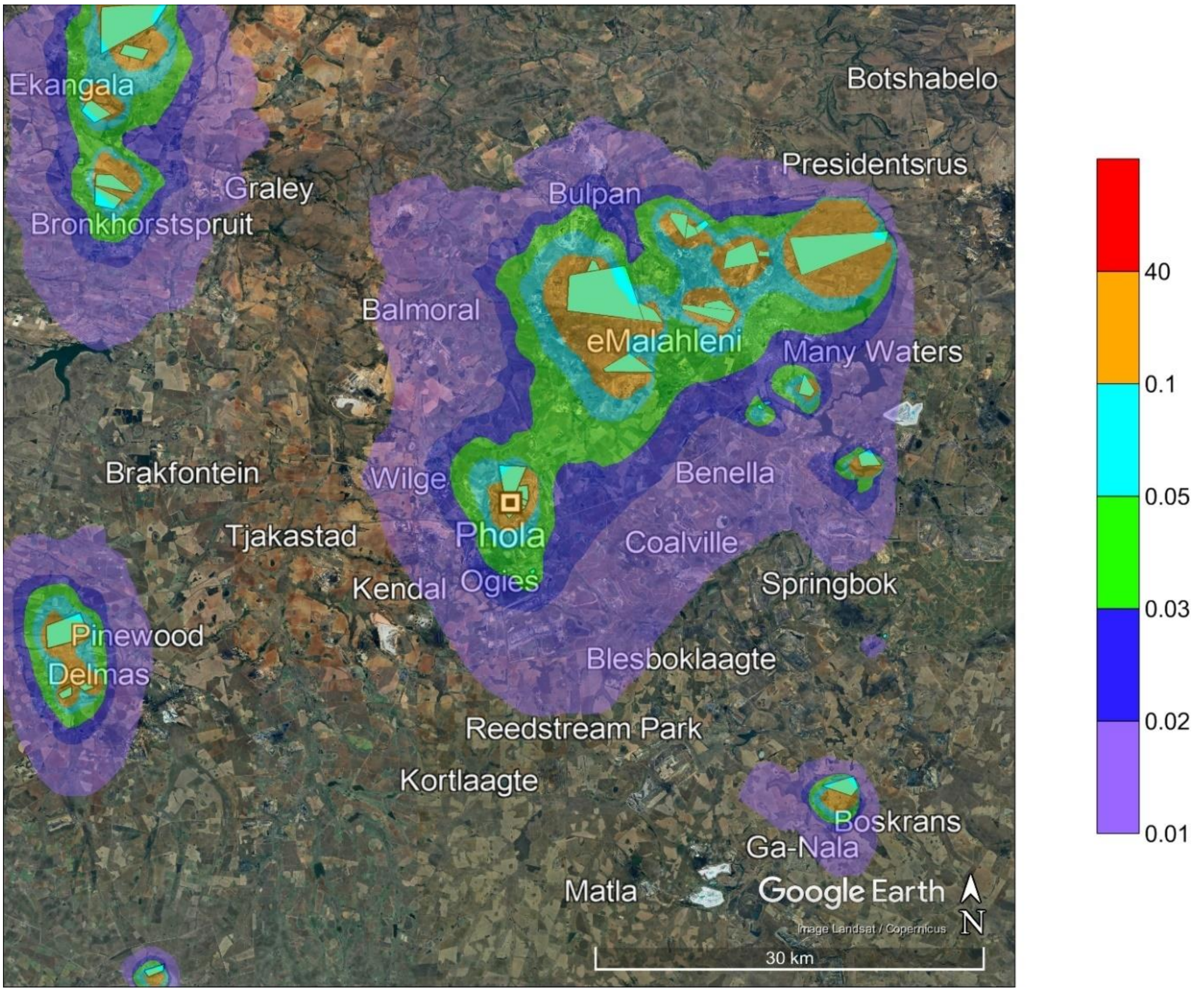


Figure 5-74: Model predicted annual NO_2 ambient concentrations in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

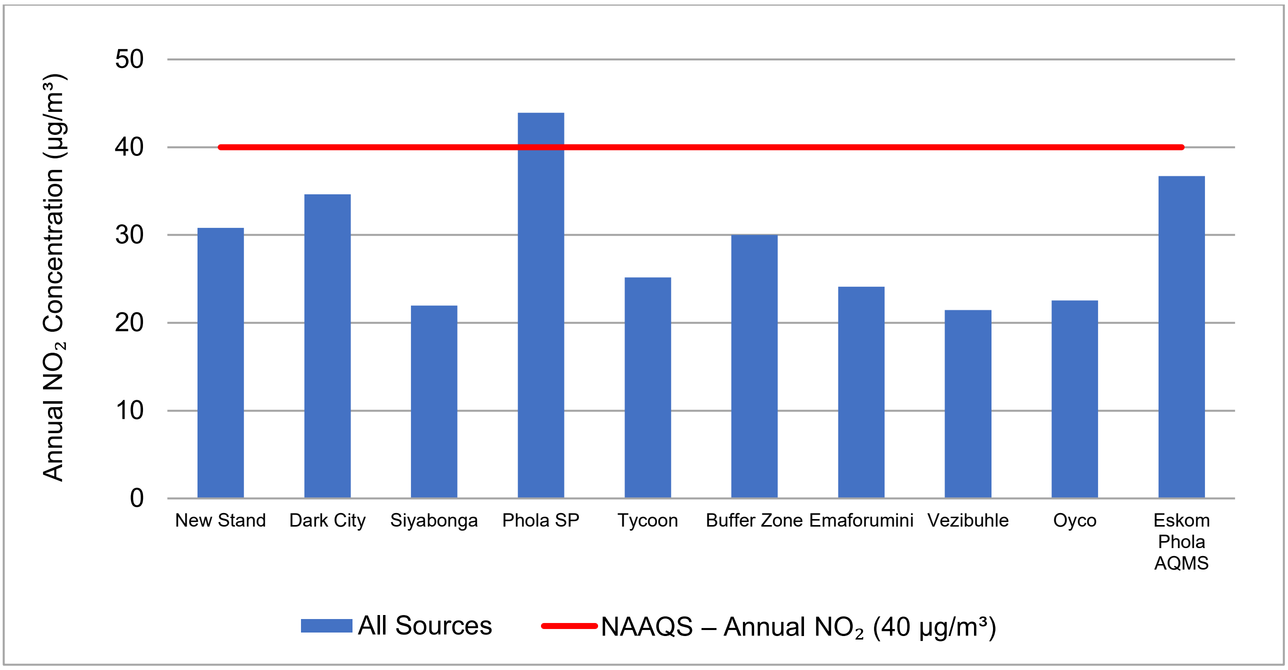


Figure 5-75: Model predicted annual NO_2 ambient concentrations in μg/m³ at discrete receptors for the All Sources emission source category

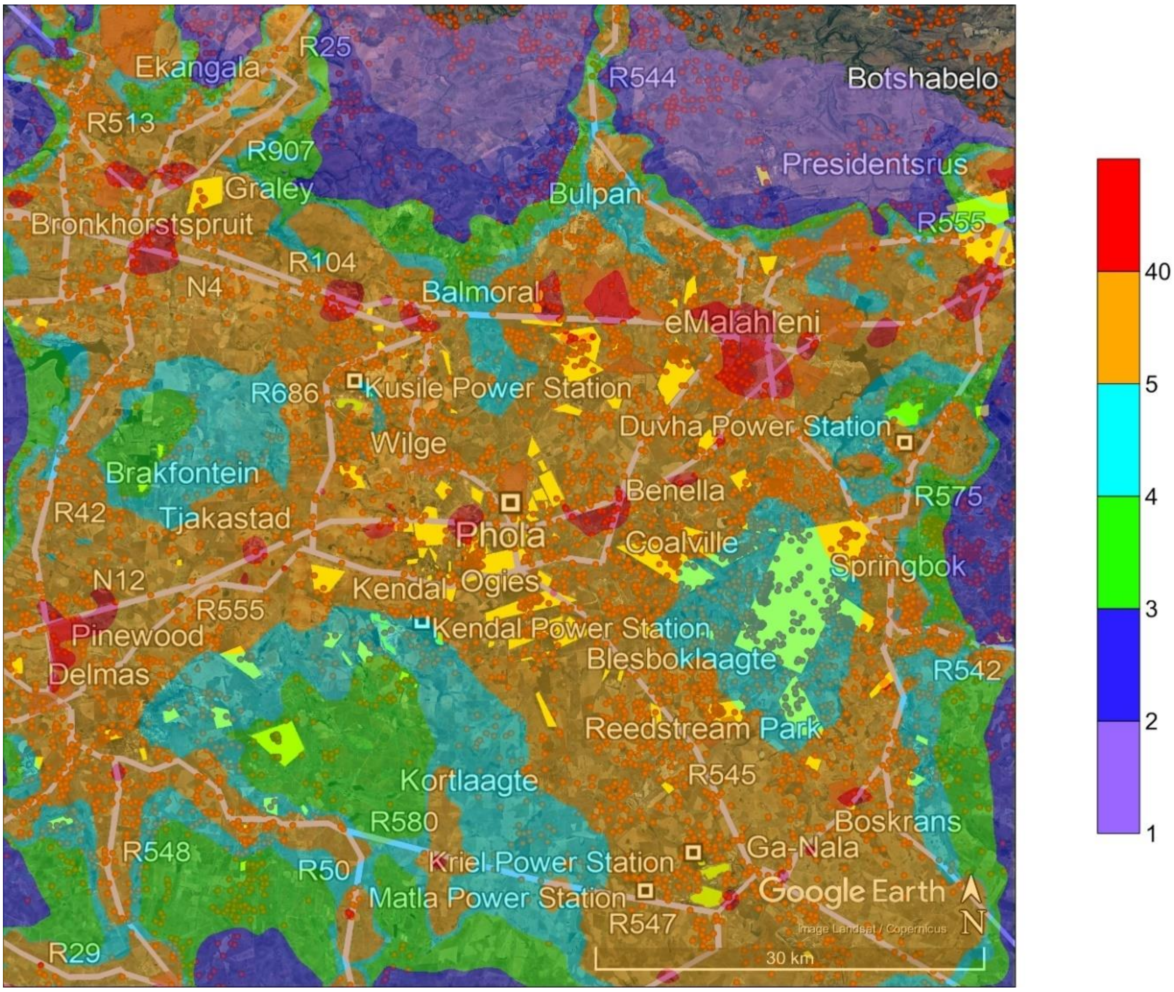


Figure 5-76: Model predicted annual NO_2 ambient concentrations in μg/m³ for the All Sources emission source category within the Greater Phola Airshed

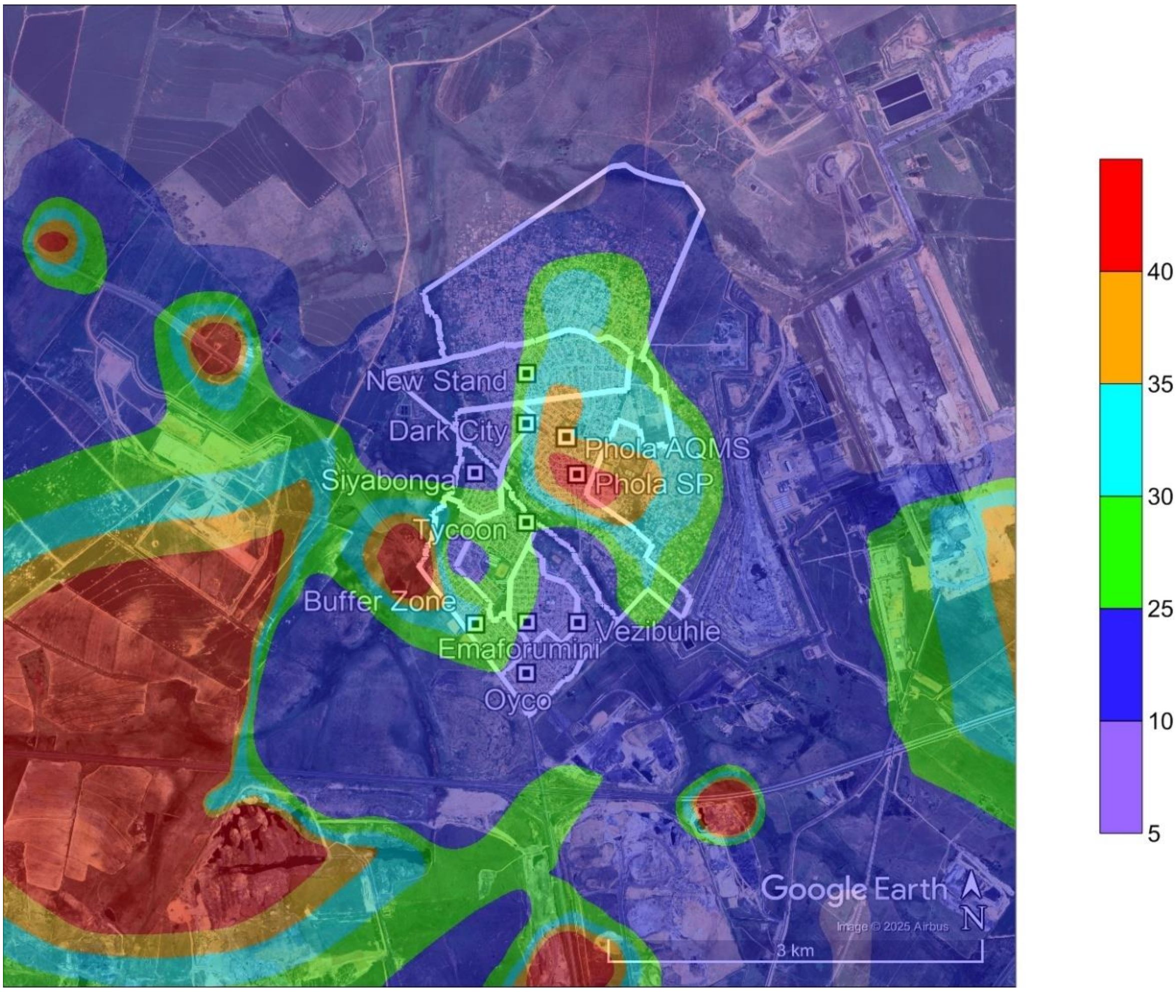


Figure 5-77: Model predicted annual NO_2 ambient concentrations in µg/m^3 for the All Sources emission source category within the Phola Airshed

5.2.3 NO_2 SOURCE CONTRIBUTION ANALYSIS

In this study, the NO_2 source contribution analysis is based on model predicted annual NO_2 ambient concentrations at the discrete receptors for the six emission source categories which include power generation, residential fuel burning, waste burning, biomass burning, vehicles – paved roads and vehicles – unpaved roads (Table 5-6). Table 5-6 is used to calculate the percent contribution of NO_2 at each discrete receptor as a function of the six source categories and is presented in Table 5-7.

Table 5-7: NO_2 source contribution (%) at discrete receptors for the six emission source categories based on model predicted annual NO_2 ambient concentrations

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	All Sources
New Stand	5.56	75.27	4.50	0.12	13.58	0.97	100.00
Dark City	4.98	73.81	4.32	0.09	16.00	0.80	100.00
Siyabonga	7.89	32.90	1.50	0.09	56.44	1.18	100.00
Phola SP	3.94	67.96	4.01	0.05	22.50	1.54	100.00
Tycoon	6.91	41.66	2.10	0.06	46.29	2.97	100.00
Buffer Zone	5.89	27.63	1.12	0.05	62.51	2.80	100.00
Emaforumini	7.32	38.51	1.60	0.06	48.70	3.82	100.00
Vezibuhle	8.19	53.15	2.63	0.06	32.43	3.54	100.00
Oyco	7.86	38.65	1.54	0.06	49.28	2.61	100.00
Eskom Phola AQMS	4.71	69.94	4.08	0.07	18.58	2.63	100.00

NO_2 ambient concentrations (in terms of $\mu g/m^3$) for each emission source category at each discrete receptor is presented in the form of a stacked bar graph in Figure 5-78. The total NO_2 ambient concentrations at each discrete receptor (which is made up of individual contributions representing each of the six emission source categories) represents the All Sources emission source category. The NO_2 source contribution in terms of percentages is presented in the form of a stacked bar graph in Figure 5-79. The sum of individual contributions resulting from each emission source category makes up 100%.

The source contribution analysis indicates that residential fuel burning and vehicles on paved roads are the main contributors to ambient NO_2 levels in the Phola Airshed. Ambient contributions from power generation, waste burning, biomass burning and vehicles on unpaved roads are much smaller in comparison.

Residential fuel burning sources account for approximately 27.63-75.27% of the total NO_2 ambient concentrations at the Phola discrete receptors. This is expected as these sources are in close proximity to the receptors.

Vehicle on paved roads account for approximately 13.58-62.51% of the total NO_2 ambient concentrations at the Phola discrete receptors. This is expected as part of the dense network of paved roads are located relatively close to Phola.

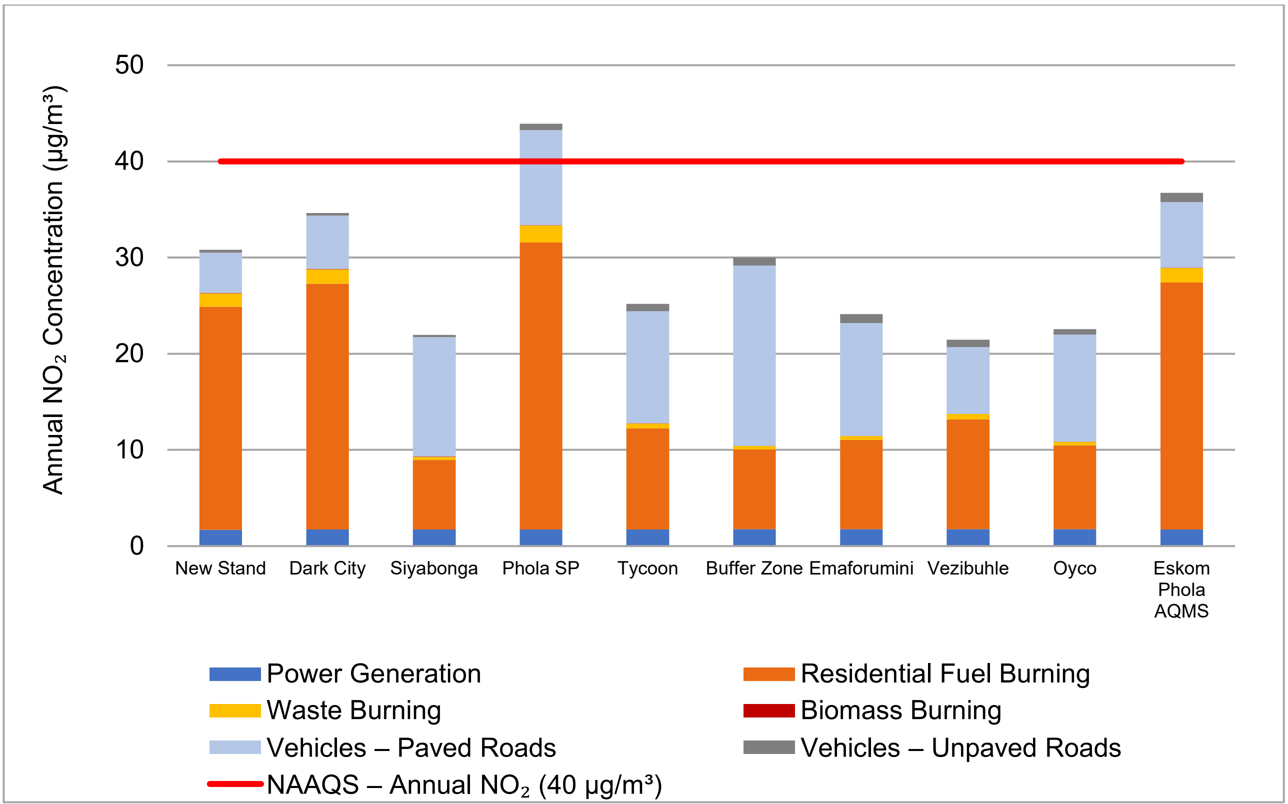


Figure 5-78: Stacked bar graph representing model predicted annual NO_2 ambient concentrations in µg/m³ at discrete receptors for the six emission source categories

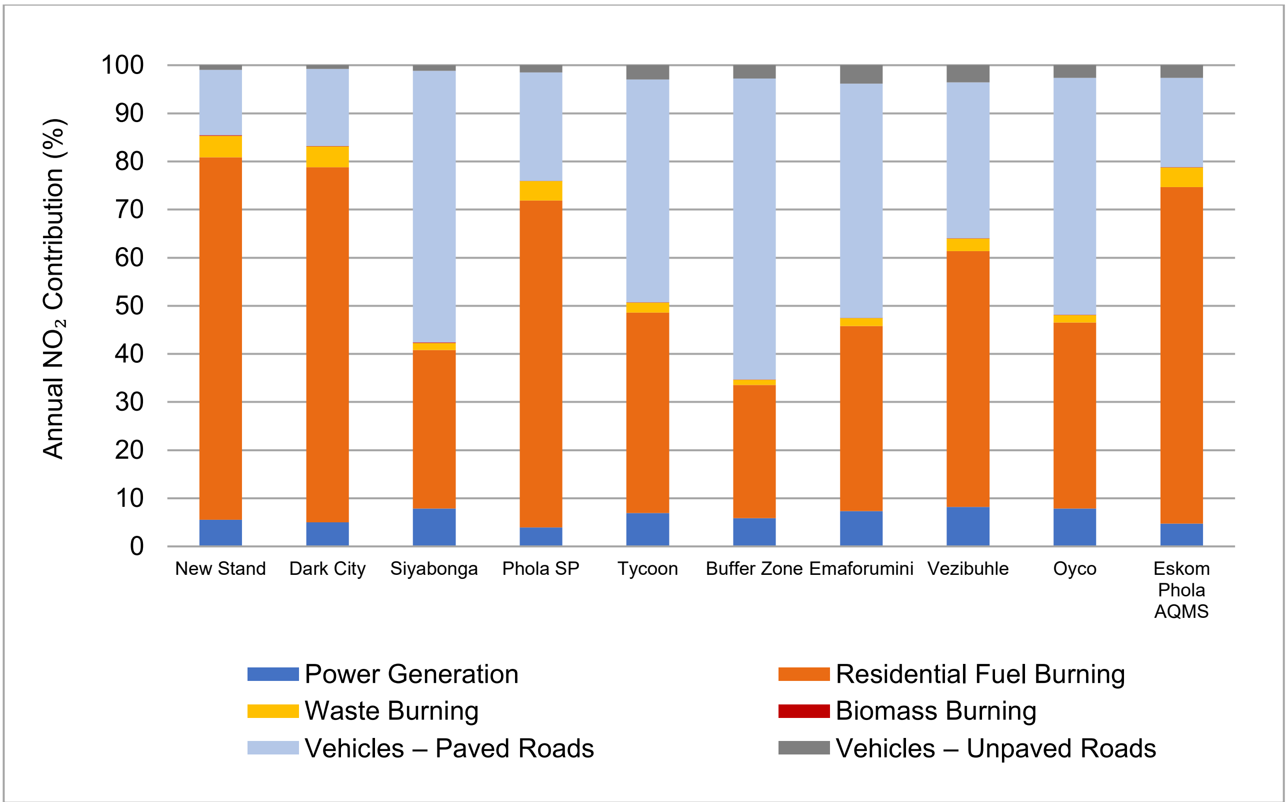


Figure 5-79: Stacked bar graph representing the percent contribution of NO_2 ambient concentrations at discrete receptors as a function of source category

5.3 PREDICTED PM_{10} AMBIENT CONCENTRATIONS

5.3.1 24-HOUR PM_{10}

Model predicted 24-hour PM_{10} ambient concentrations at discrete receptors and at the point of maximum for the eight emission source categories are presented in Table 5-8. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted 24-hour PM_{10} ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-80 for the Power Generation emission source category
- Figure 5-82 for the Residential Fuel Burning emission source category
- Figure 5-84 for the Waste Burning emission source category
- Figure 5-86 for the Biomass Burning emission source category
- Figure 5-88 for the Vehicles – Paved Roads emission source category
- Figure 5-90 for the Vehicles – Unpaved Roads emission source category
- Figure 5-92 for the Mining emission source category
- Figure 5-94 for the All Sources emission source category

Contour plots for model predicted 24-hour PM_{10} ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-81 for the Power Generation emission source category
- Figure 5-83 for the Residential Fuel Burning emission source category
- Figure 5-85 for the Waste Burning emission source category
- Figure 5-87 for the Biomass Burning emission source category
- Figure 5-89 for the Vehicles – Paved Roads emission source category
- Figure 5-91 for the Vehicles – Unpaved Roads emission source category
- Figure 5-93 for the Mining emission source category
- Figure 5-95 for the All Sources emission source category

Contour plots for model predicted 24-hour PM_{10} ambient concentrations for the Phola Airshed is presented in Figure 5-96 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-8: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	17.79	279.46	45.17	5.12	1.42	45.37	27.21	368.41
Dark City	17.64	265.22	44.05	4.75	1.52	48.90	28.22	354.69
Siyabonga	17.26	75.56	10.90	2.71	1.67	42.14	26.18	138.86
Phola SP	17.88	294.78	57.95	3.31	1.72	117.71	31.73	456.68
Tycoon	17.46	96.55	16.39	2.31	1.67	99.58	28.27	224.44
Buffer Zone	18.73	89.91	12.62	2.29	2.26	135.03	29.28	229.17
Emaforumini	19.24	100.23	13.40	2.16	1.73	140.41	30.33	254.92
Vezibuhle	19.05	115.32	19.09	2.08	1.49	104.84	33.36	263.48
Oyco	19.79	90.80	12.42	2.10	1.75	93.48	33.97	203.44
Eskom Phola AQMS	17.36	259.48	46.65	3.69	1.60	163.86	31.09	464.24
Maximum	383.62	1819.54	249.88	40.69	35.06	401.51	273.09	2037.67
	NAAQS – 24-hour PM_{10} (75 µg/m³)							

According to Table 5-8, model predicted 24-hour PM_{10} ambient concentrations exceed the 24-hour PM_{10} NAAQS of 75 µg/m³ at all discrete receptors and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories; and at six discrete receptors (Phola SP, Tycoon, Buffer Zone, Emaforumini, Vezibuhle, Oyco) and the Eskom Phola AQMS for the Vehicles-Unpaved Roads emission source category in the Phola Airshed.

Model predicted 24-hour PM_{10} ambient concentrations also exceed the 24-hour PM_{10} NAAQS of 75 µg/m³ at the point of maximum for the Power Generation, Residential Fuel Burning, Waste Burning, Vehicles – Unpaved Roads, Mining and All Sources emission source categories in the Greater Phola Airshed.

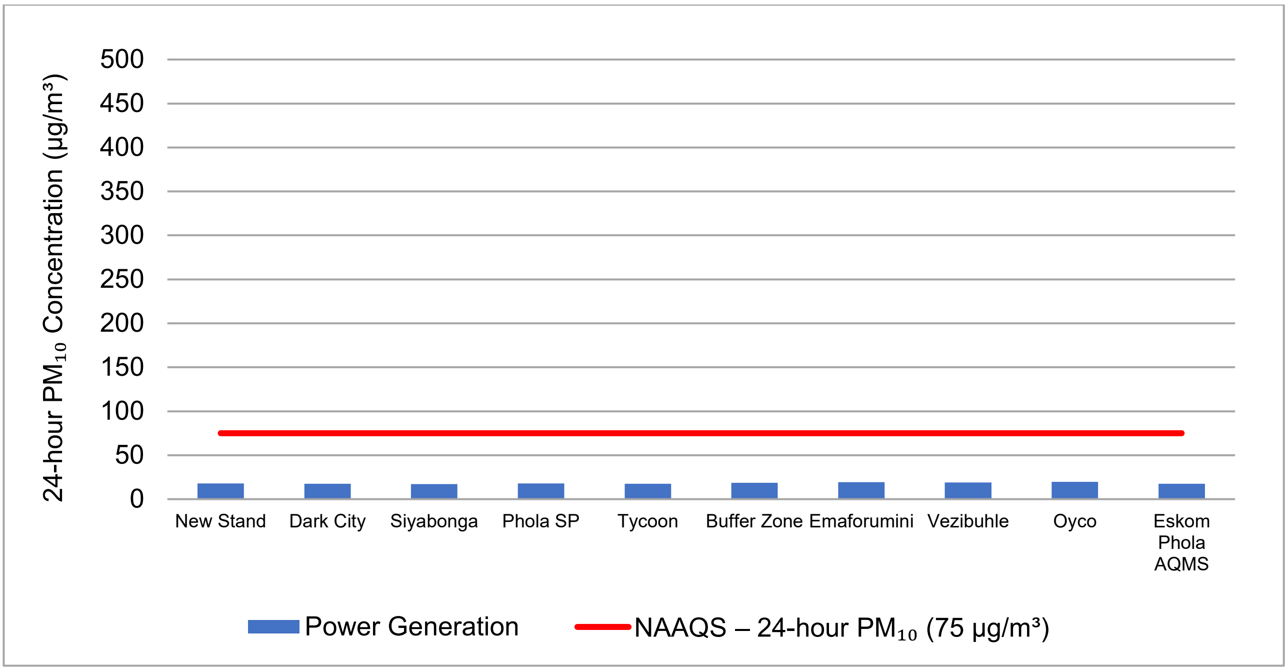


Figure 5-80: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Power Generation emission source category

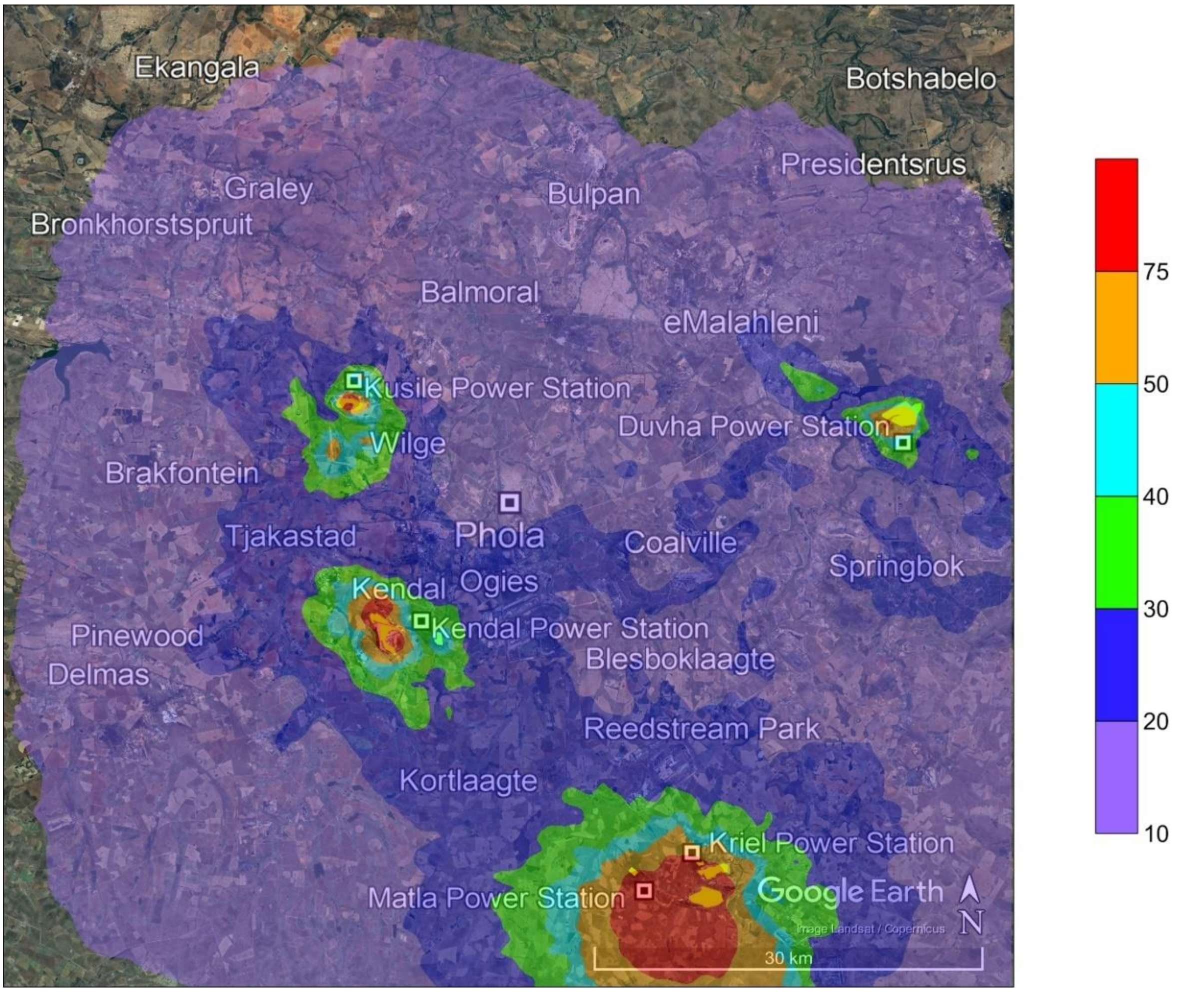


Figure 5-81: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

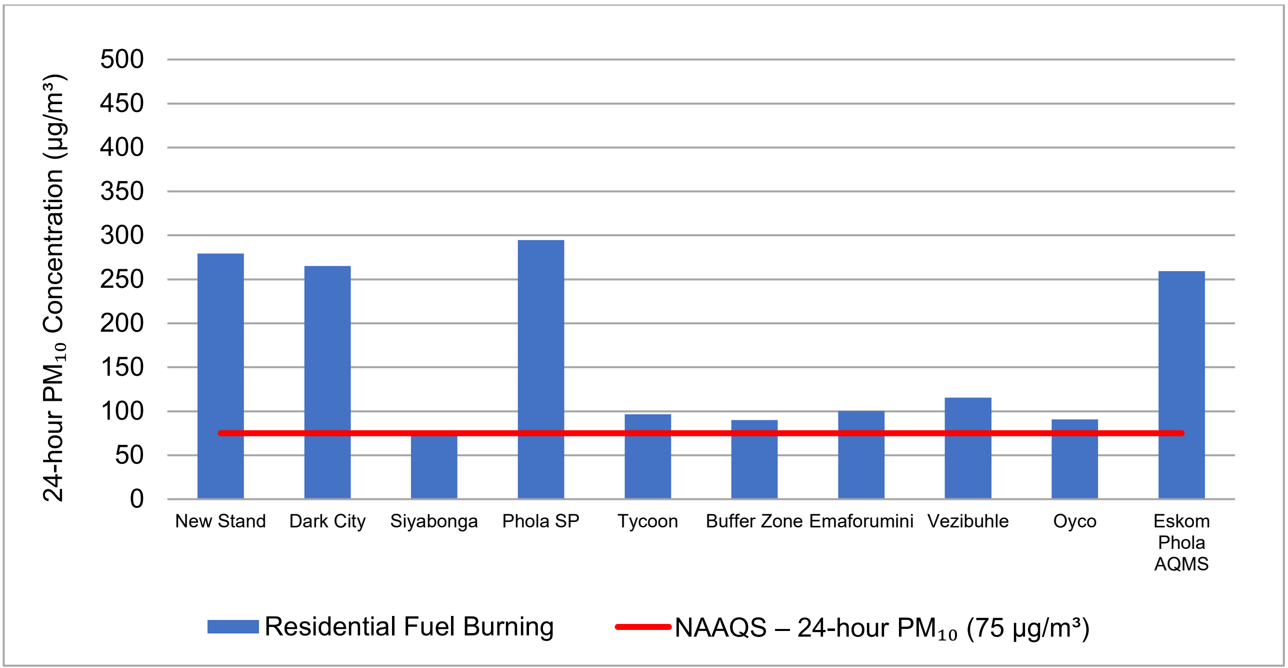


Figure 5-82: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

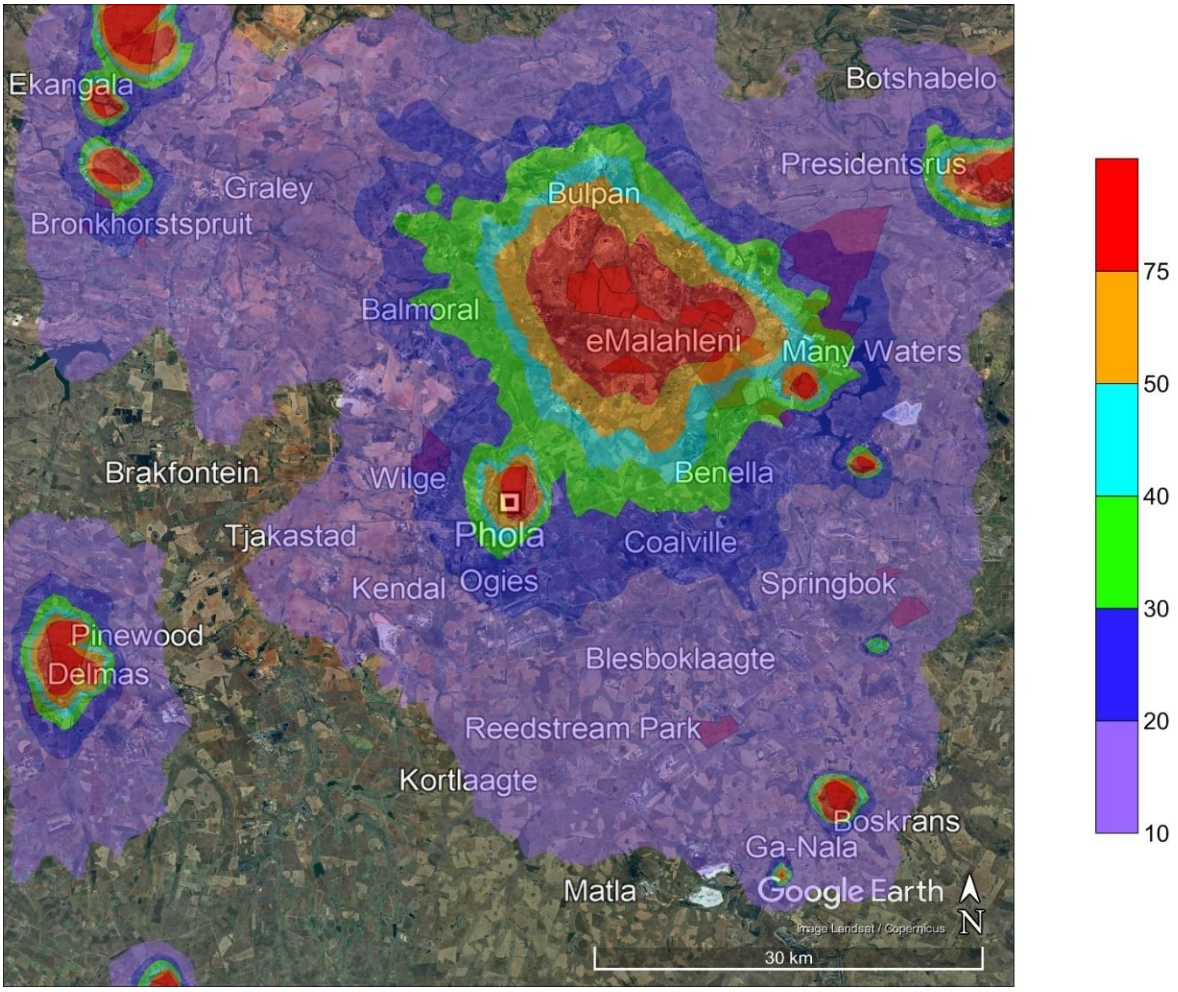


Figure 5-83: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

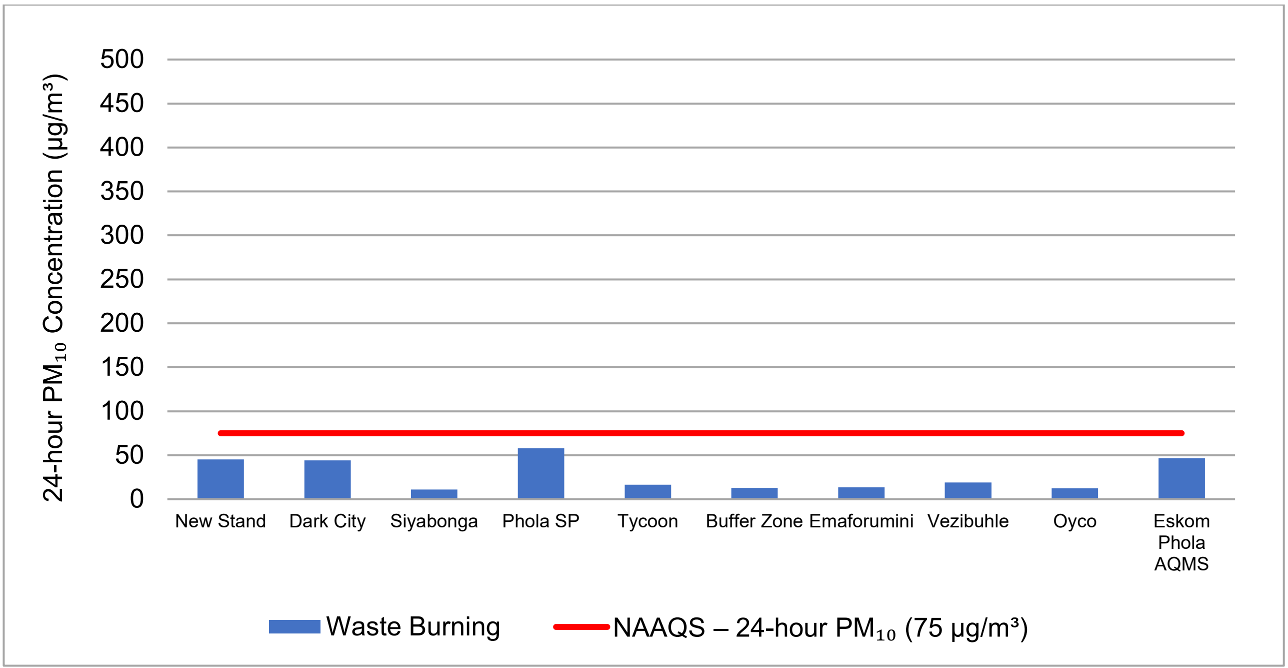


Figure 5-84: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Waste Burning emission source category

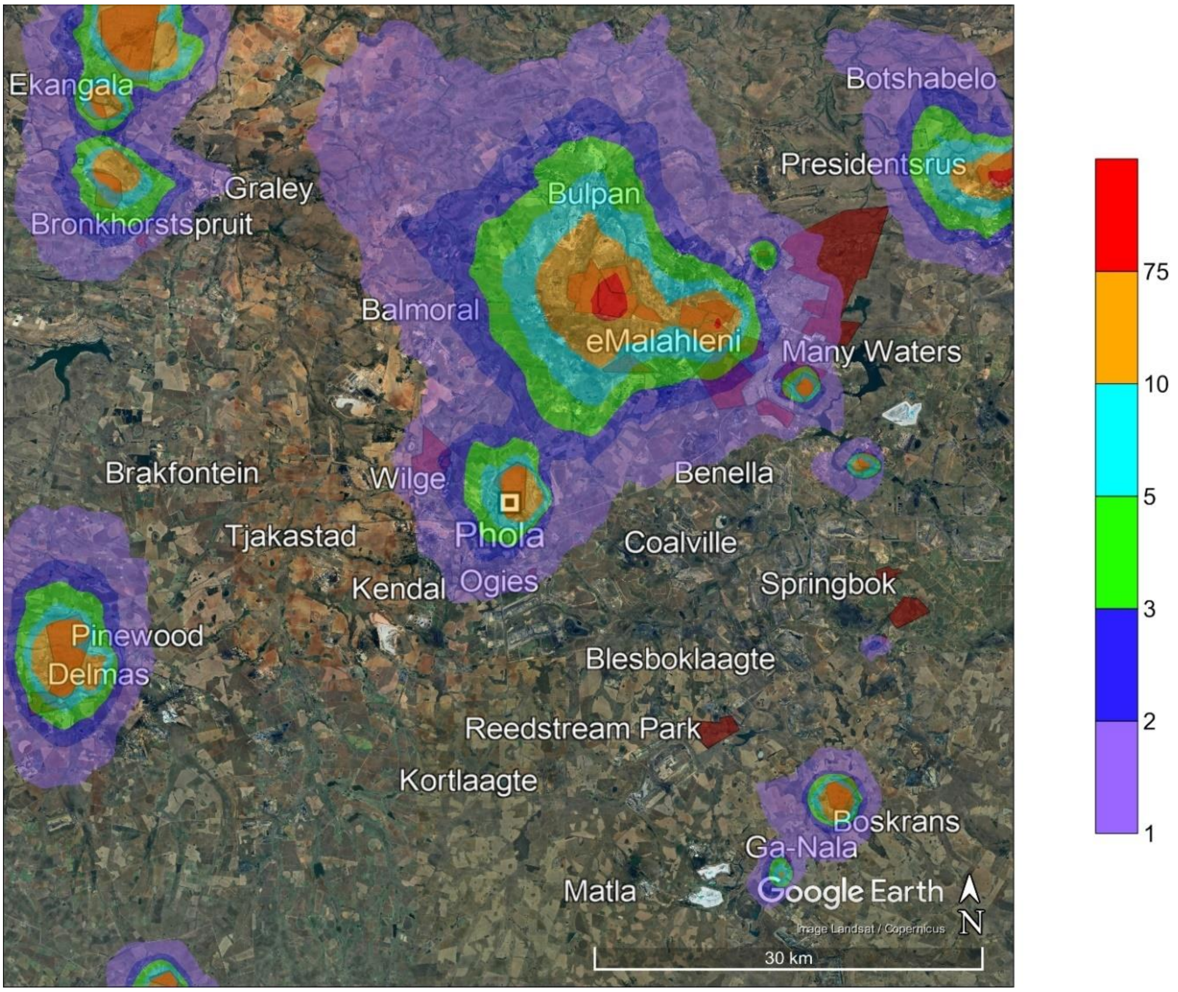


Figure 5-85: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

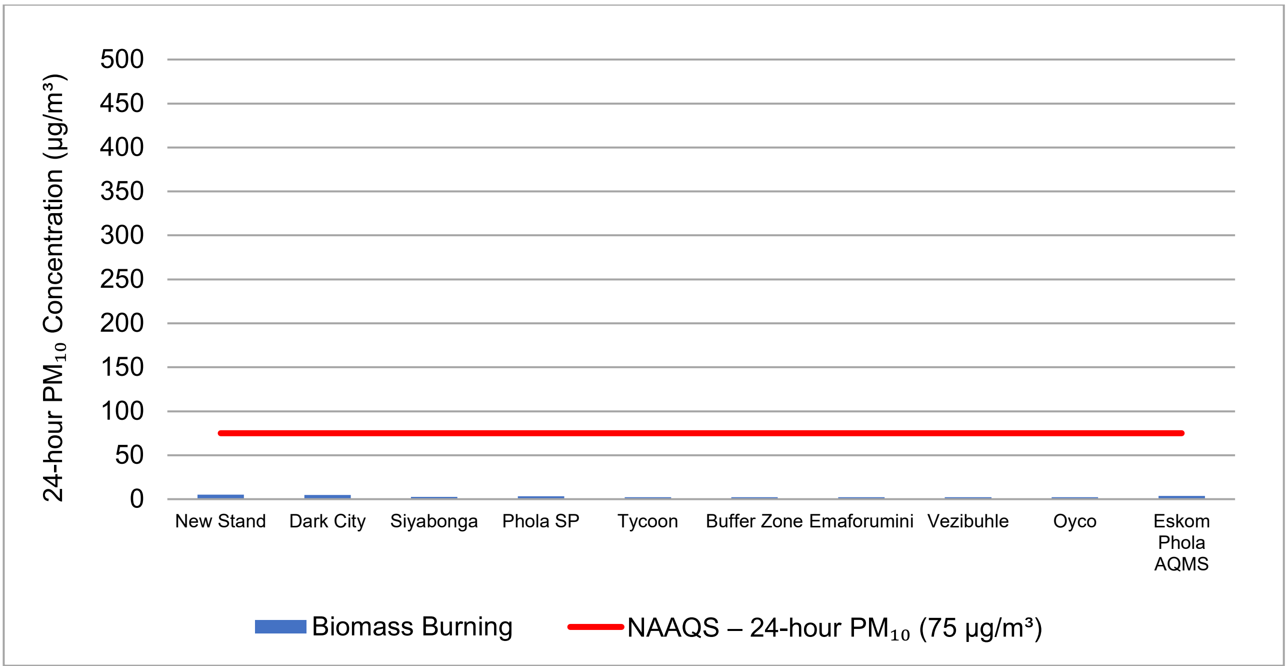


Figure 5-86: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Biomass Burning emission source category

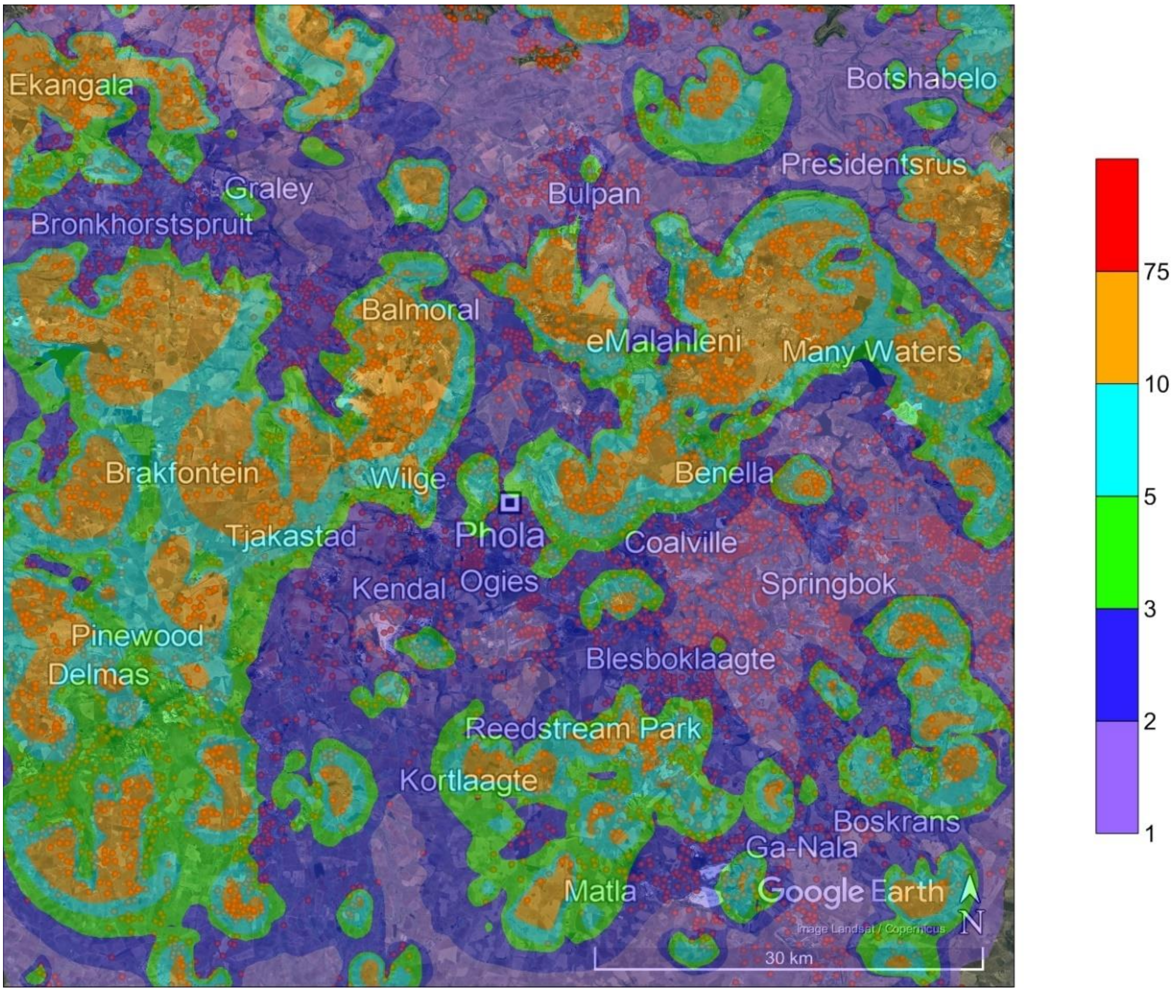


Figure 5-87: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

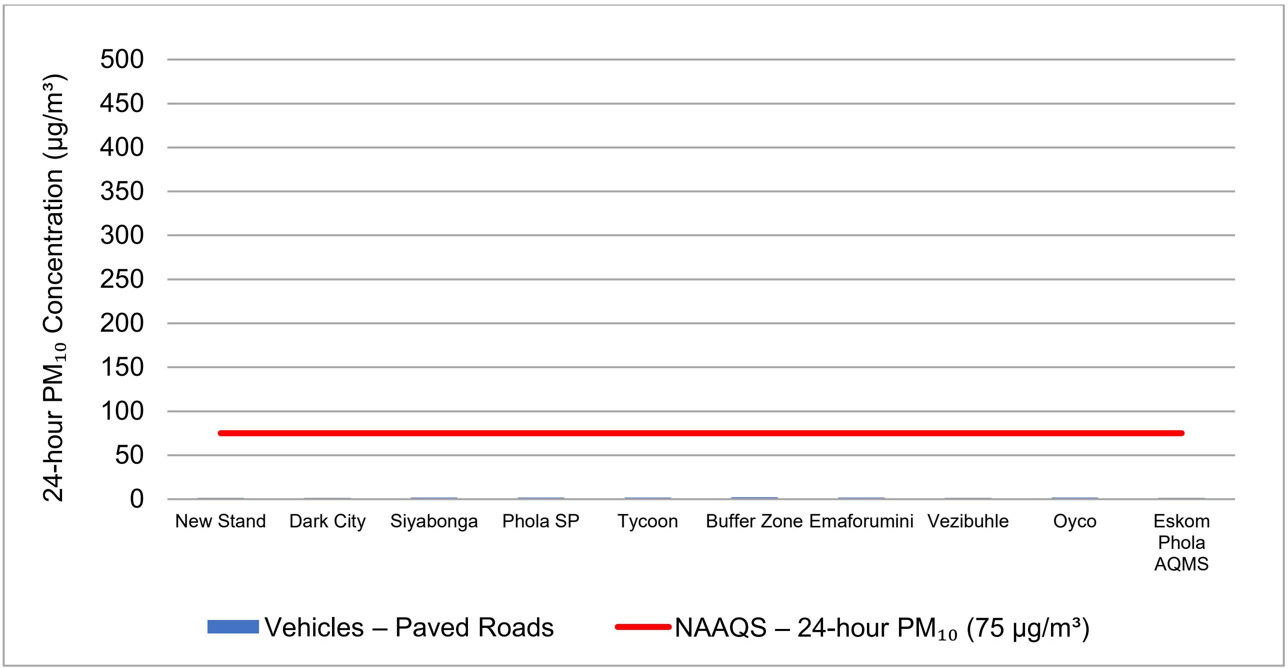


Figure 5-88: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Vehicles – Paved Roads emission source category

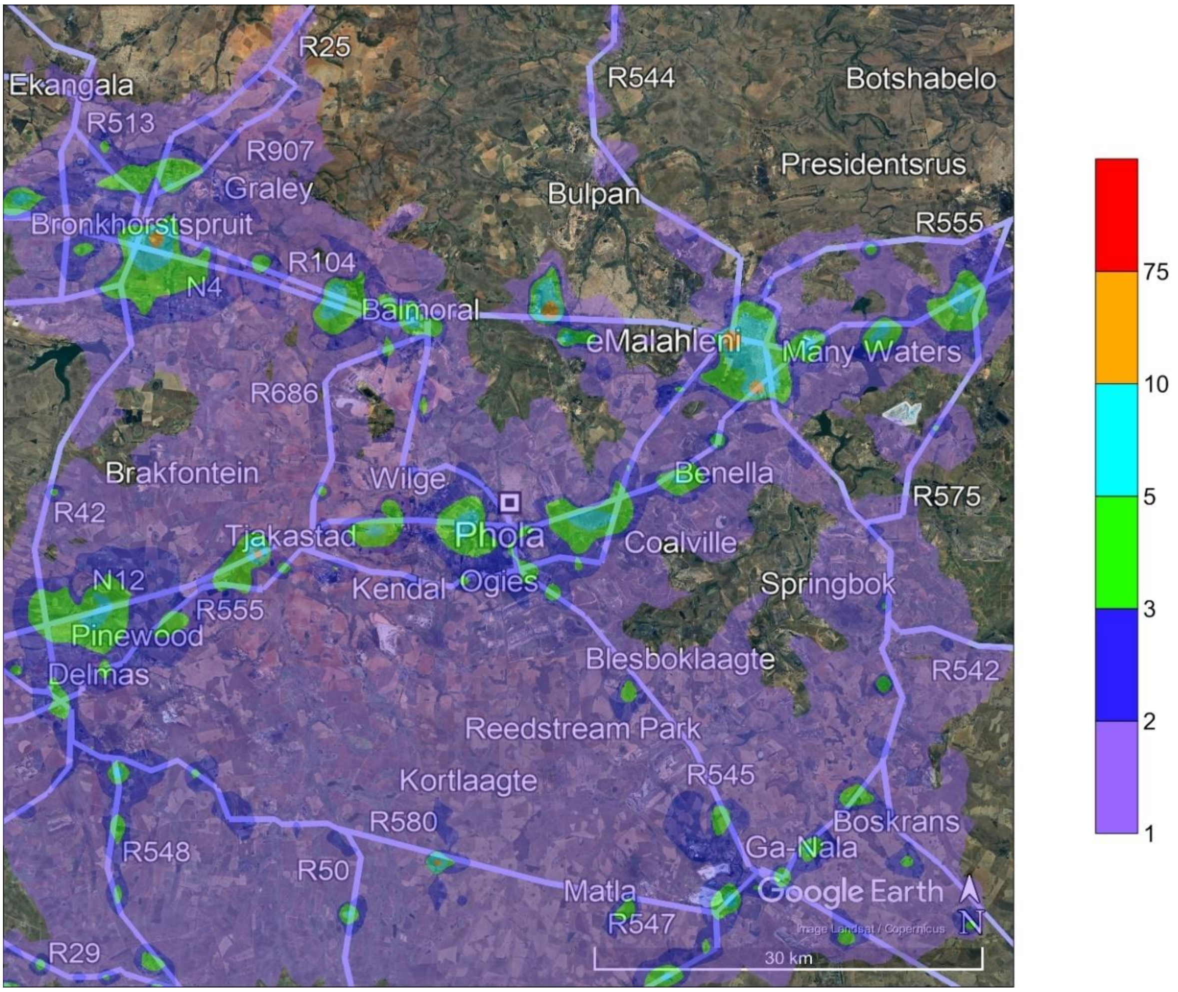


Figure 5-89: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m^3 for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

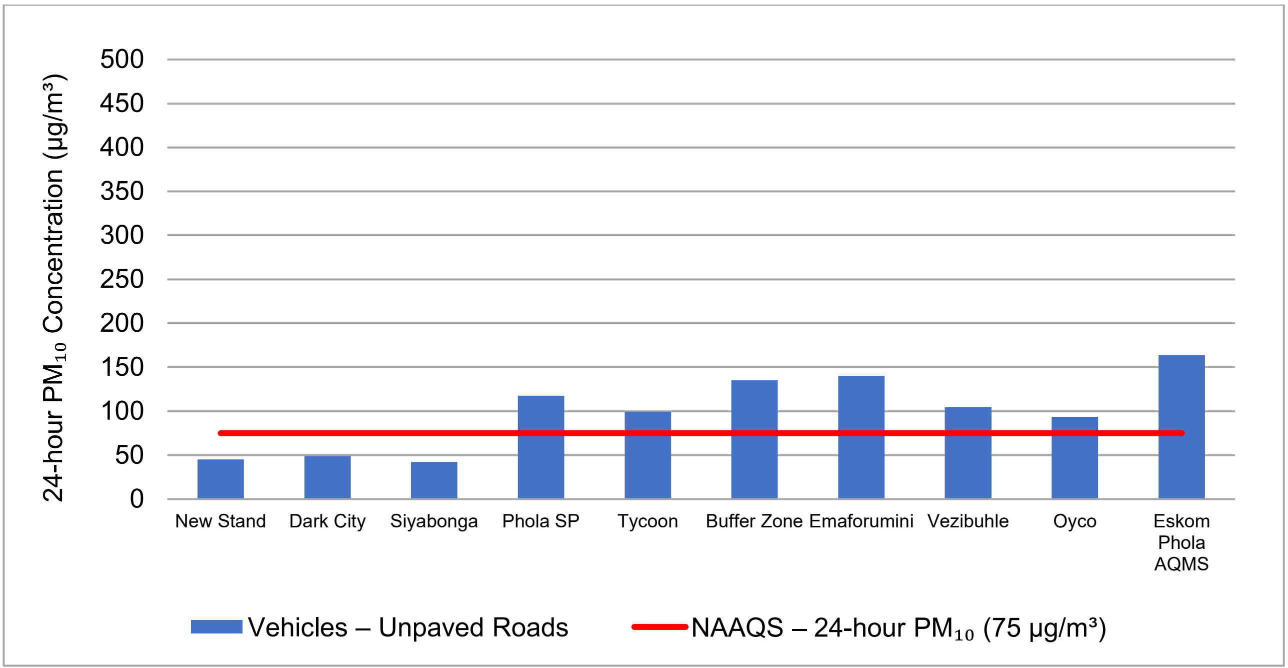


Figure 5-90: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Vehicles – Unpaved Roads emission source category

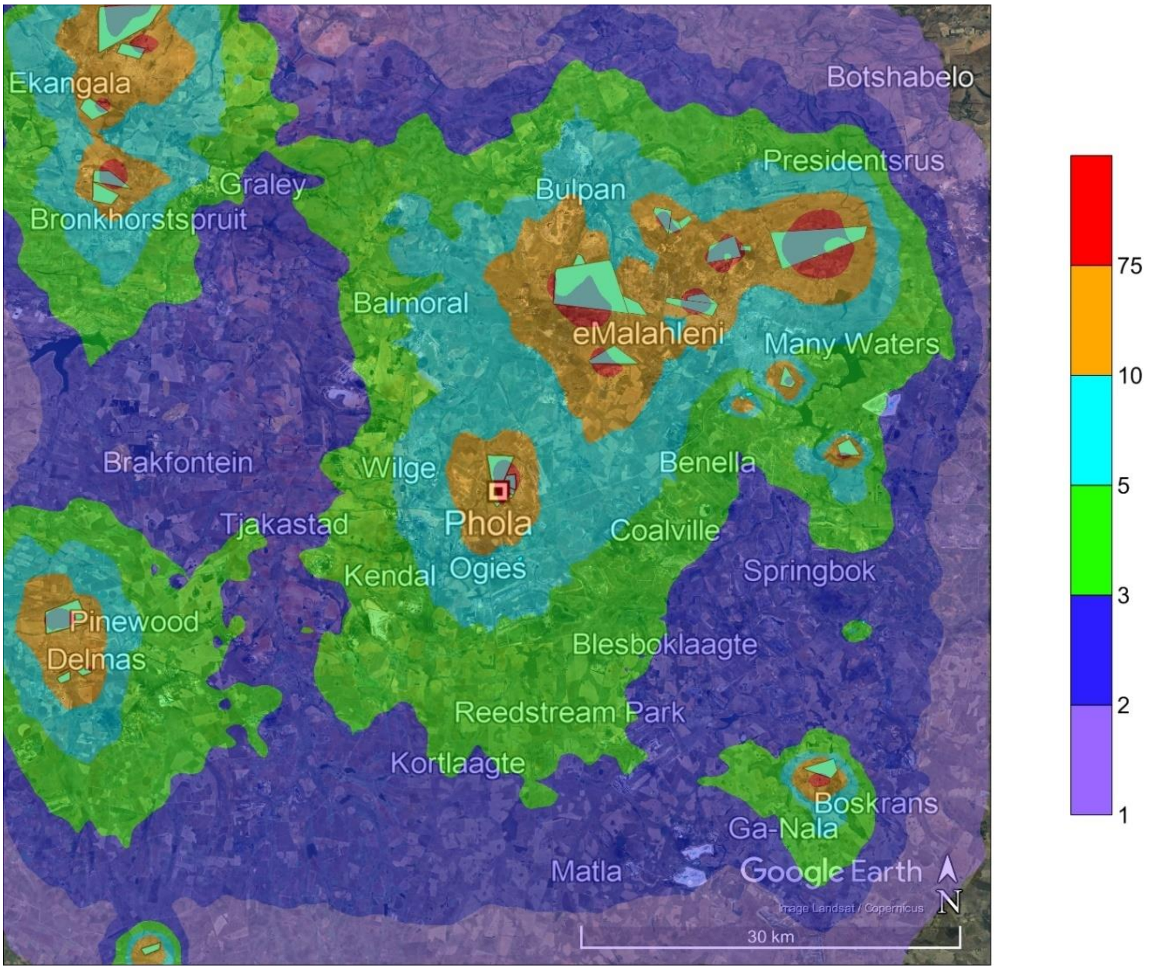


Figure 5-91: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m^3 for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

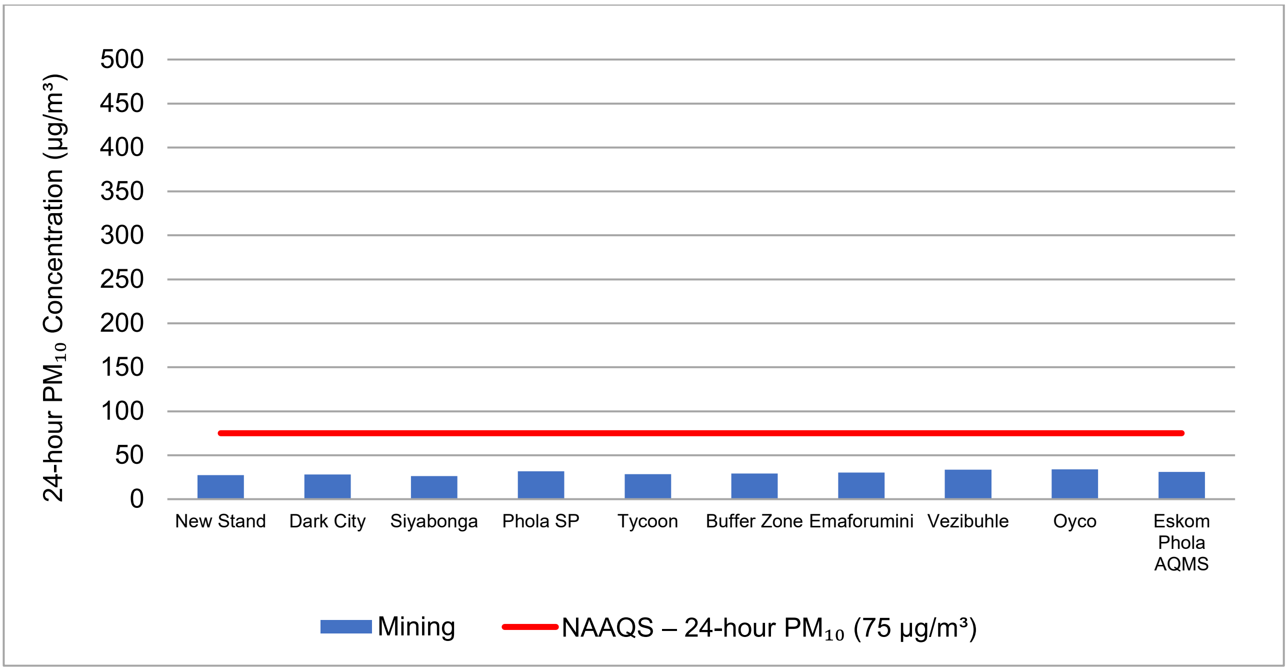


Figure 5-92: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Mining emission source category

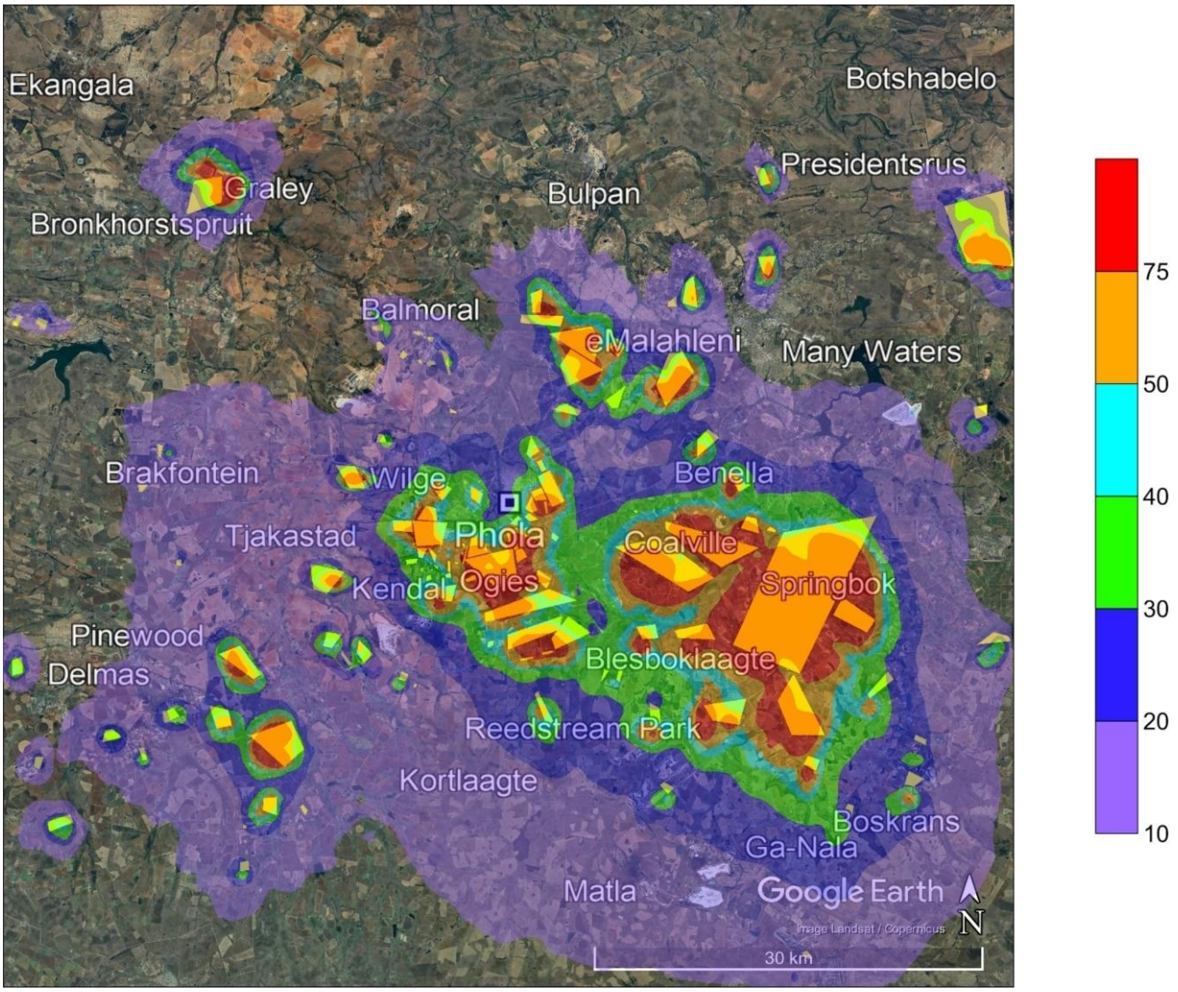


Figure 5-93: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the Mining emission source category within the Greater Phola Airshed

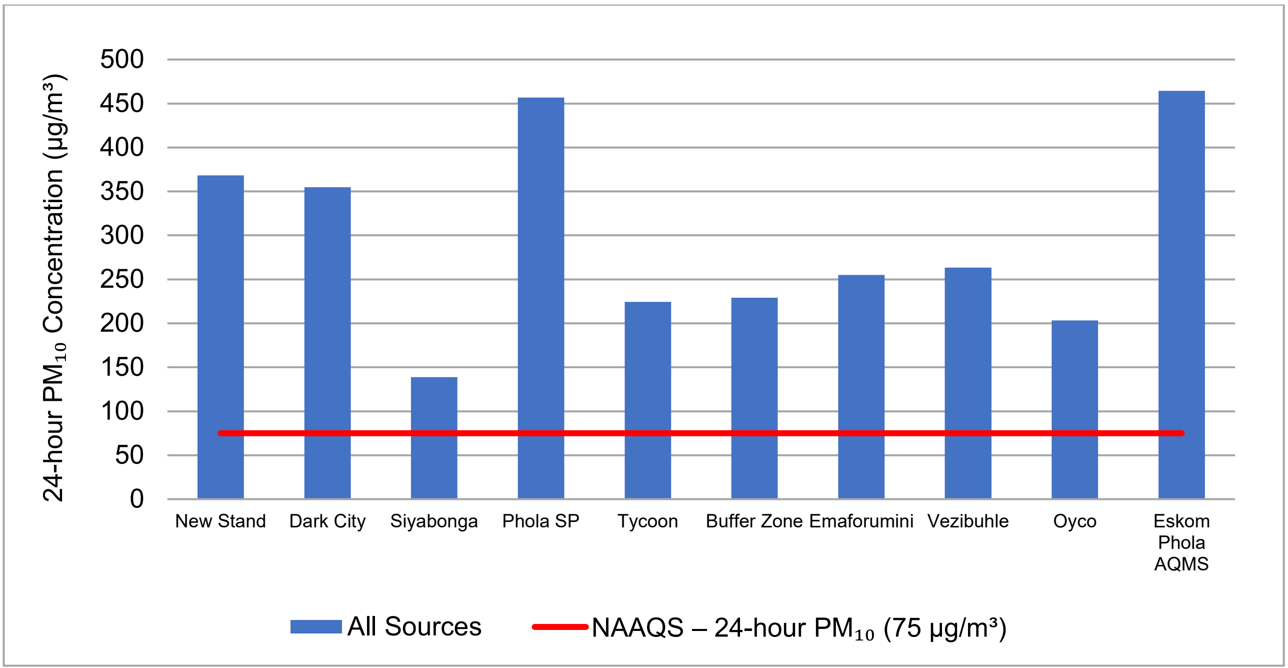


Figure 5-94: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the All Sources emission source category

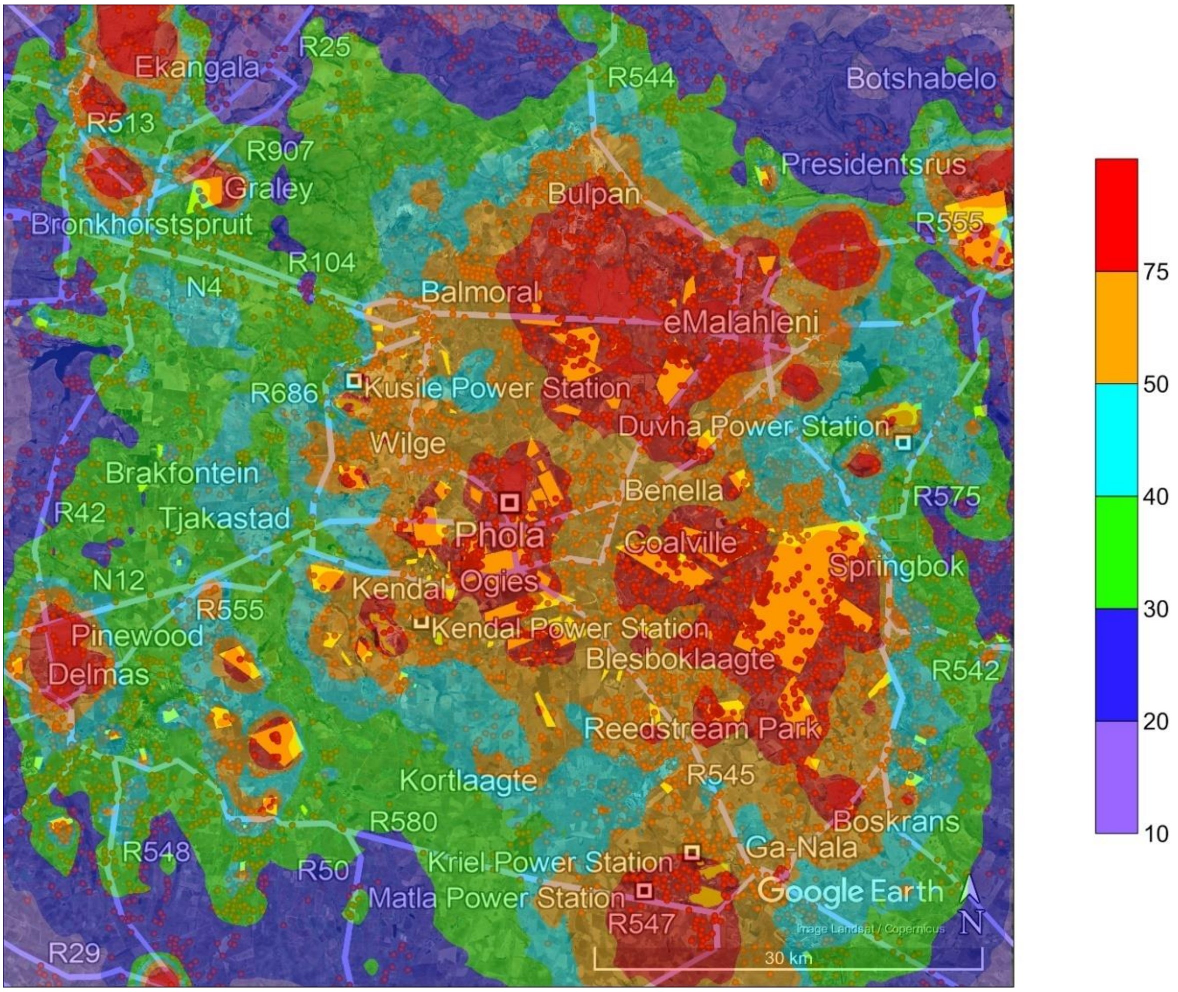


Figure 5-95: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

Figure 5-96: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in $\mu g/m^3$ for the All Sources emission source category within the Phola Airshed

5.3.2 Annual PM_{10}

Model predicted annual PM_{10} ambient concentrations at discrete receptors and at the point of maximum for the eight emission source categories are presented in Table 5-9. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted annual PM_{10} ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-97 for the Power Generation emission source category
- Figure 5-99 for the Residential Fuel Burning emission source category
- Figure 5-101 for the Waste Burning emission source category
- Figure 5-103 for the Biomass Burning emission source category
- Figure 5-105 for the Vehicles – Paved Roads emission source category
- Figure 5-107 for the Vehicles – Unpaved Roads emission source category
- Figure 5-109 for the Mining emission source category
- Figure 5-111 for the All Sources emission source category

Contour plots for model predicted annual PM_{10} ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-98 for the Power Generation emission source category
- Figure 5-100 for the Residential Fuel Burning emission source category
- Figure 5-102 for the Waste Burning emission source category
- Figure 5-104 for the Biomass Burning emission source category
- Figure 5-106 for the Vehicles – Paved Roads emission source category
- Figure 5-108 for the Vehicles – Unpaved Roads emission source category
- Figure 5-110 for the Mining emission source category
- Figure 5-112 for the All Sources emission source category

Contour plots for model predicted annual PM_{10} ambient concentrations for the Phola Airshed is presented in Figure 5-113 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-9: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	2.12	83.90	17.57	2.26	0.28	20.23	9.05	135.40
Dark City	2.14	92.37	18.99	2.01	0.32	18.67	9.41	143.90
Siyabonga	2.12	26.53	4.27	1.22	0.49	17.53	8.56	60.73
Phola SP	2.18	107.94	22.46	1.46	0.44	45.22	10.92	190.61
Tycoon	2.15	38.28	6.81	0.96	0.47	50.05	9.52	108.25
Buffer Zone	2.17	30.33	4.34	0.96	0.66	56.19	10.30	104.95
Emaforumini	2.18	33.92	4.99	0.91	0.48	61.60	10.89	114.97
Vezibuhle	2.20	41.59	7.25	0.89	0.36	50.83	11.82	114.94
Oyco	2.21	31.91	4.51	0.89	0.48	39.42	12.51	91.92
Eskom Phola AQMS	2.17	92.90	19.09	1.67	0.36	64.70	10.57	191.46
Maximum	57.33	644.92	116.05	16.43	7.00	186.84	123.56	782.45
	NAAQS – Annual PM_{10} (40 µg/m³)							

According to Table 5-9, model predicted annual PM_{10} ambient concentrations exceed the annual PM_{10} NAAQS of 40 µg/m³ at all discrete receptors and the Eskom Phola AQMS for the All Sources emission source category; at four discrete receptors (New Stand, Dark City, Phola SP, Vezibuhle) and the Eskom Phola AQMS for the Residential Fuel Burning emission source category; and at five discrete receptors (Phola SP, Tycoon, Buffer Zone, Emaforumini, Vezibuhle) and the Eskom Phola AQMS for the Vehicles-Unpaved Roads emission source category in the Phola Airshed.

Model predicted annual PM_{10} ambient concentrations also exceed the annual PM_{10} NAAQS of 40 µg/m³ at the point of maximum for the Power Generation, Residential Fuel Burning, Waste Burning, Vehicles – Unpaved Roads, Mining and All Sources emission source categories in the Greater Phola Airshed.

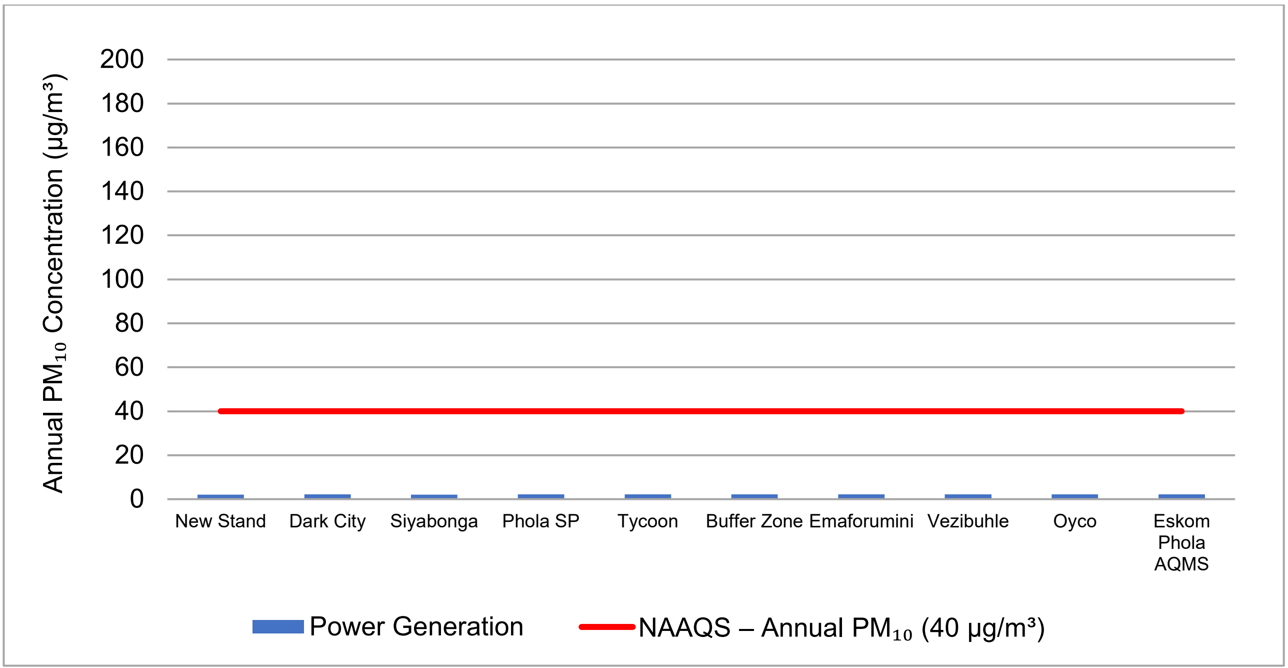


Figure 5-97: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the Power Generation emission source category

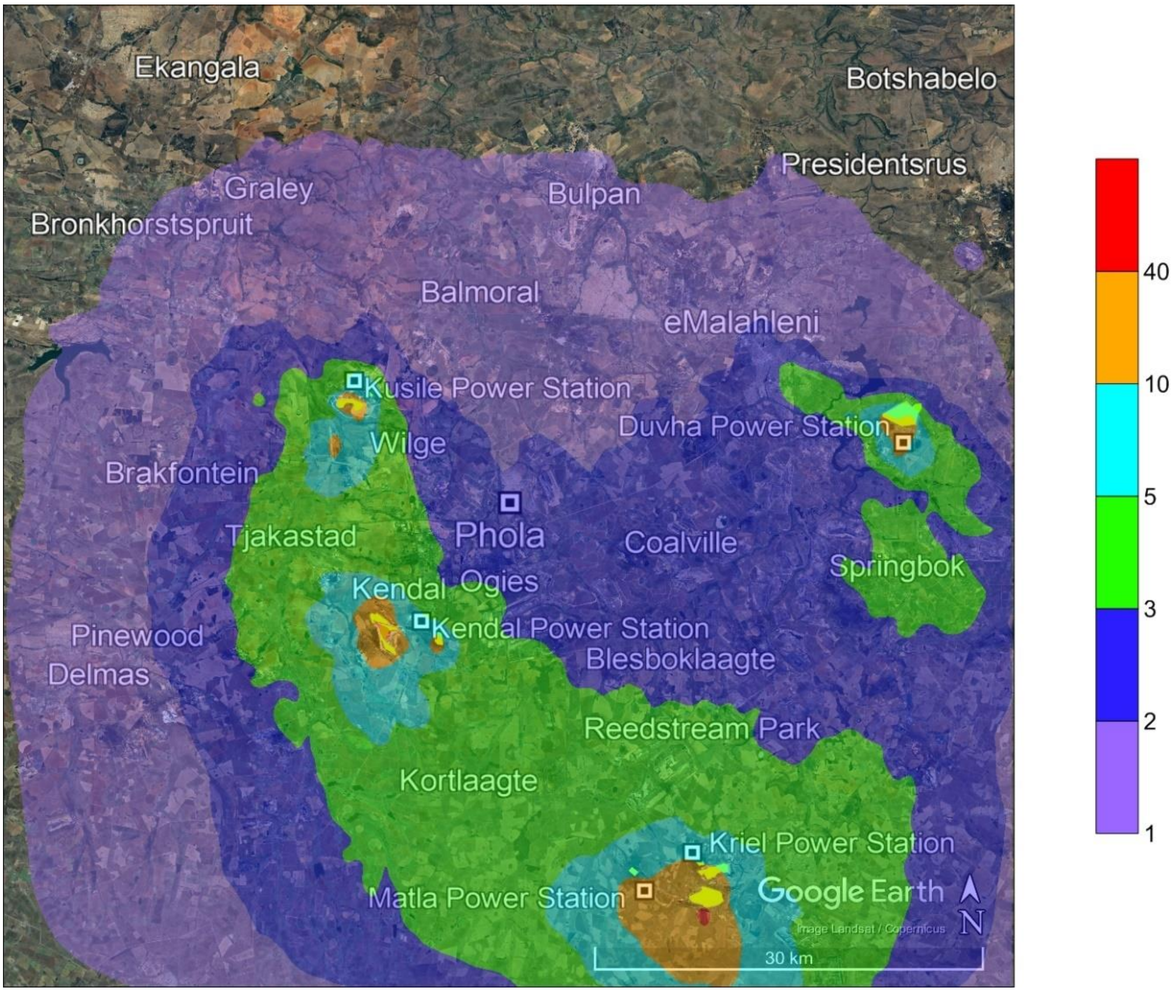


Figure 5-98: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

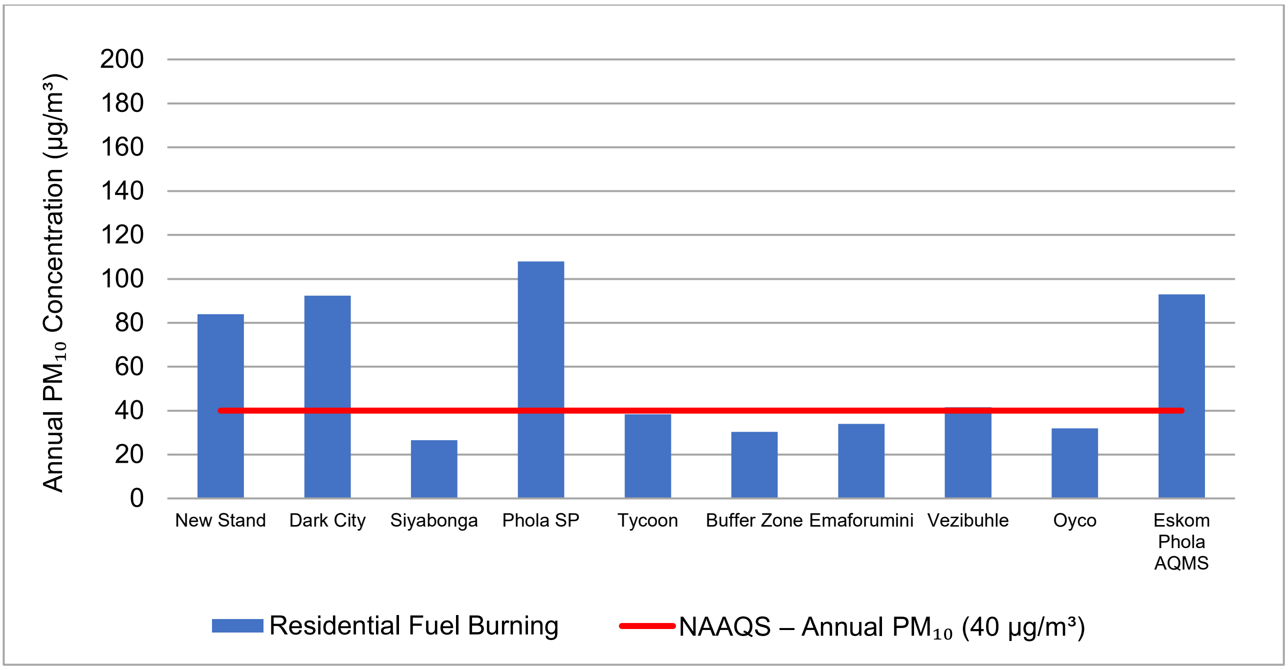


Figure 5-99: Model predicted annual PM_{10} ambient concentrations in μg/m^3 at discrete receptors for the Residential Fuel Burning emission source category

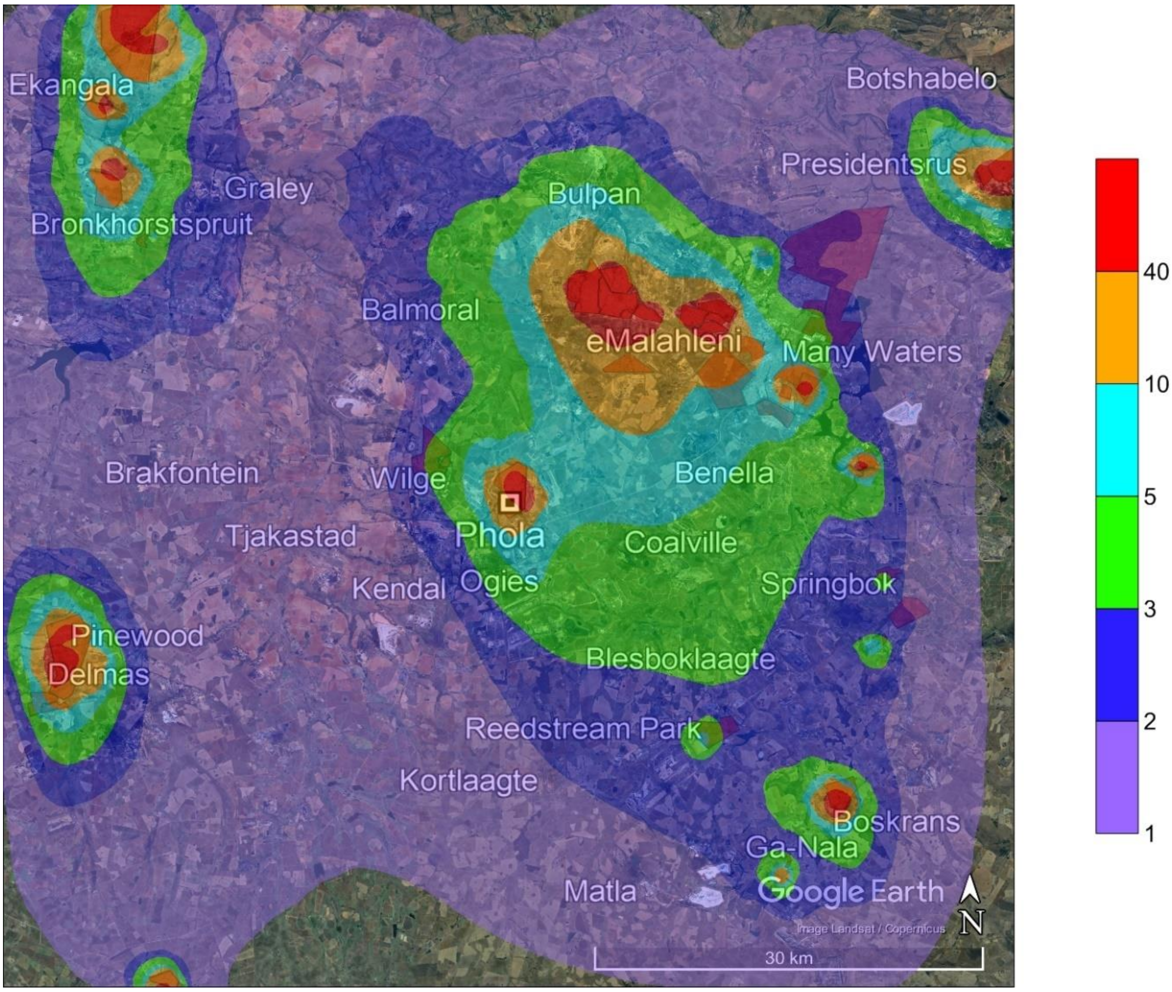


Figure 5-100: Model predicted annual PM_{10} ambient concentrations in μg/m^3 for the Residential Fuel Burning emission source category within the Greater Phola Airshed

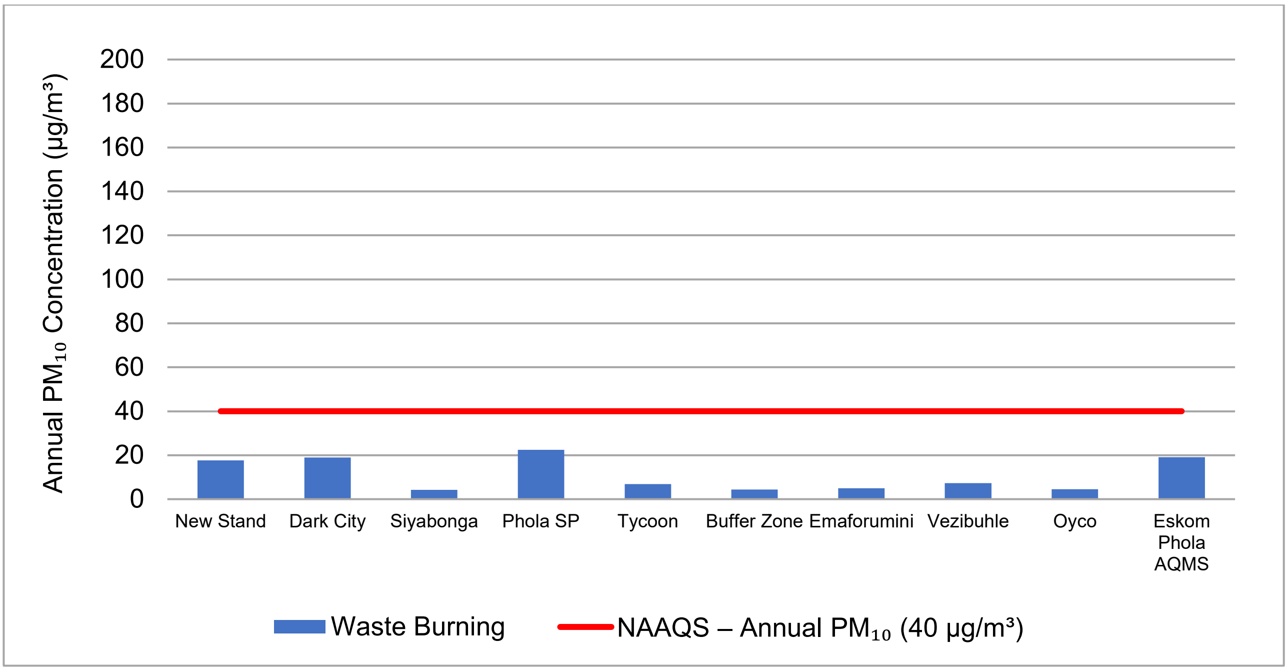


Figure 5-101: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the Waste Burning emission source category

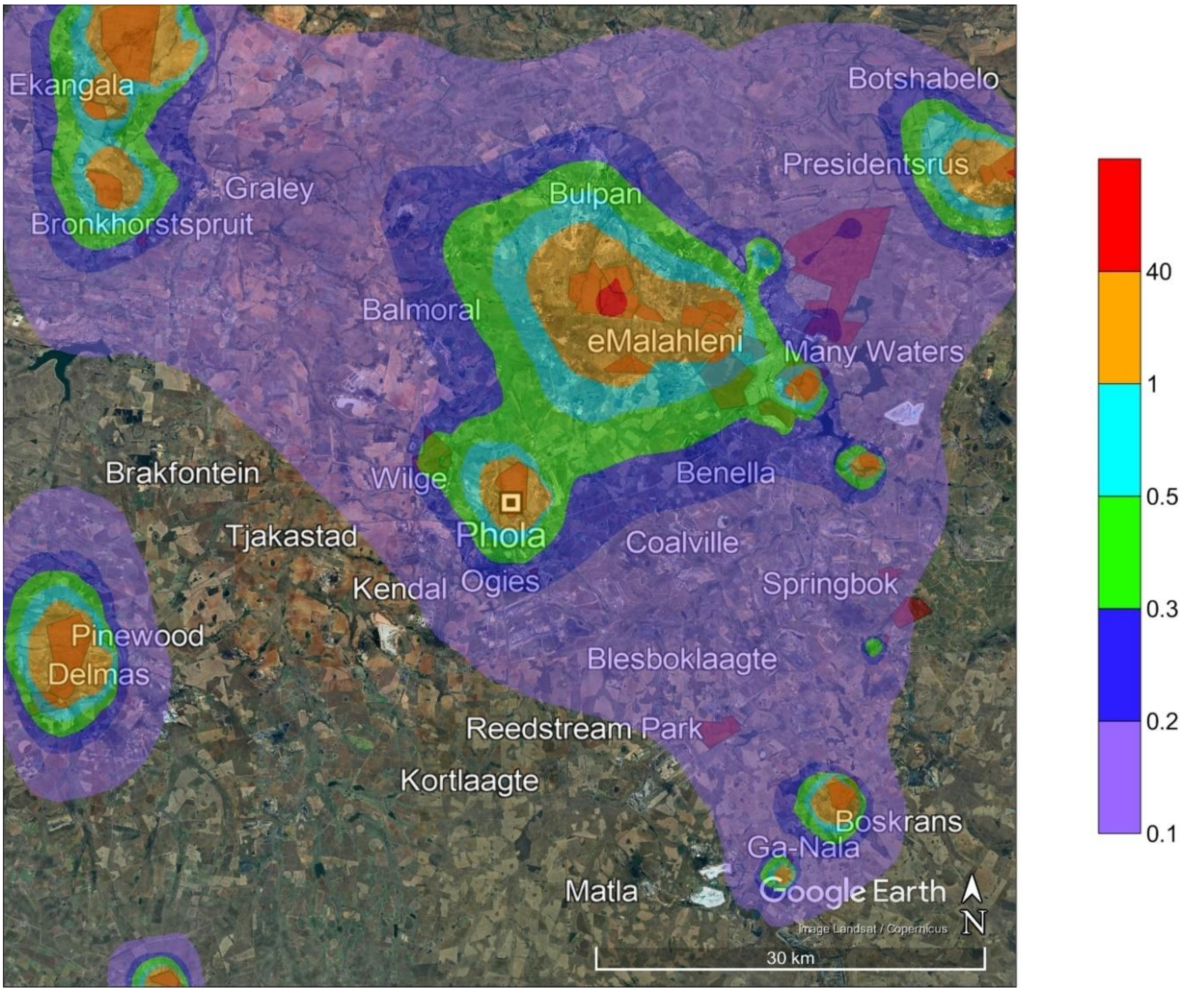


Figure 5-102: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

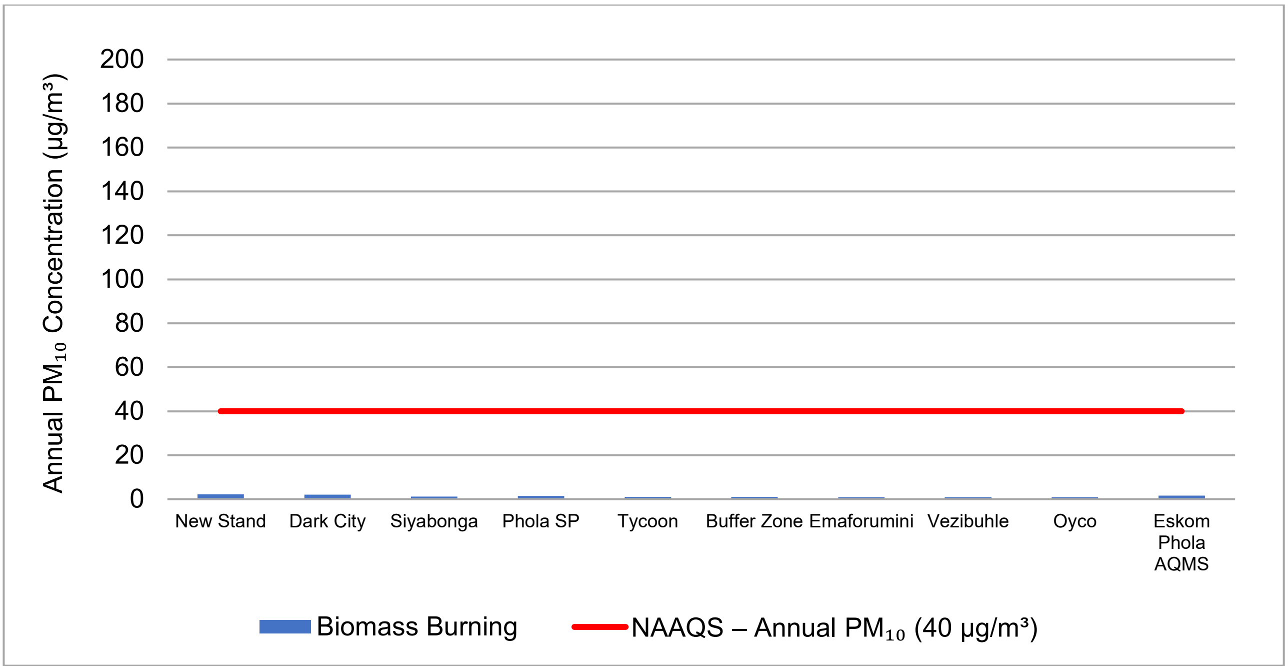


Figure 5-103: Model predicted annual PM_{10} ambient concentrations in µg/m^3 at discrete receptors for the Biomass Burning emission source category

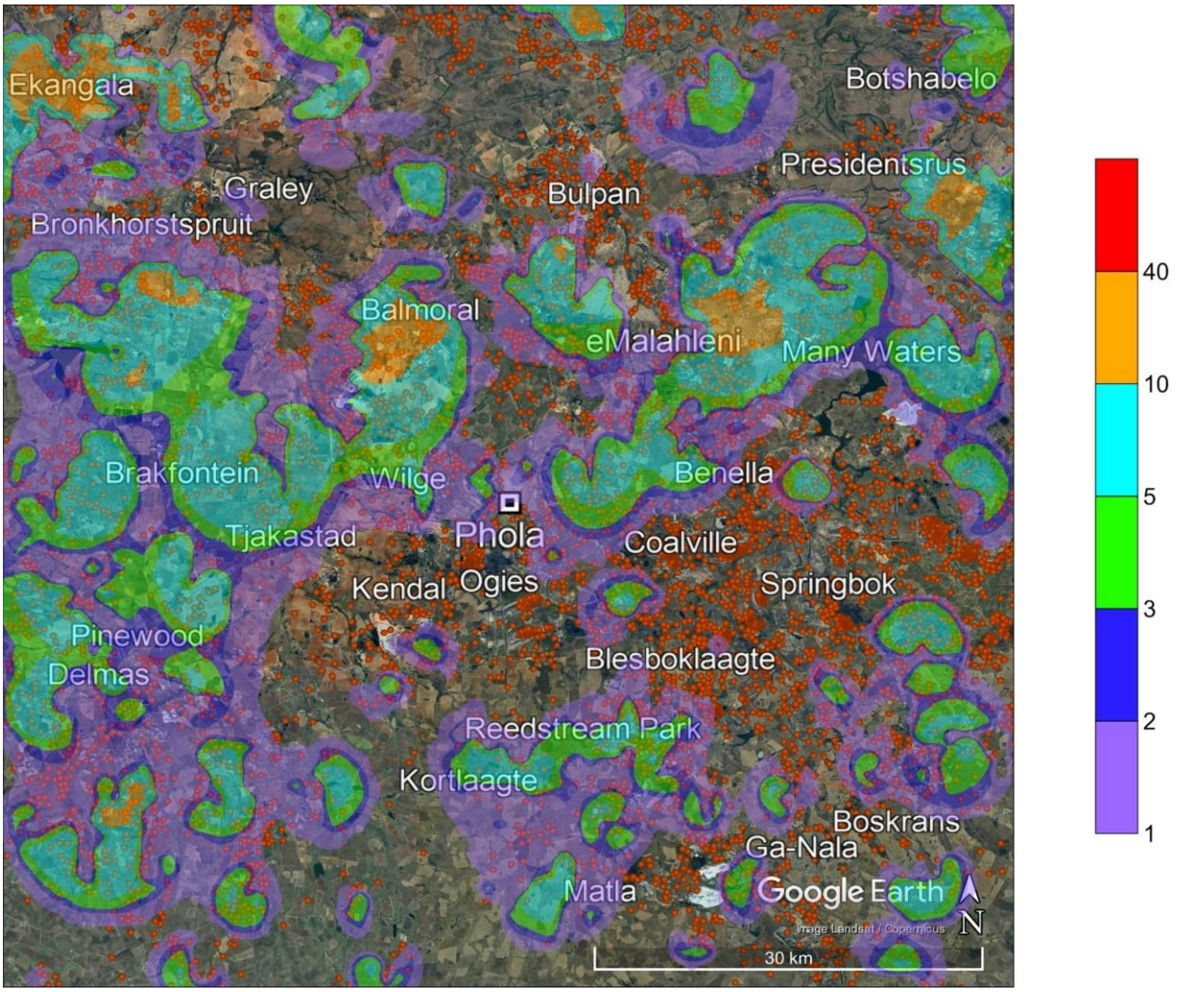


Figure 5-104: Model predicted annual PM_{10} ambient concentrations in µg/m^3 for the Biomass Burning emission source category within the Greater Phola Airshed

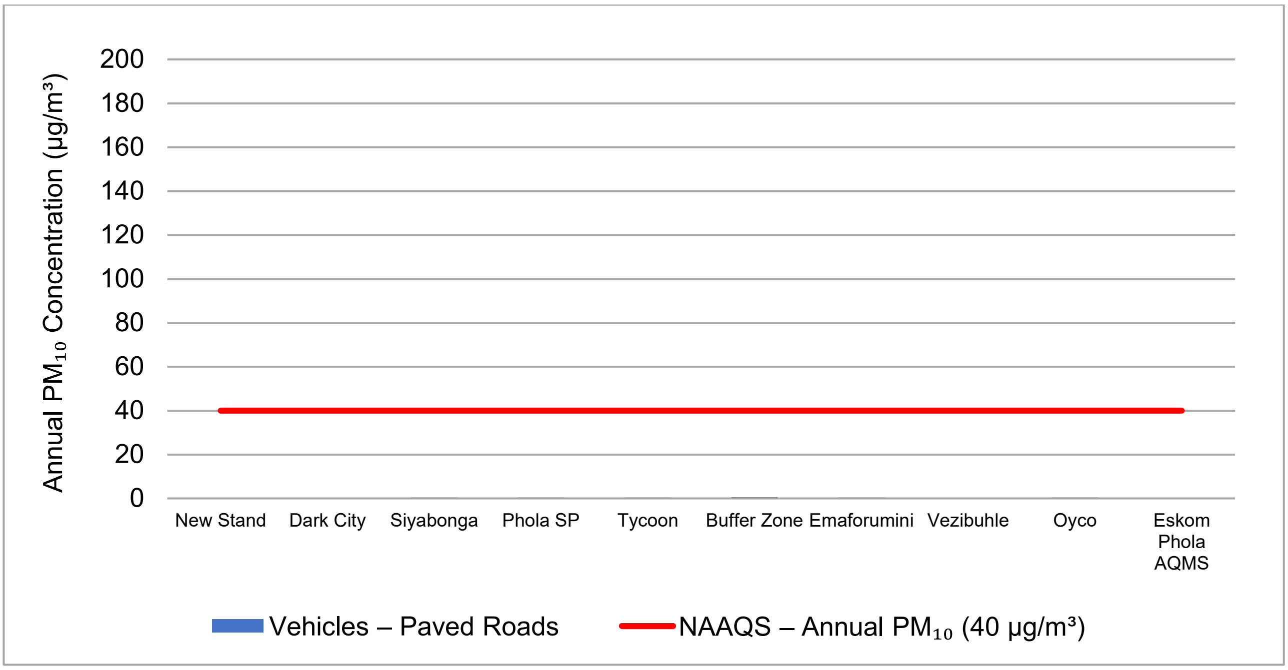


Figure 5-105: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Paved Roads emission source category

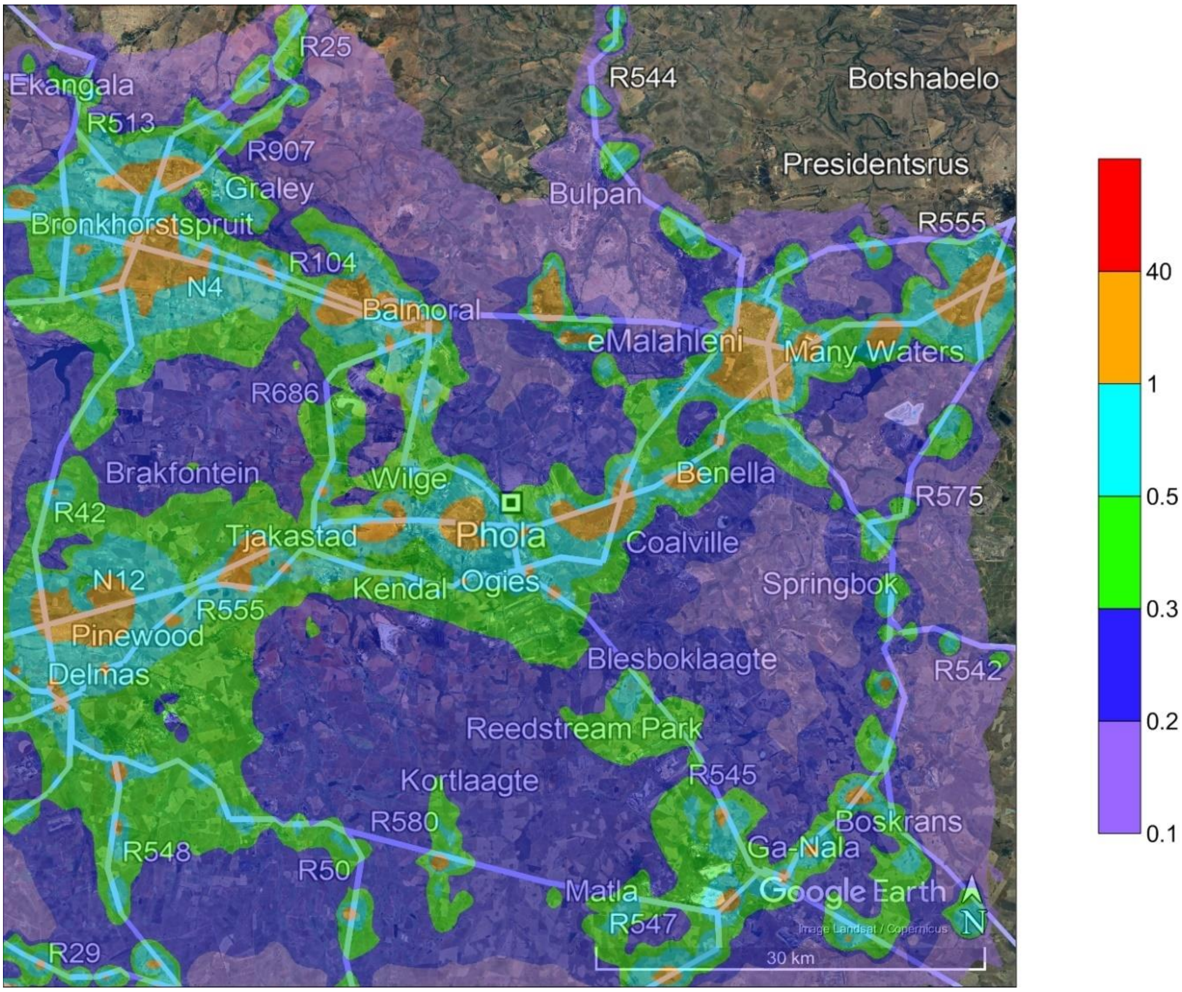


Figure 5-106: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

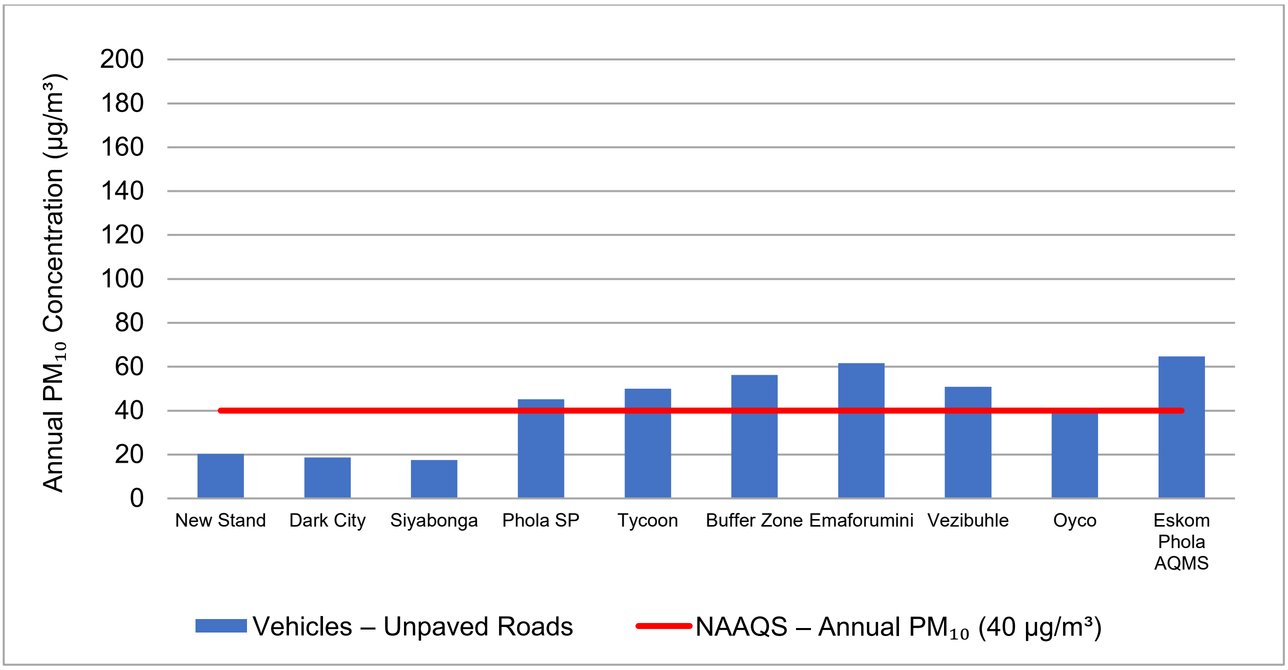


Figure 5-107: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

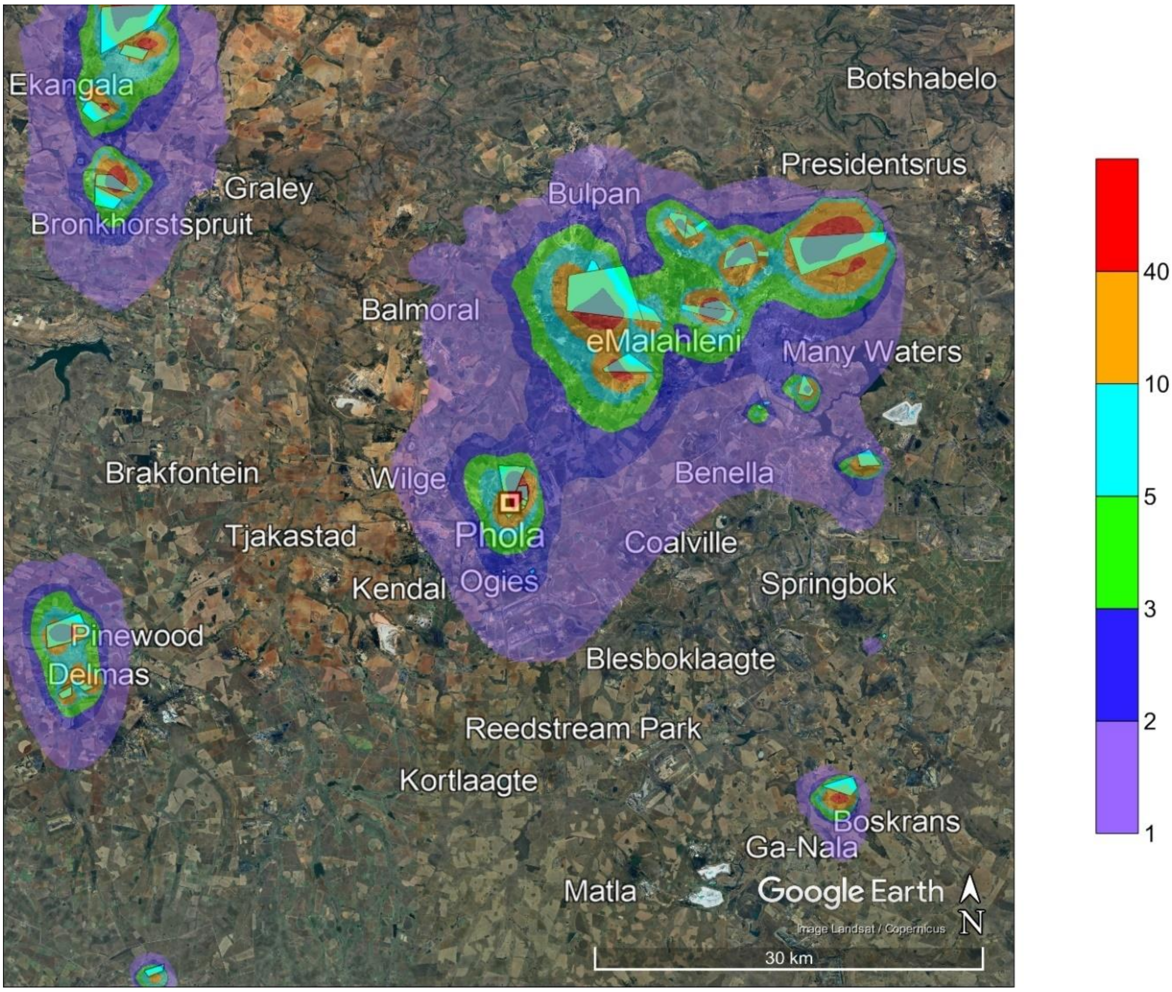


Figure 5-108: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

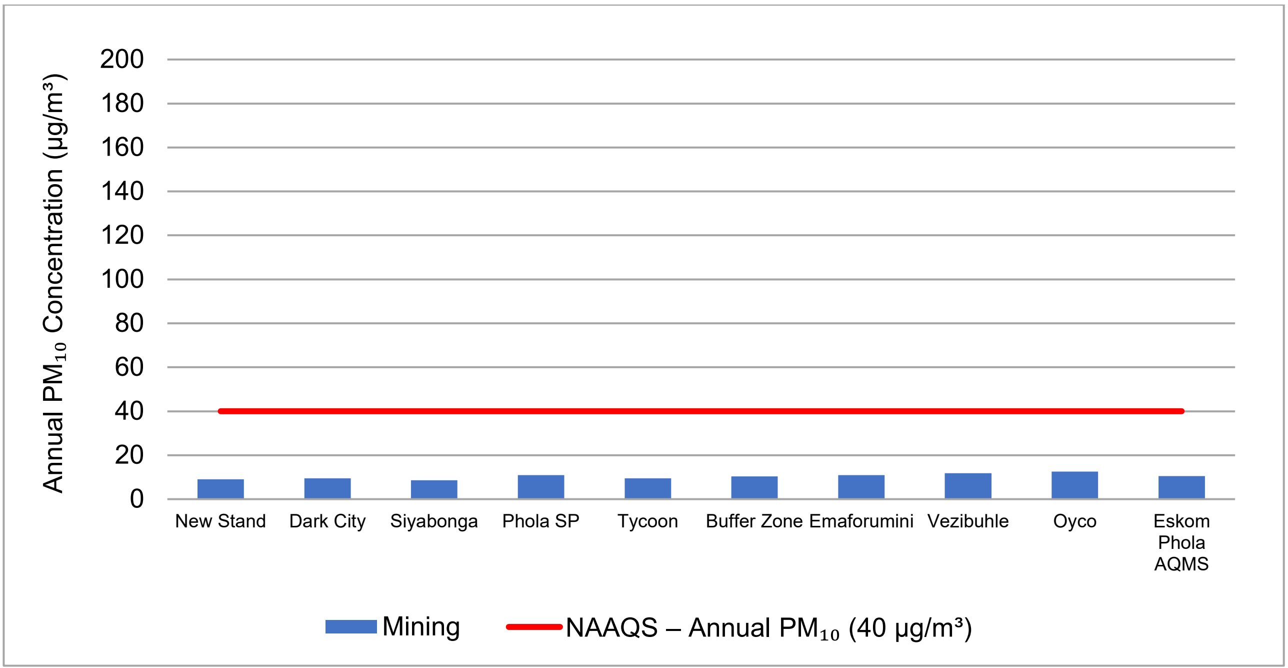


Figure 5-109: Model predicted annual PM_{10} ambient concentrations in μg/m³ at discrete receptors for the Mining emission source category

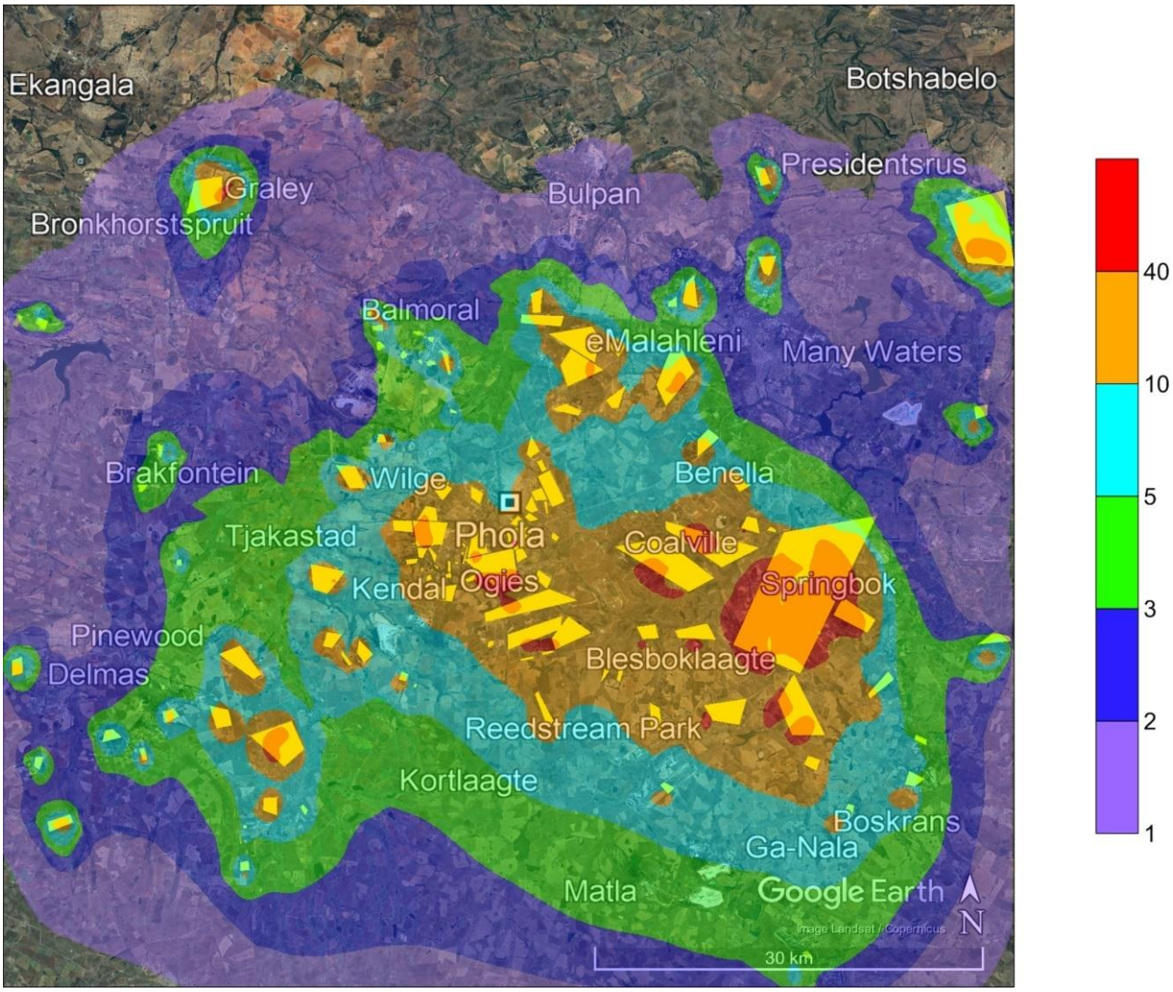


Figure 5-110: Model predicted annual PM_{10} ambient concentrations in μg/m³ for the Mining emission source category within the Greater Phola Airshed

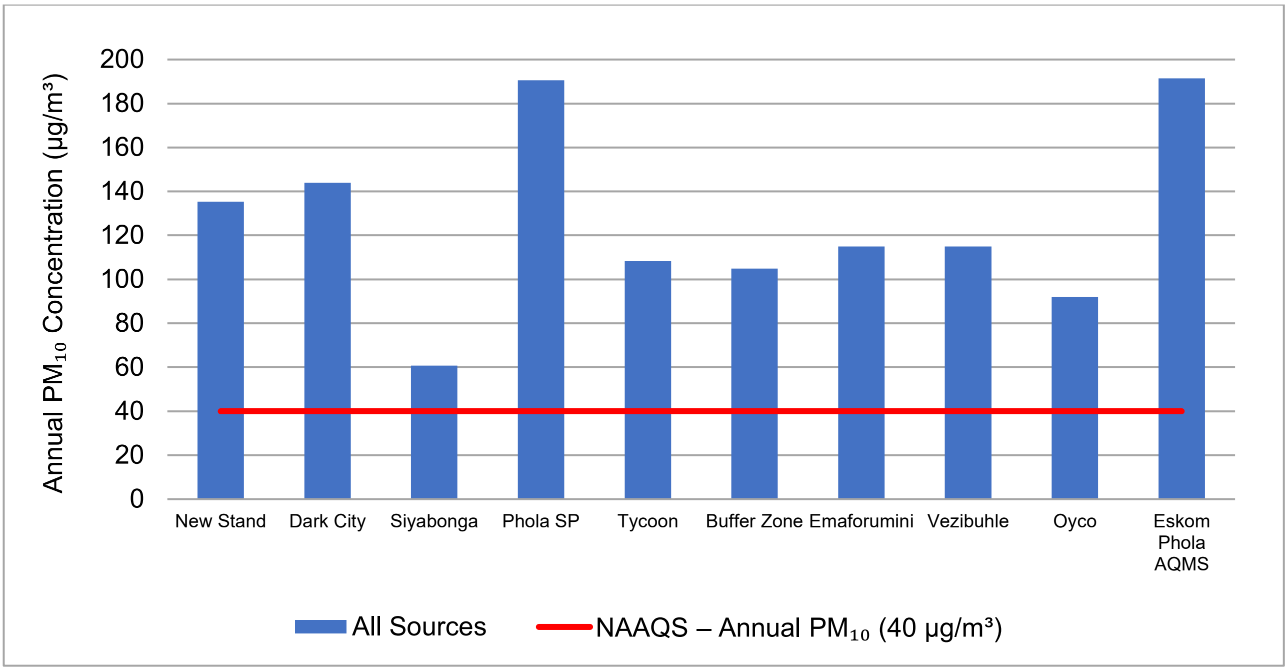


Figure 5-111: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the All Sources emission source category

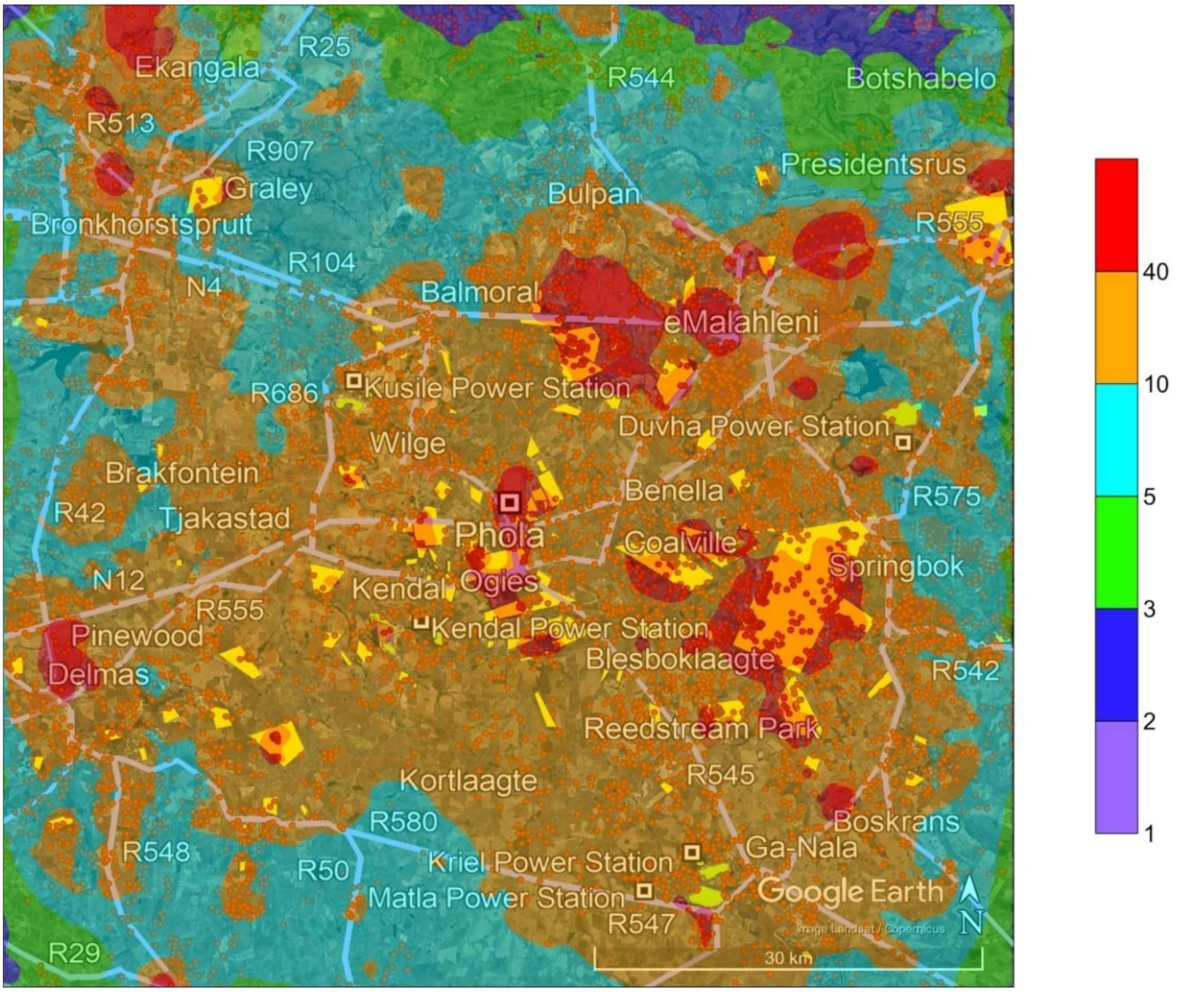


Figure 5-112: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

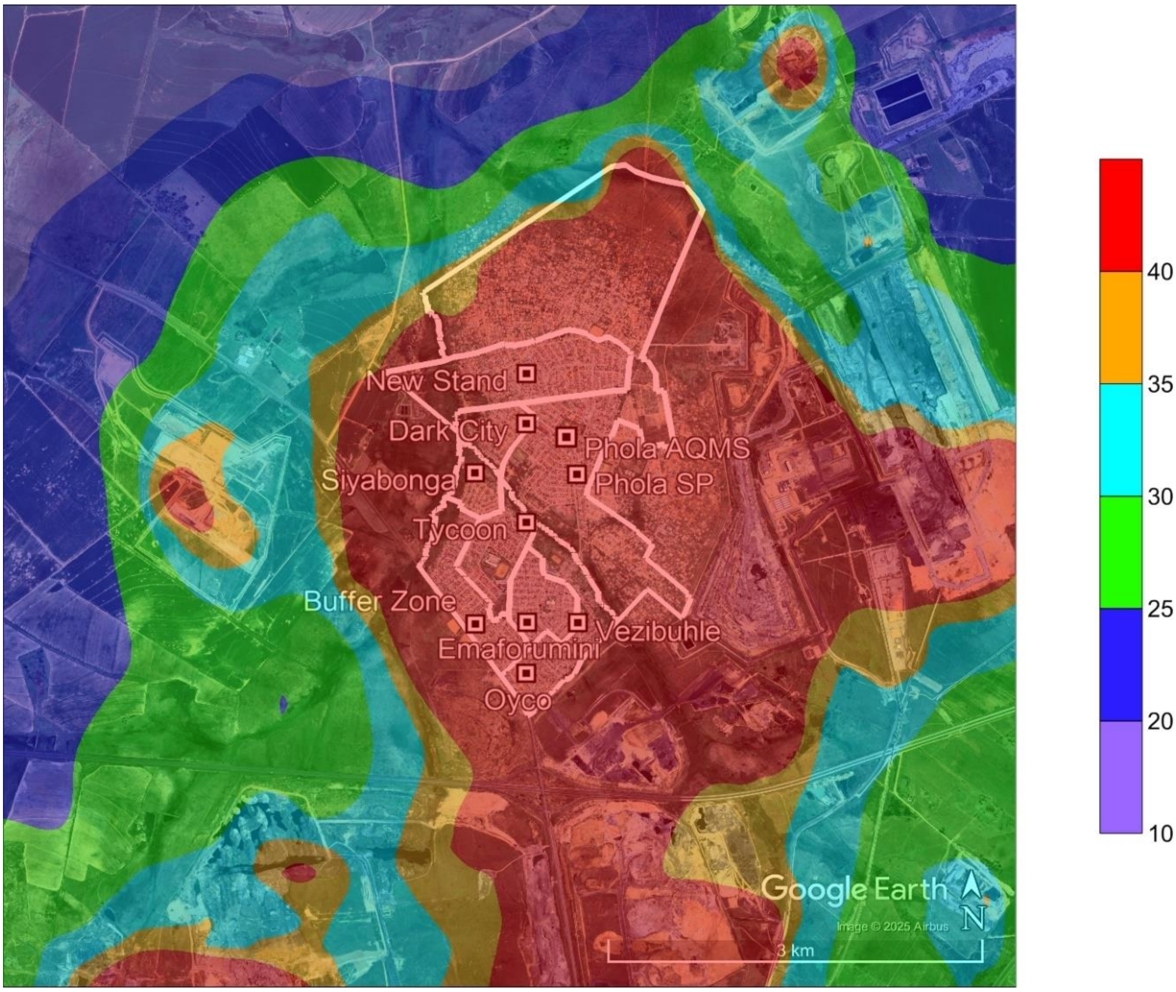


Figure 5-113: Model predicted annual PM_{10} ambient concentrations in µg/m³ for the All Sources emission source category within the Phola Airshed

5.3.3 PM_{10} SOURCE CONTRIBUTION ANALYSIS

In this study, the PM_{10} source contribution analysis is based on model predicted annual PM_{10} ambient concentrations at the discrete receptors for the seven emission source categories which include power generation, residential fuel burning, waste burning, biomass burning, vehicles – paved roads, vehicles – unpaved roads and mining (Table 5-9). Table 5-9 is used to calculate the percent contribution of PM_{10} at each discrete receptor as a function of the seven source categories, and is presented in Table 5-10.

Table 5-10: PM_{10} source contribution (%) at discrete receptors for the seven emission source categories based on model predicted annual PM_{10} ambient concentrations

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	1.57	61.96	12.97	1.67	0.21	14.94	6.68	100.00
Dark City	1.49	64.19	13.20	1.39	0.22	12.97	6.54	100.00
Siyabonga	3.49	43.69	7.04	2.01	0.80	28.86	14.10	100.00
Phola SP	1.14	56.63	11.78	0.76	0.23	23.73	5.73	100.00
Tycoon	1.98	35.37	6.29	0.89	0.44	46.23	8.80	100.00
Buffer Zone	2.07	28.90	4.14	0.91	0.63	53.54	9.82	100.00
Emaforumini	1.90	29.50	4.34	0.79	0.42	53.58	9.47	100.00
Vezibuhle	1.91	36.18	6.31	0.77	0.31	44.22	10.28	100.00
Oyco	2.40	34.72	4.90	0.97	0.52	42.88	13.61	100.00
Eskom Phola AQMS	1.13	48.52	9.97	0.87	0.19	33.79	5.52	100.00

PM_{10} ambient concentrations (in terms of $\mu g/m^3$) for each emission source category at each discrete receptor is presented in the form of a stacked bar graph in Figure 5-114. The total PM_{10} ambient concentrations at each discrete receptor (which is made up of individual contributions representing each of the seven emission source categories) represents the All Sources emission source category. The PM_{10} source contribution in terms of percentages is presented in the form of a stacked bar graph in Figure 5-115. The sum of individual contributions resulting from each emission source category makes up 100%.

The source contribution analysis indicates that residential fuel burning and vehicles on unpaved roads are the main contributors to ambient PM_{10} levels in the Phola Airshed. It also indicates that waste burning and mining are relatively large contributors to the ambient PM_{10} levels. Ambient contributions from power generation, biomass burning and vehicles on paved roads are much smaller in comparison.

Residential fuel burning sources account for approximately 28.90-64.19% of the total PM_{10} ambient concentrations at the Phola discrete receptors. This is expected as these sources are in close proximity to the receptors.

Vehicle on unpaved roads account for approximately 12.97-53.58% of the total PM_{10} ambient concentrations at the Phola discrete receptors. This is expected as dense network of unpaved roads are located close to the receptors.

Waste burning sources account for approximately 4.14-13.20% of the total PM_{10} ambient concentrations while mining sources account for approximately 5.73-14.10% of the total PM_{10} ambient concentrations at the Phola discrete receptors.

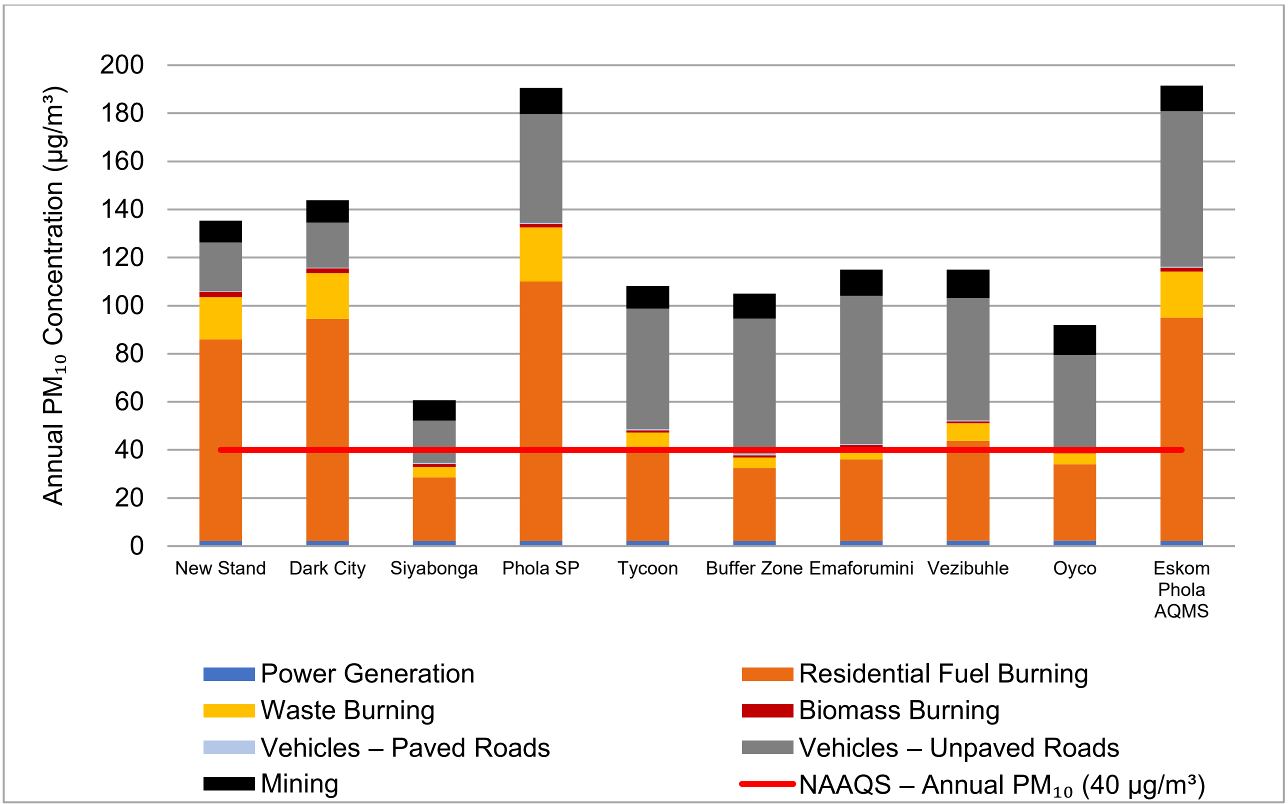


Figure 5-114: Stacked bar graph representing model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors for the six emission source categories

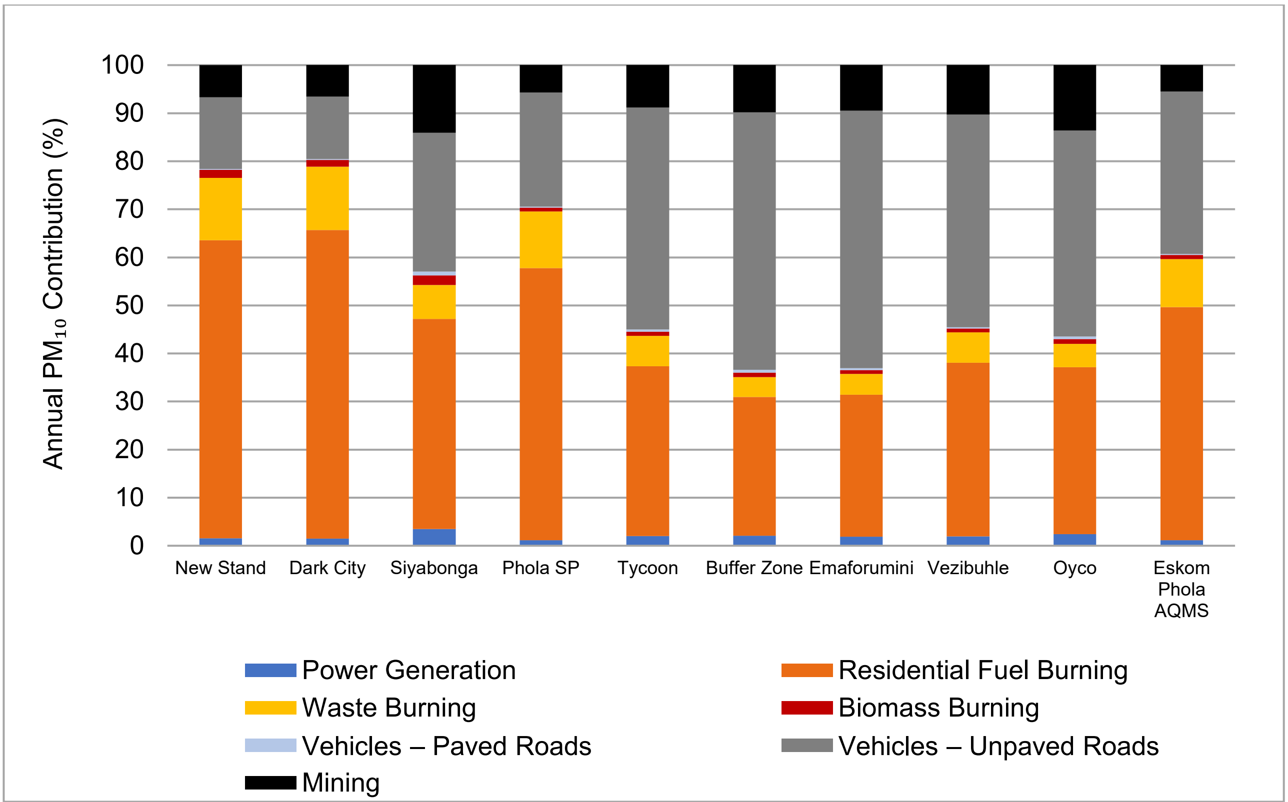


Figure 5-115: Stacked bar graph representing the percent contribution of PM_{10} ambient concentrations at discrete receptors as a function of source category

5.4 PREDICTED $PM_{2.5}$ AMBIENT CONCENTRATIONS

5.4.1 24-HOUR $PM_{2.5}$

Model predicted 24-hour $PM_{2.5}$ ambient concentrations at discrete receptors and at the point of maximum for the eight emission source categories are presented in Table 5-11. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted 24-hour $PM_{2.5}$ ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-116 for the Power Generation emission source category
- Figure 5-118 for the Residential Fuel Burning emission source category
- Figure 5-120 for the Waste Burning emission source category
- Figure 5-122 for the Biomass Burning emission source category
- Figure 5-124 for the Vehicles – Paved Roads emission source category
- Figure 5-126 for the Vehicles – Unpaved Roads emission source category
- Figure 5-128 for the Mining emission source category
- Figure 5-130 for the All Sources emission source category

Contour plots for model predicted 24-hour $PM_{2.5}$ ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-117 for the Power Generation emission source category
- Figure 5-119 for the Residential Fuel Burning emission source category
- Figure 5-121 for the Waste Burning emission source category
- Figure 5-123 for the Biomass Burning emission source category
- Figure 5-125 for the Vehicles – Paved Roads emission source category
- Figure 5-127 for the Vehicles – Unpaved Roads emission source category
- Figure 5-129 for the Mining emission source category
- Figure 5-131 for the All Sources emission source category

Contour plots for model predicted 24-hour $PM_{2.5}$ ambient concentrations for the Phola Airshed is presented in Figure 5-132 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-11: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	11.70	260.07	45.00	4.93	1.42	4.56	7.25	300.82
Dark City	11.65	246.83	43.88	4.57	1.52	4.91	7.52	286.79
Siyabonga	11.54	70.36	10.86	2.61	1.67	4.23	6.98	95.83
Phola SP	11.91	274.35	57.72	3.18	1.72	11.81	8.46	337.44
Tycoon	11.66	89.90	16.32	2.22	1.67	9.99	7.53	125.40
Buffer Zone	12.37	83.72	12.57	2.20	2.26	13.55	7.80	116.58
Emaforumini	12.50	93.31	13.35	2.08	1.73	14.09	8.08	127.16
Vezibuhle	12.38	107.35	19.01	2.00	1.49	10.52	8.89	141.45
Oyco	12.81	84.54	12.38	2.02	1.75	9.38	9.06	114.73
Eskom Phola AQMS	11.51	241.49	46.47	3.55	1.60	16.44	8.29	300.06
Maximum	156.91	1693.14	248.89	39.12	35.06	40.30	72.79	1876.17
	NAAQS – 24-hour $PM_{2.5}$ (40 µg/m³)							

According to Table 5-11, model predicted 24-hour $PM_{2.5}$ ambient concentrations exceed the 24-hour $PM_{2.5}$ NAAQS of 40 µg/m³ at all discrete receptors and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories; and at three discrete receptors (New Stand, Dark City, Phola SP) and the Eskom Phola AQMS for the Waste Burning emission source category in the Phola Airshed.

Model predicted 24-hour $PM_{2.5}$ ambient concentrations also exceed the 24-hour $PM_{2.5}$ NAAQS of 40 µg/m³ at the point of maximum for the Power Generation, Residential Fuel Burning, Waste Burning, Vehicles – Unpaved Roads, Mining and All Sources emission source categories in the Greater Phola Airshed.

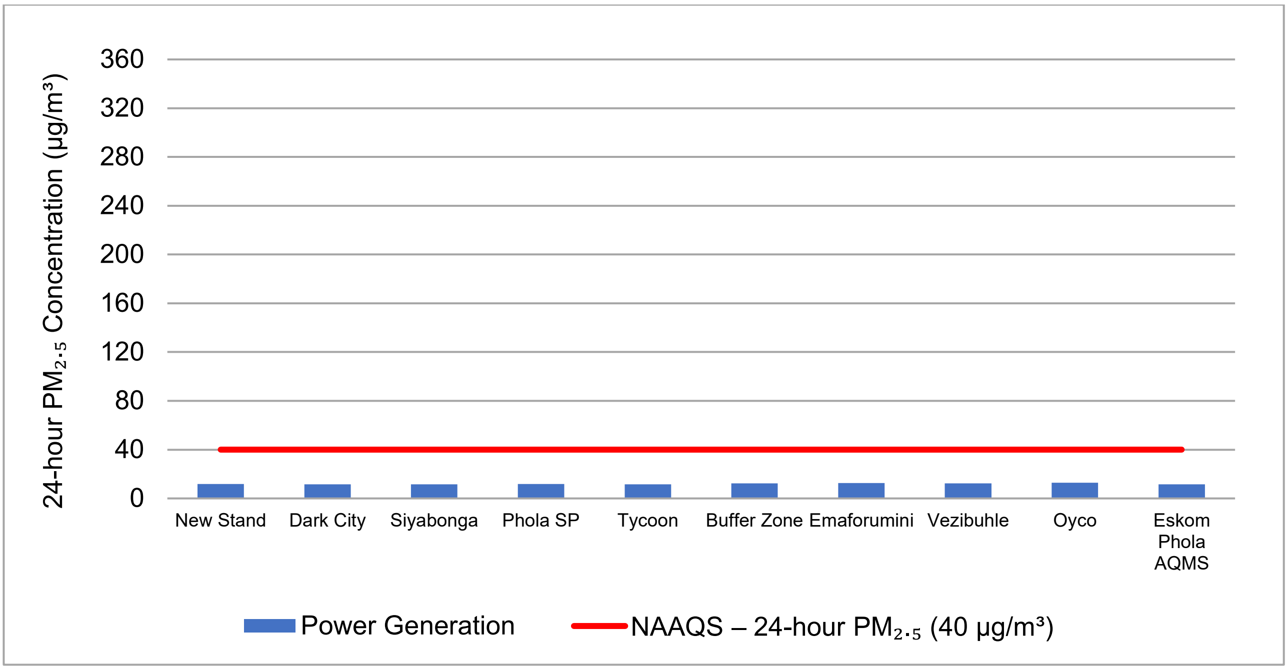


Figure 5-116: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Power Generation emission source category

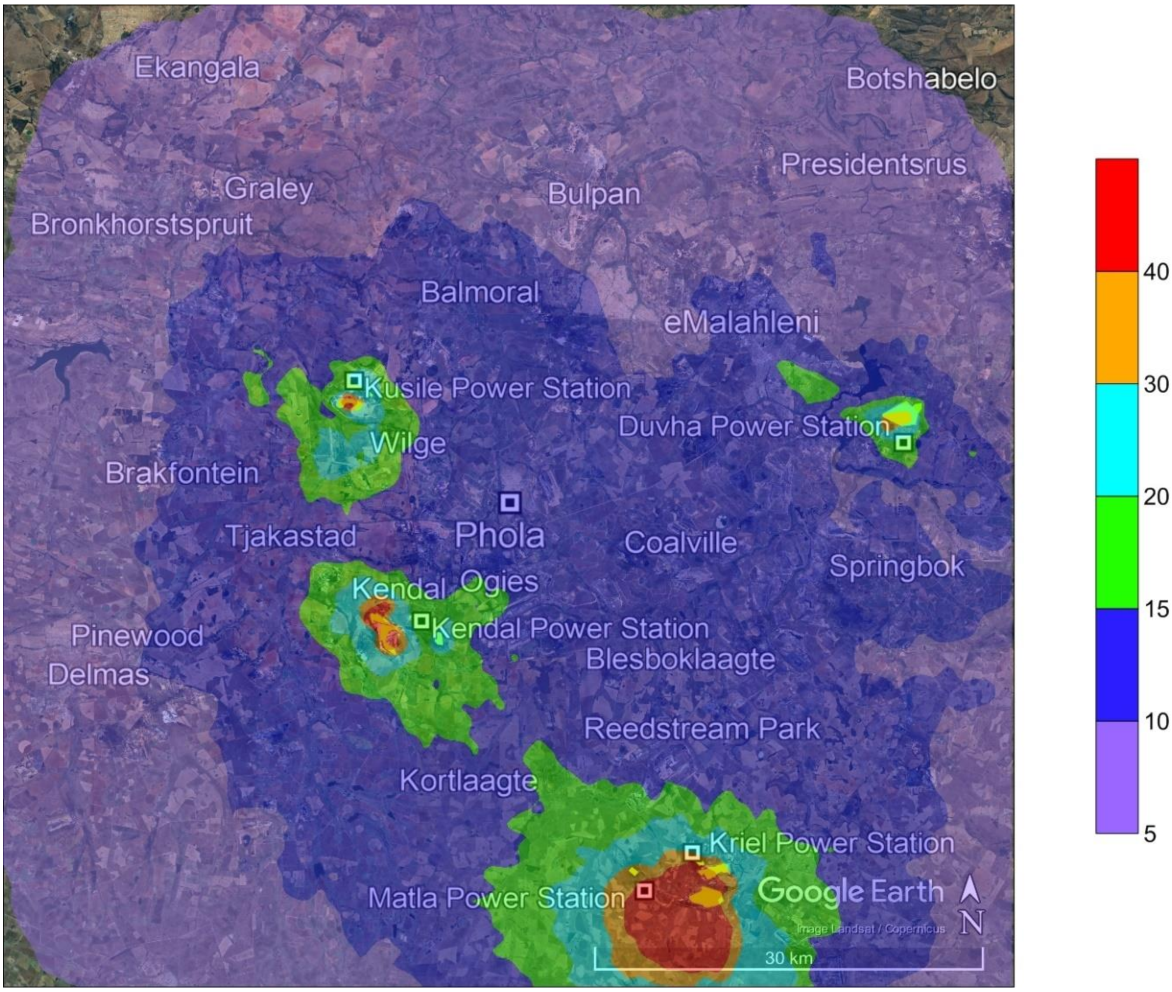


Figure 5-117: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

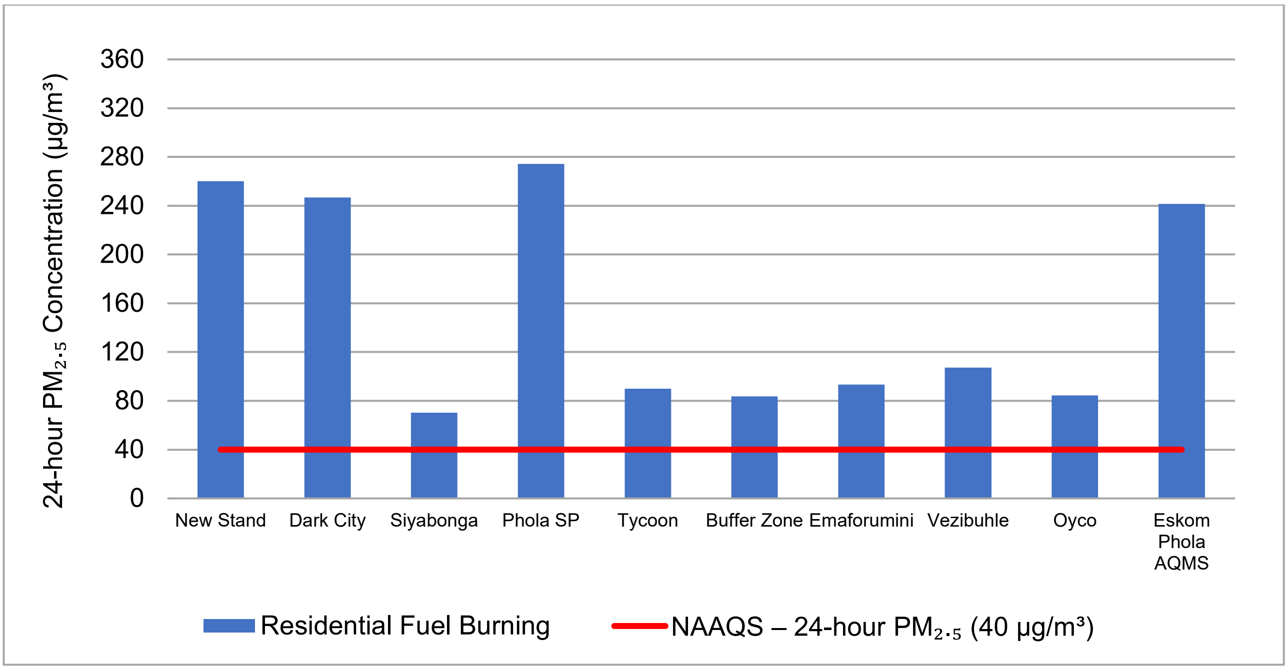


Figure 5-118: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

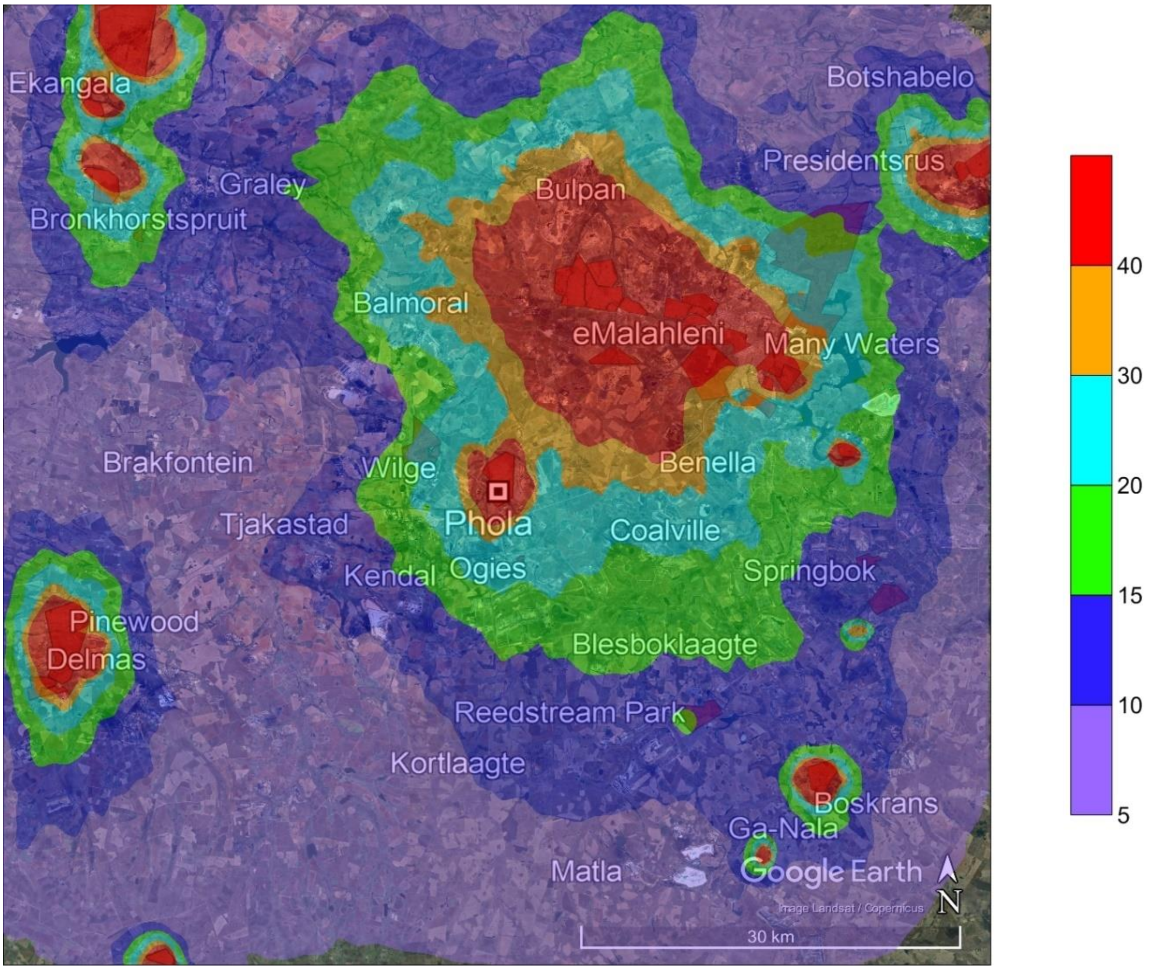


Figure 5-119: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

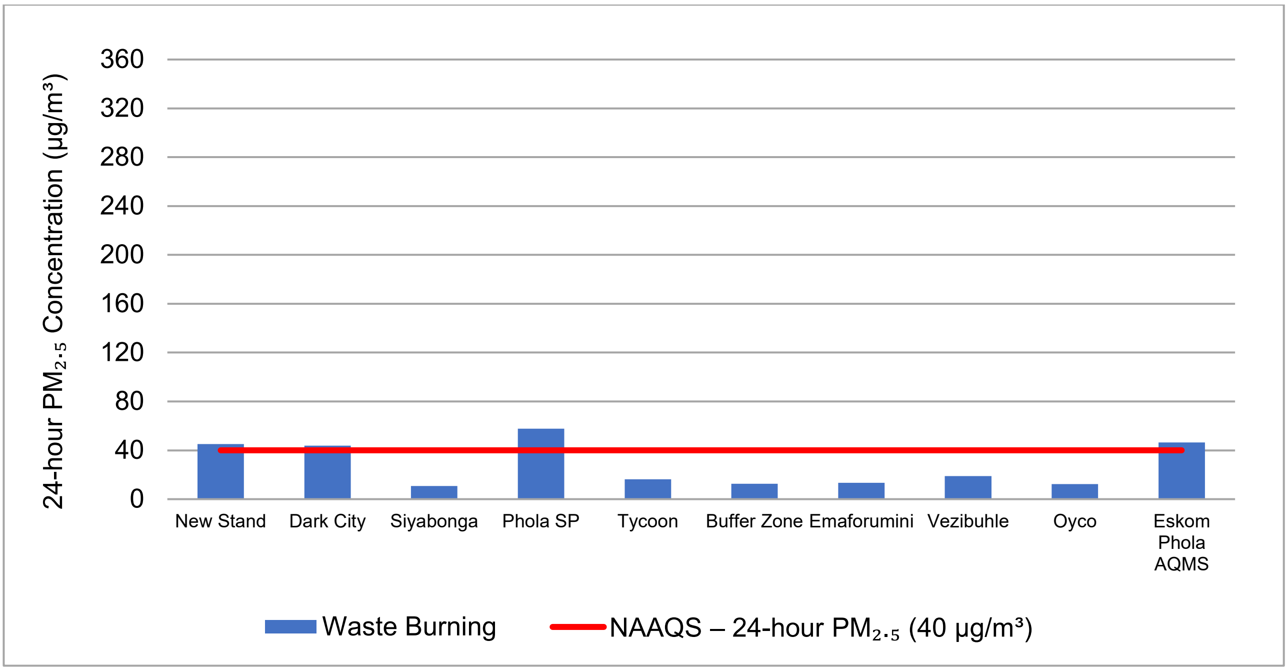


Figure 5-120: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Waste Burning emission source category

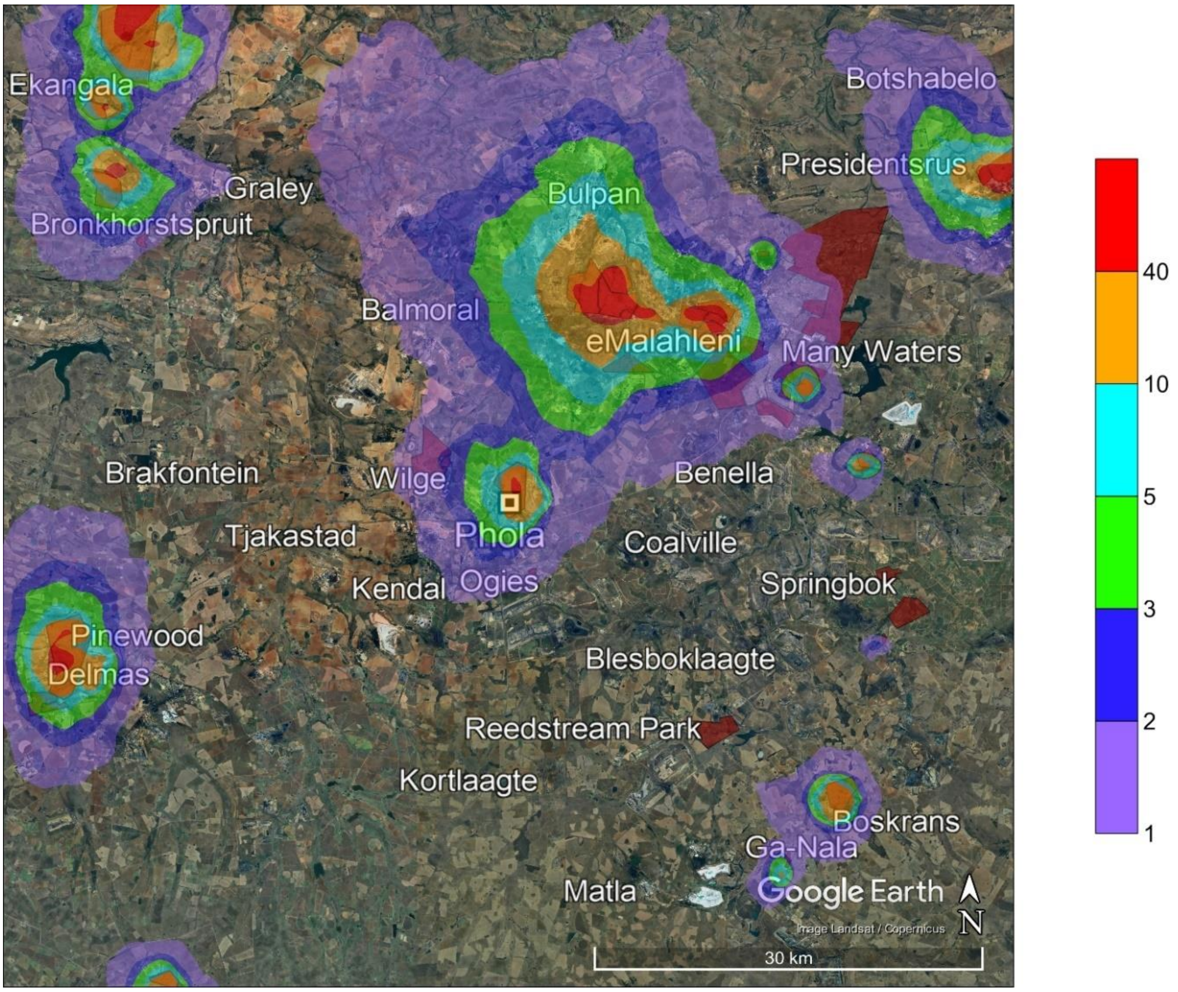


Figure 5-121: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

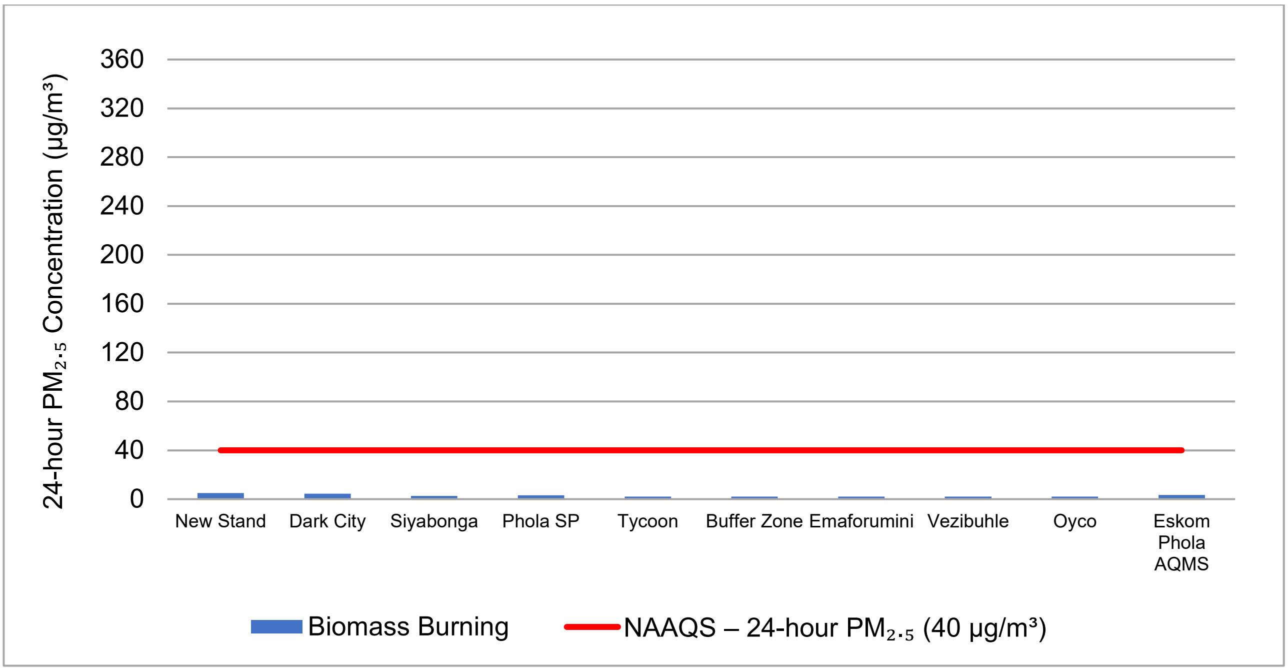


Figure 5-122: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Biomass Burning emission source category

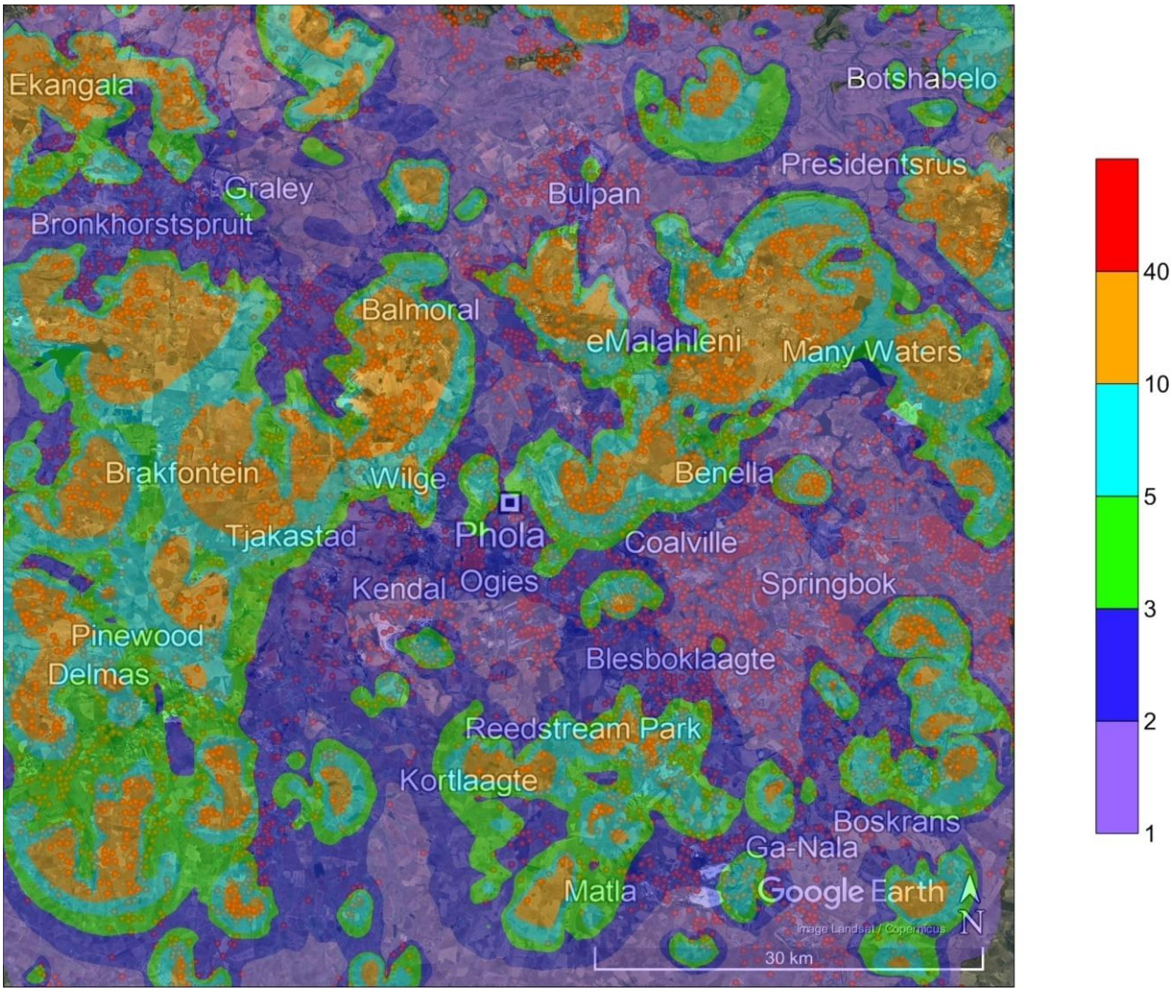


Figure 5-123: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the Biomass Burning emission source category within the Greater Phola Airshed

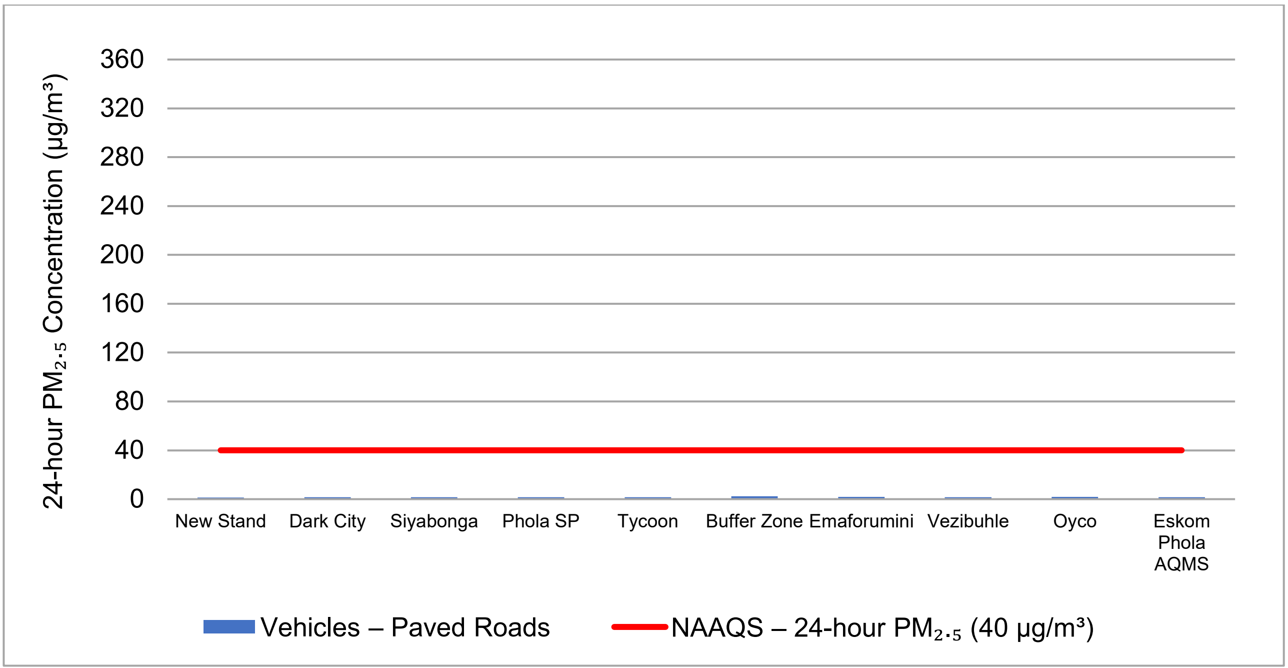


Figure 5-124: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m^3 at discrete receptors for the Vehicles – Paved Roads emission source category

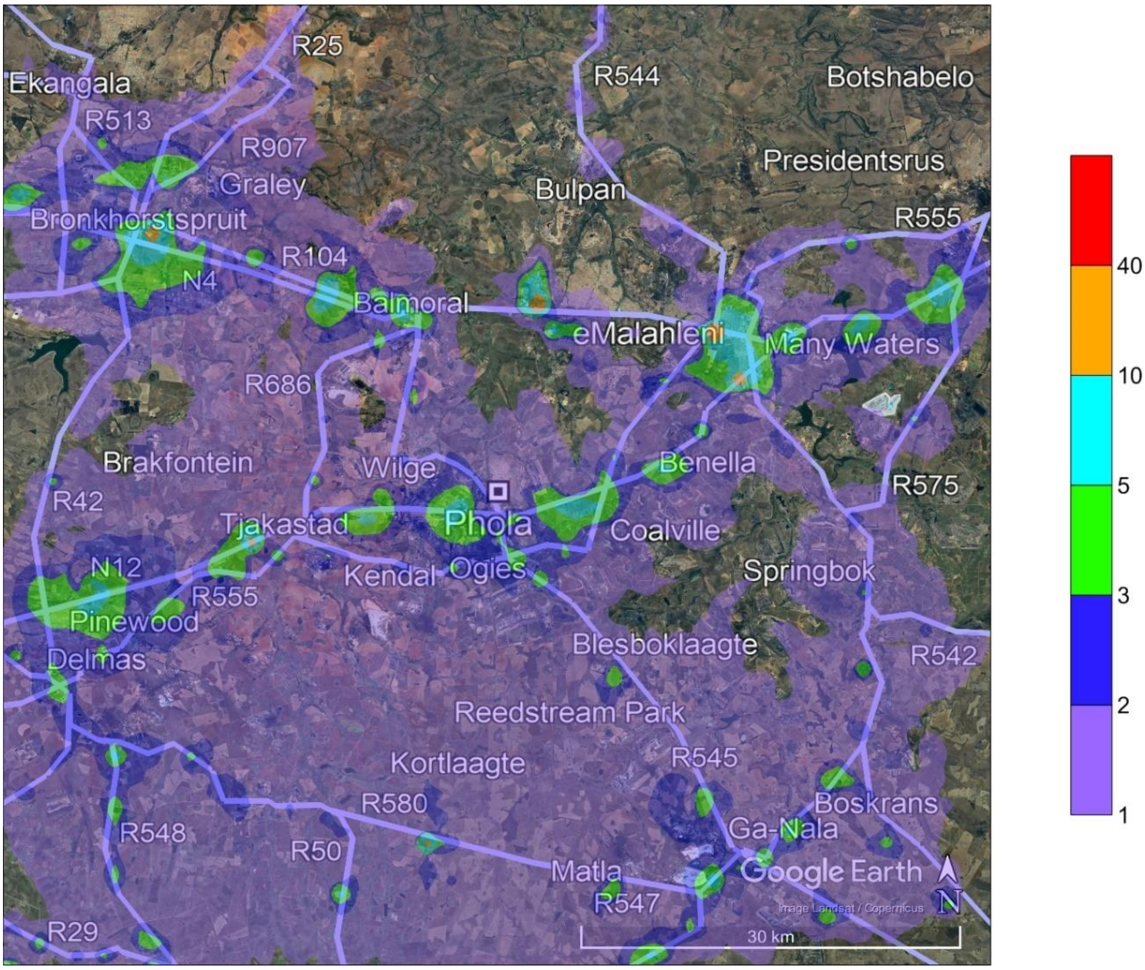


Figure 5-125: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m^3 for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

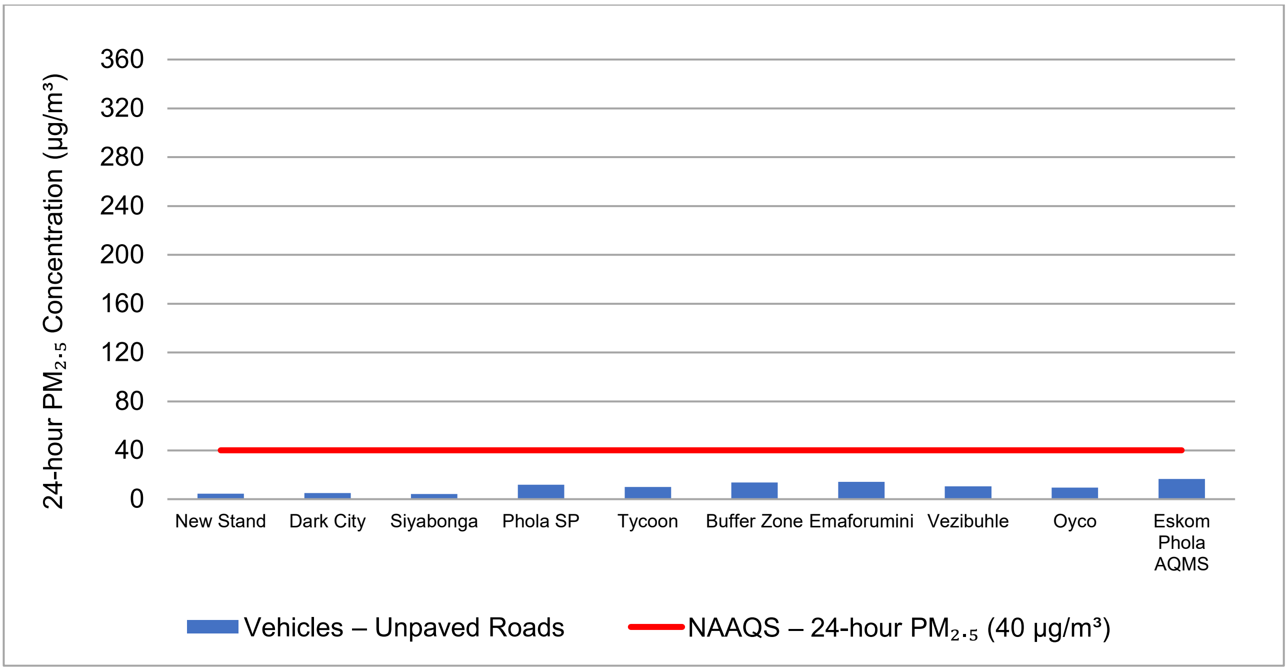


Figure 5-126: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in μg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

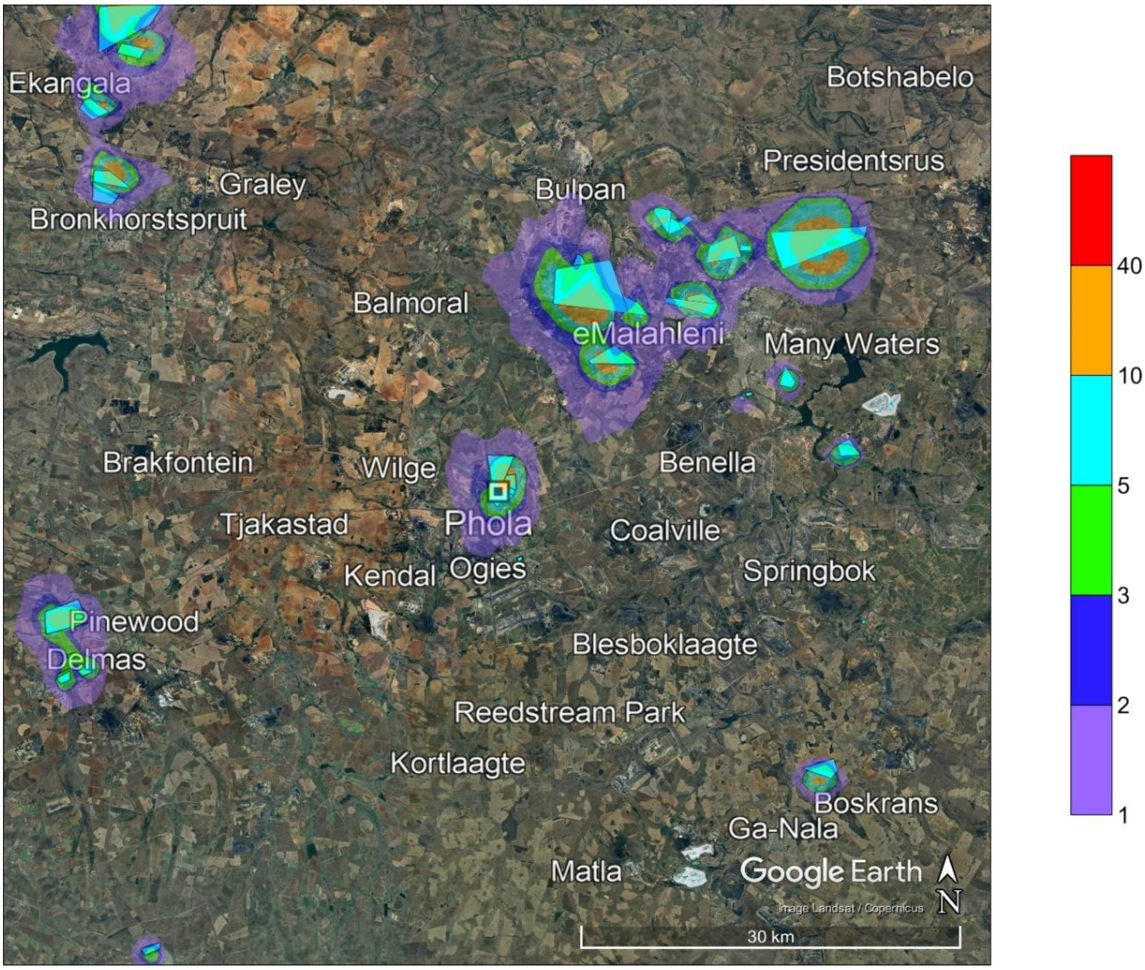


Figure 5-127: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in μg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

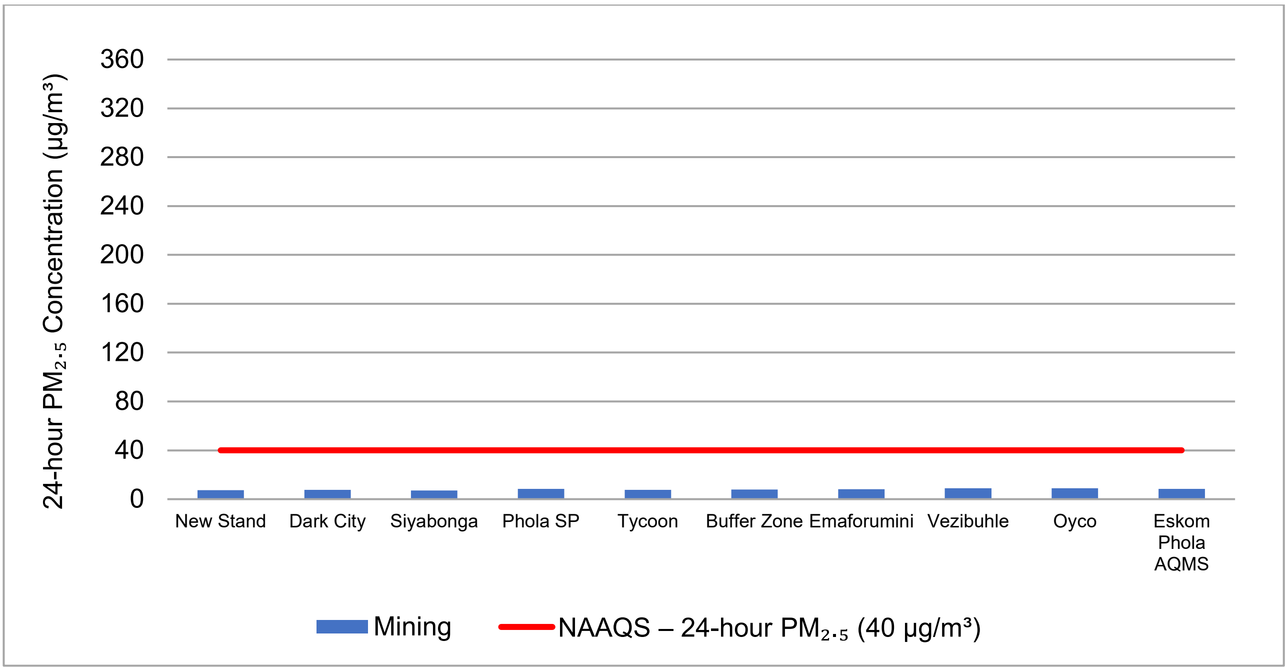


Figure 5-128: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the Mining emission source category

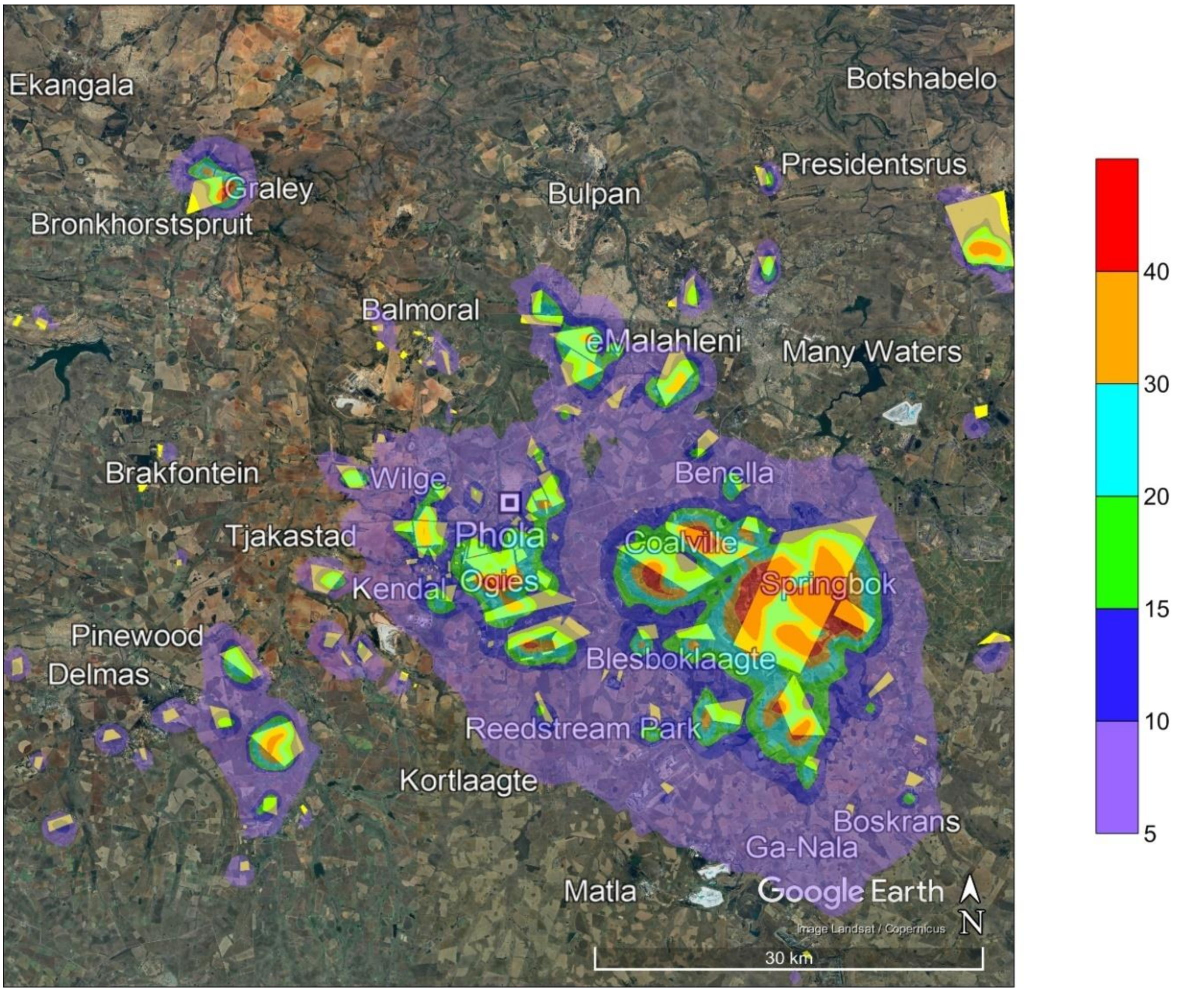


Figure 5-129: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the Mining emission source category within the Greater Phola Airshed

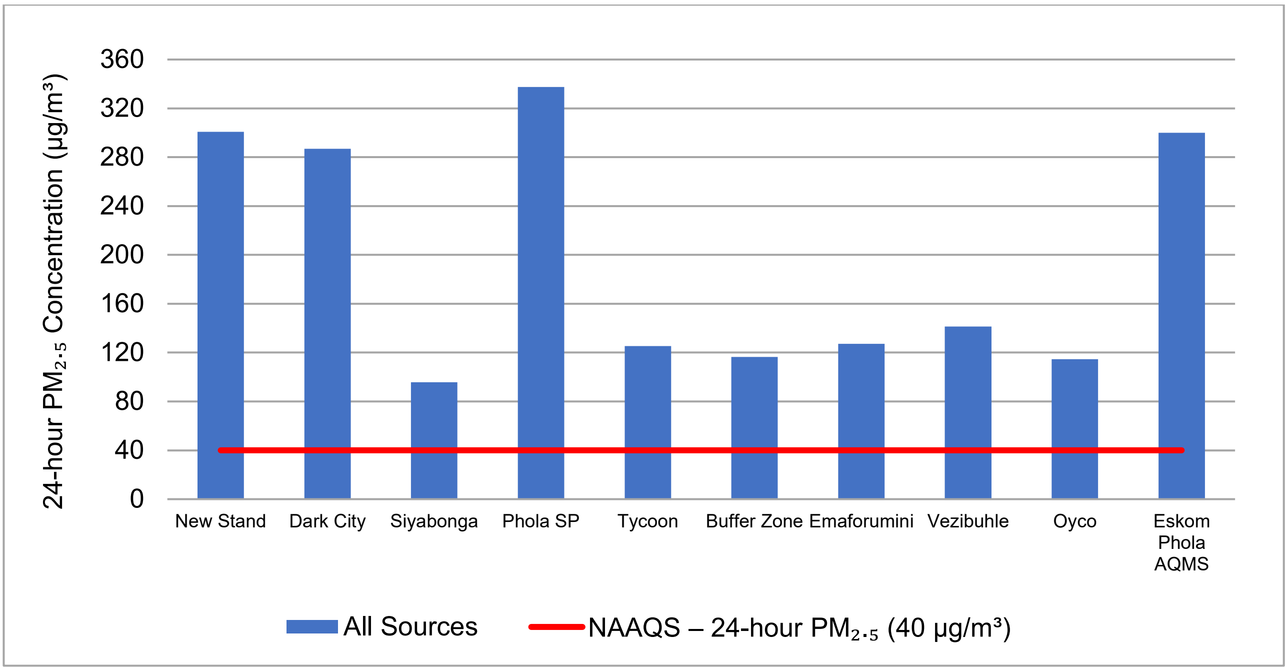


Figure 5-130: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors for the All Sources emission source category

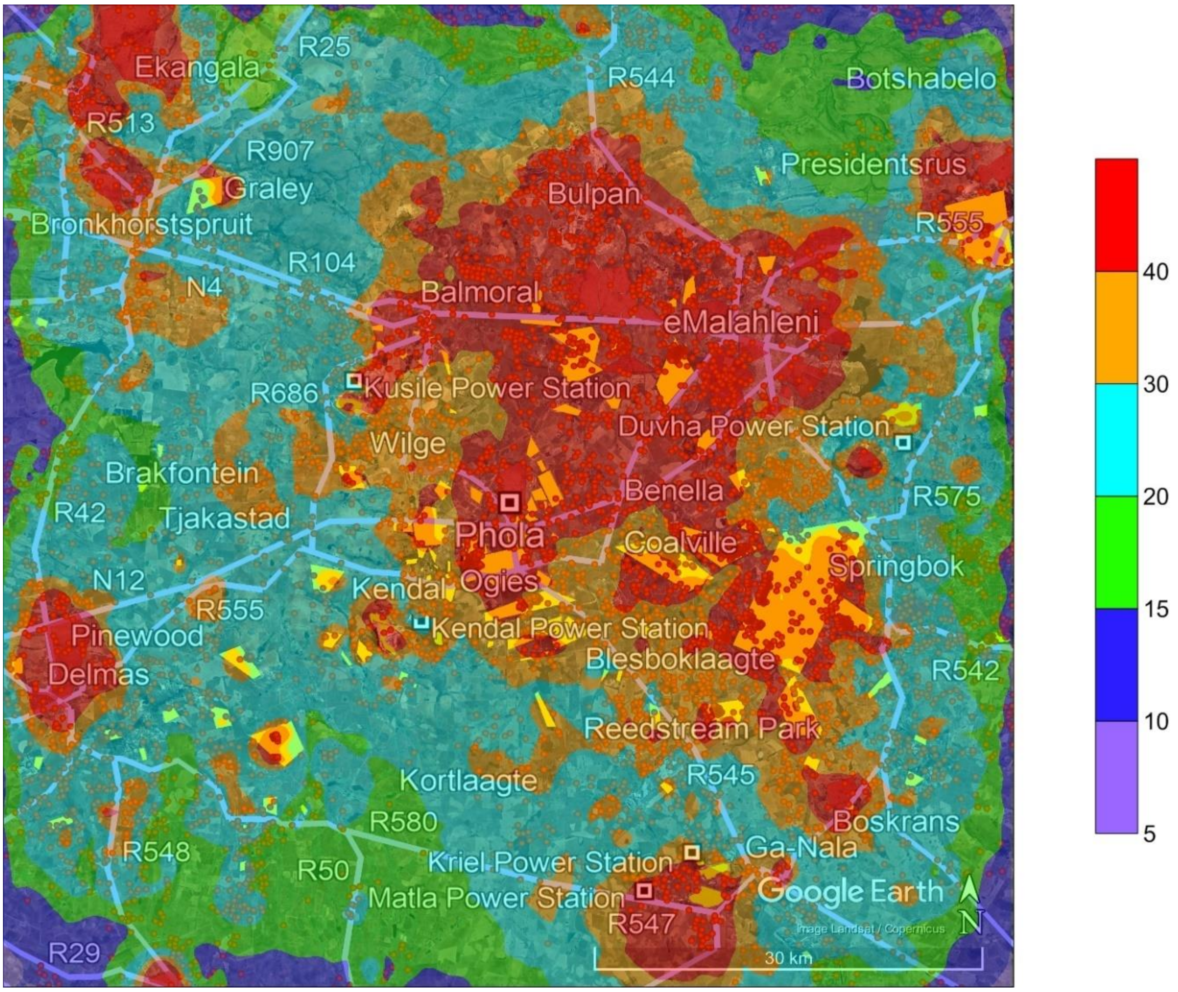


Figure 5-131: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

Figure 5-132: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ for the All Sources emission source category within the Phola Airshed

5.4.2 ANNUAL $PM_{2.5}$

Model predicted annual $PM_{2.5}$ ambient concentrations at discrete receptors and at the point of maximum for the eight emission source categories are presented in Table 5-12. If applicable, exceedances of the NAAQS are highlighted in red.

Bar graphs for model predicted annual $PM_{2.5}$ ambient concentrations at discrete receptors are presented in the following order:

- Figure 5-133 for the Power Generation emission source category
- Figure 5-135 for the Residential Fuel Burning emission source category
- Figure 5-137 for the Waste Burning emission source category
- Figure 5-139 for the Biomass Burning emission source category
- Figure 5-141 for the Vehicles – Paved Roads emission source category
- Figure 5-143 for the Vehicles – Unpaved Roads emission source category
- Figure 5-145 for the Mining emission source category
- Figure 5-147 for the All Sources emission source category

Contour plots for model predicted annual $PM_{2.5}$ ambient concentrations for the Greater Phola Airshed are presented in the following order:

- Figure 5-134 for the Power Generation emission source category
- Figure 5-136 for the Residential Fuel Burning emission source category
- Figure 5-138 for the Waste Burning emission source category
- Figure 5-140 for the Biomass Burning emission source category
- Figure 5-142 for the Vehicles – Paved Roads emission source category
- Figure 5-144 for the Vehicles – Unpaved Roads emission source category
- Figure 5-146 for the Mining emission source category
- Figure 5-148 for the All Sources emission source category

Contour plots for model predicted annual $PM_{2.5}$ ambient concentrations for the Phola Airshed is presented in Figure 5-149 for the All Sources emission source category.

With respect to contour plots for the primary and Phola Airshed, areas of exceedance of the NAAQS is coloured in red.

Table 5-12: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	1.18	78.07	17.50	2.17	0.28	2.03	2.41	103.65
Dark City	1.19	85.95	18.92	1.93	0.32	1.87	2.51	112.69
Siyabonga	1.18	24.69	4.26	1.18	0.49	1.76	2.28	35.84
Phola SP	1.21	100.43	22.37	1.40	0.44	4.54	2.91	133.30
Tycoon	1.20	35.63	6.79	0.92	0.47	5.02	2.54	52.56
Buffer Zone	1.21	28.22	4.32	0.92	0.66	5.64	2.75	43.72
Emaforumini	1.21	31.57	4.97	0.87	0.48	6.18	2.90	48.18
Vezibuhle	1.22	38.70	7.22	0.85	0.36	5.10	3.15	56.60
Oyco	1.22	29.70	4.49	0.85	0.48	3.95	3.34	44.03
Eskom Phola AQMS	1.21	86.44	19.01	1.60	0.36	6.49	2.82	117.94
Maximum	23.22	600.05	115.59	15.79	7.00	18.74	32.94	720.25
	NAAQS – Annual $PM_{2.5}$ (20 µg/m³)							

According to Table 5-12, model predicted annual $PM_{2.5}$ ambient concentrations exceed the annual $PM_{2.5}$ NAAQS of 20 µg/m³ at all discrete receptors and the Eskom Phola AQMS for the Residential Fuel Burning and All Sources emission source categories; and at one discrete receptors (Phola SP) for the Waste Burning emission source category in the Phola Airshed.

Model predicted annual $PM_{2.5}$ ambient concentrations also exceed the annual $PM_{2.5}$ NAAQS of 20 µg/m³ at the point of maximum for the Power Generation, Residential Fuel Burning, Waste Burning, Mining and All Sources emission source categories in the Greater Phola Airshed.

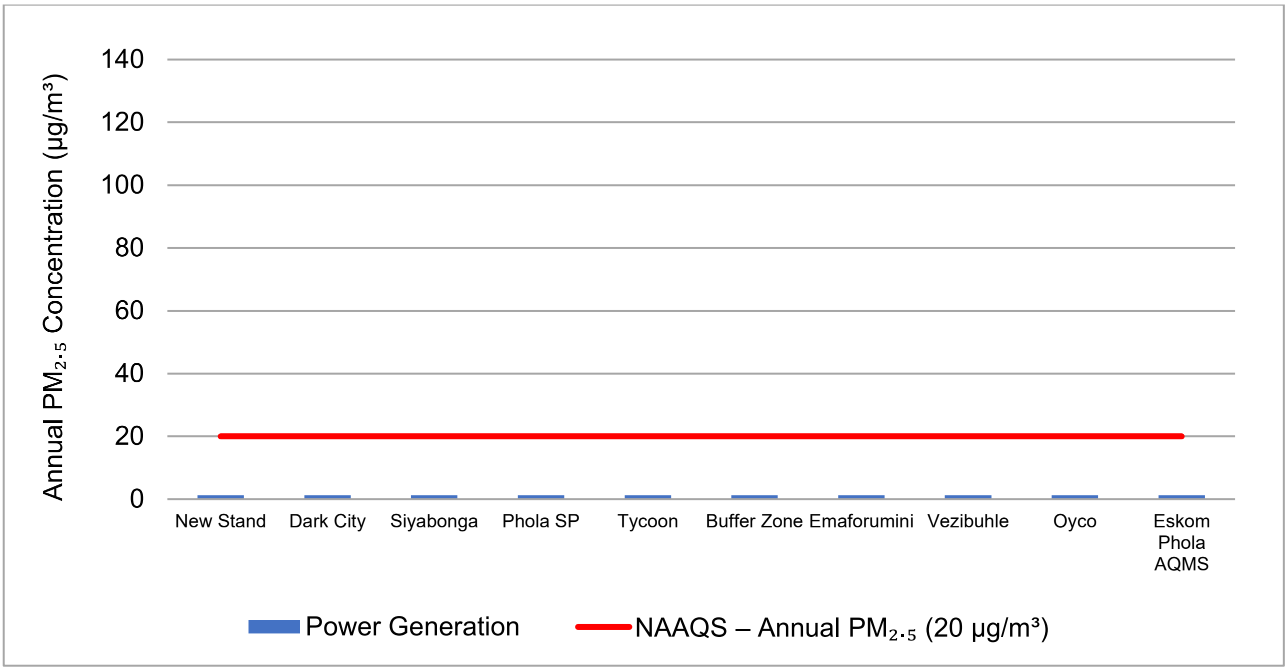


Figure 5-133: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Power Generation emission source category

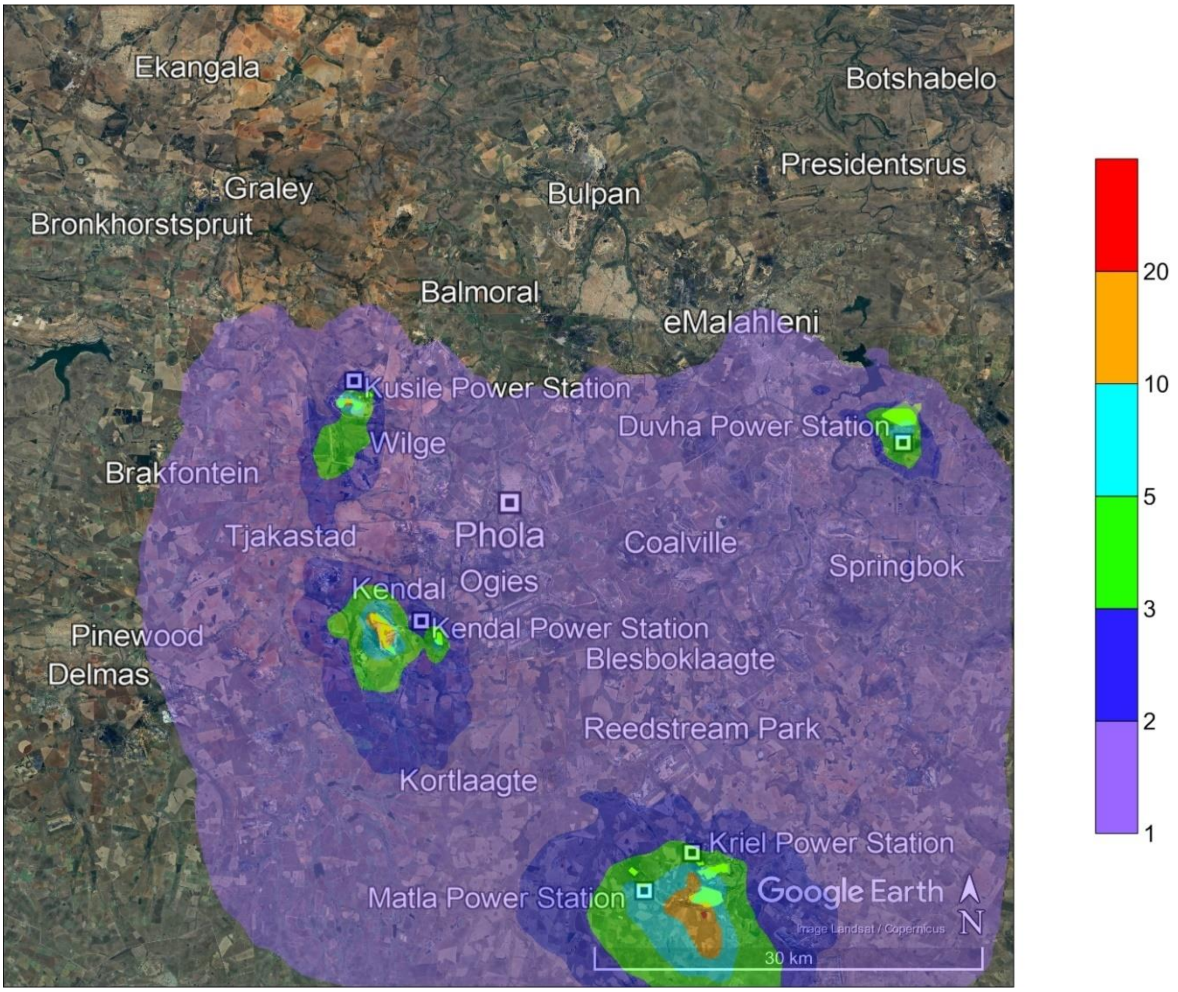


Figure 5-134: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Power Generation emission source category within the Greater Phola Airshed

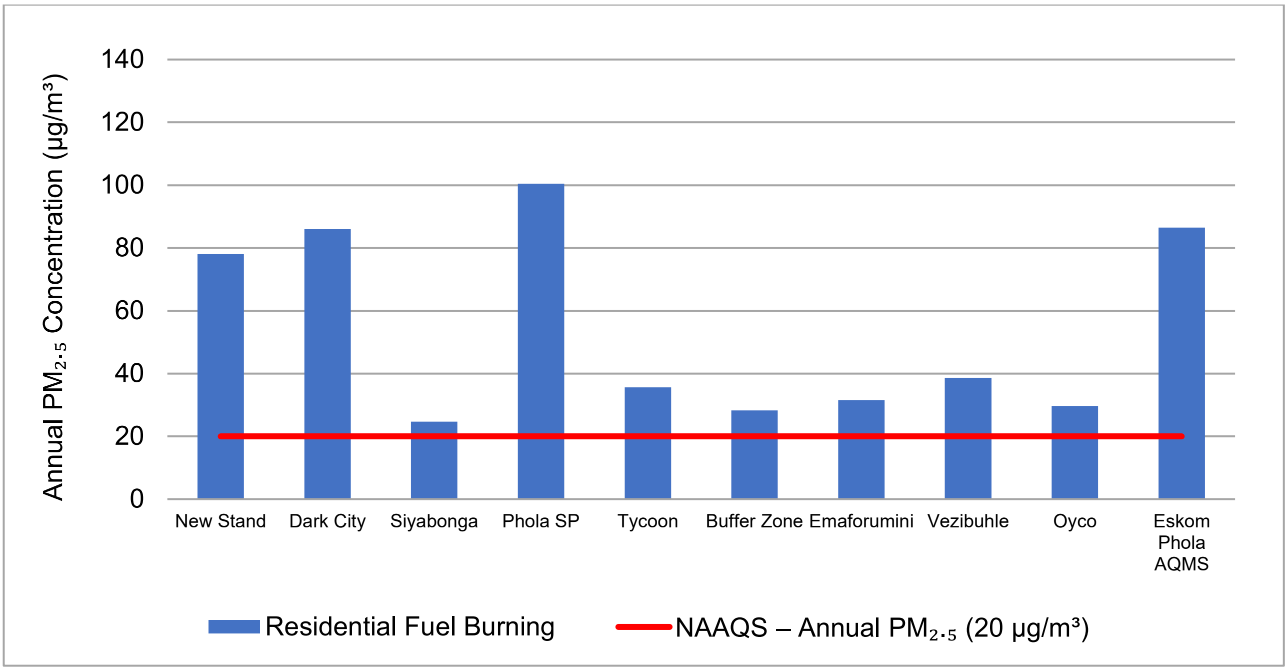


Figure 5-135: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Residential Fuel Burning emission source category

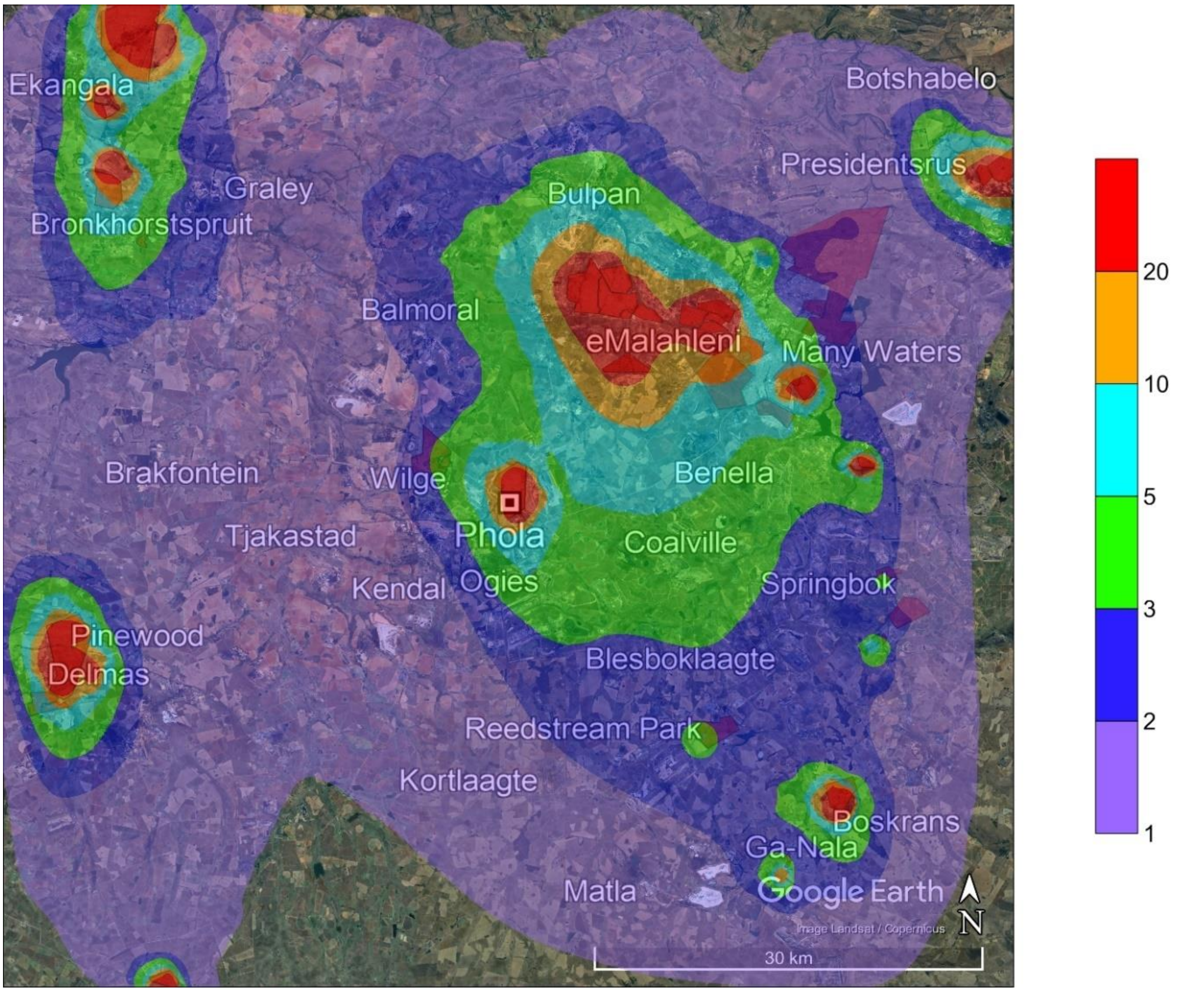


Figure 5-136: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Residential Fuel Burning emission source category within the Greater Phola Airshed

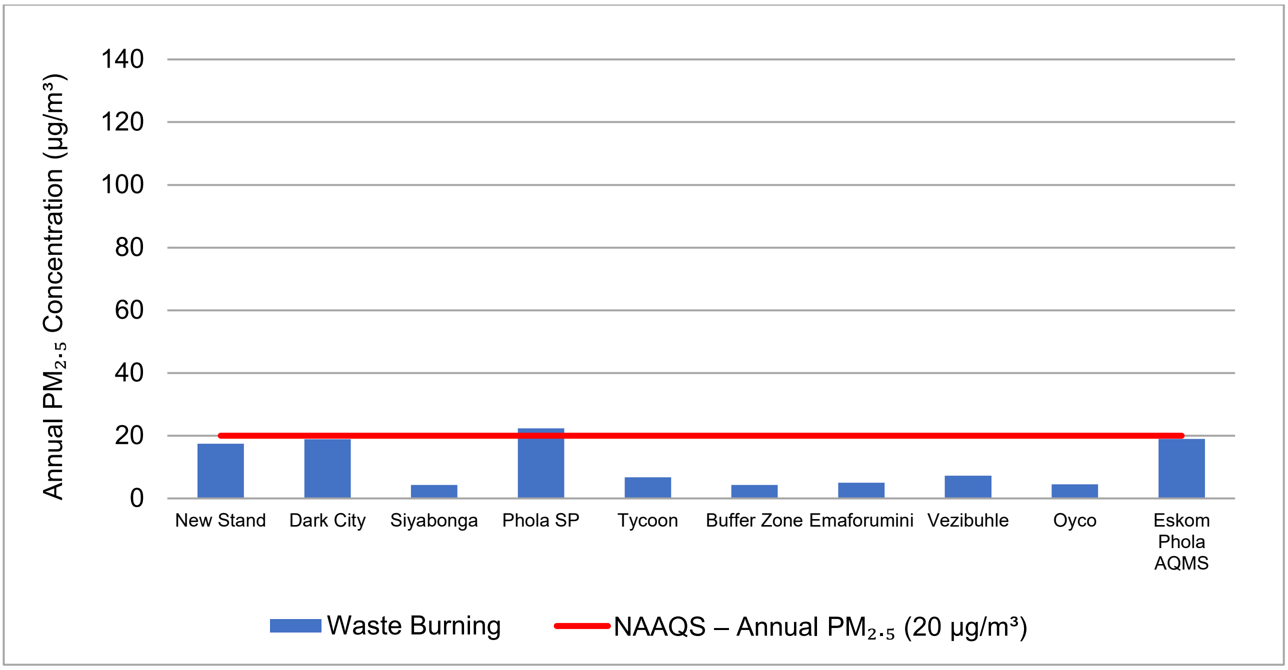


Figure 5-137: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Waste Burning emission source category

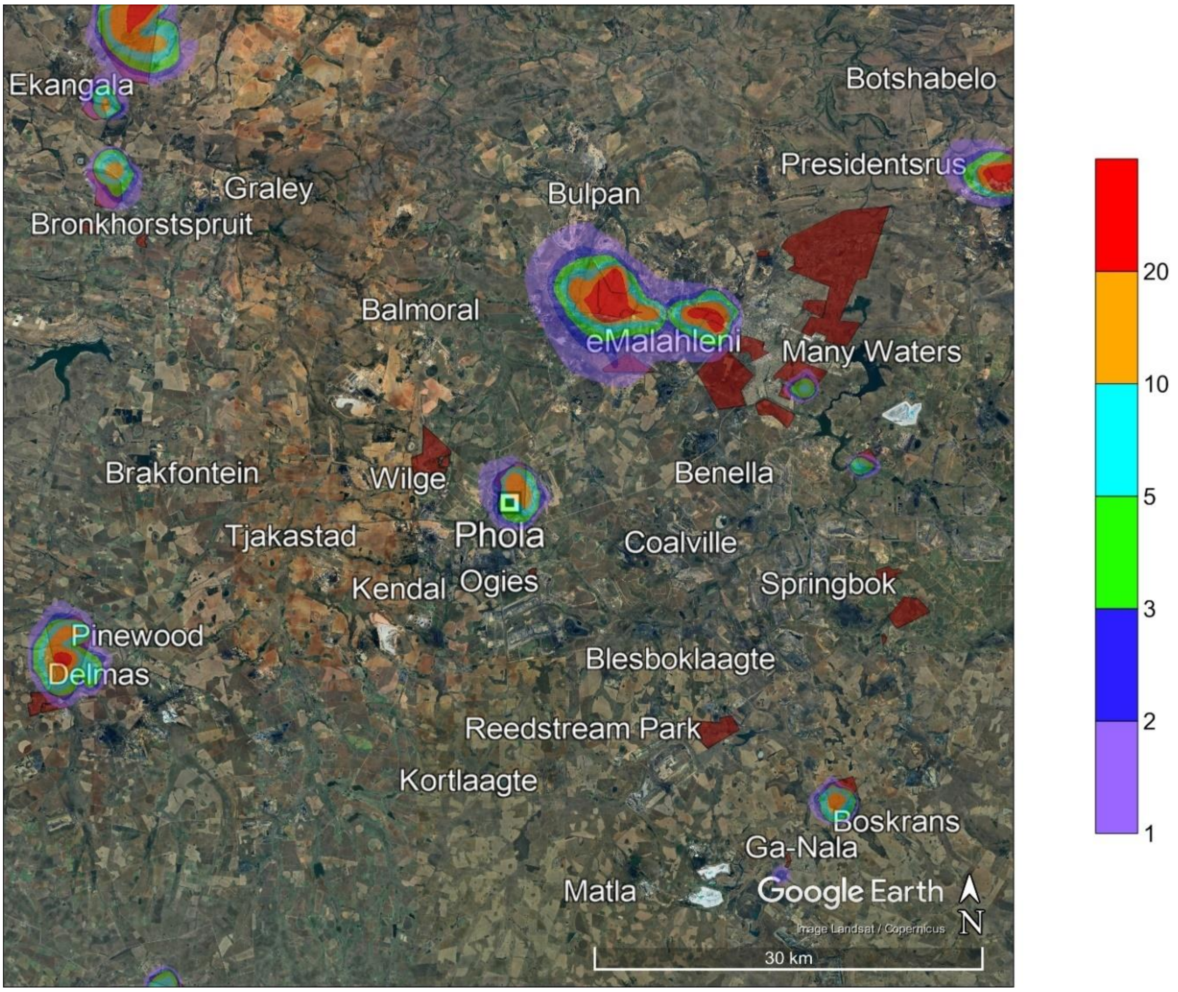


Figure 5-138: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Waste Burning emission source category within the Greater Phola Airshed

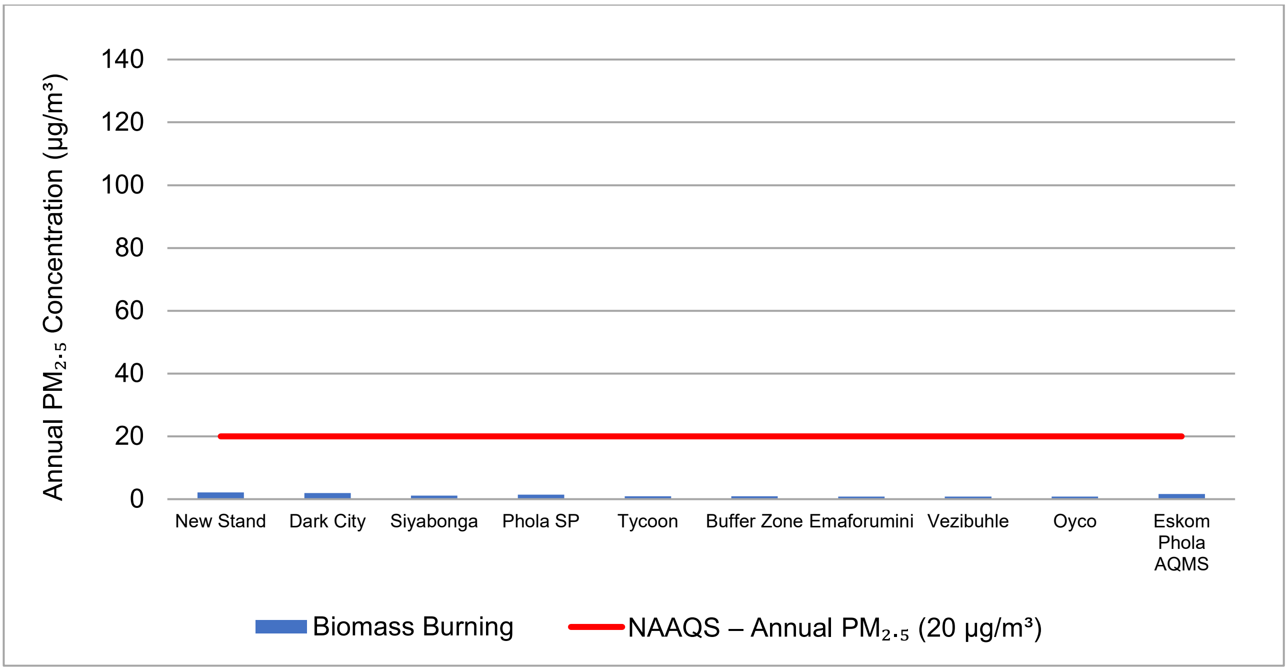


Figure 5-139: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m^3 at discrete receptors for the Biomass Burning emission source category

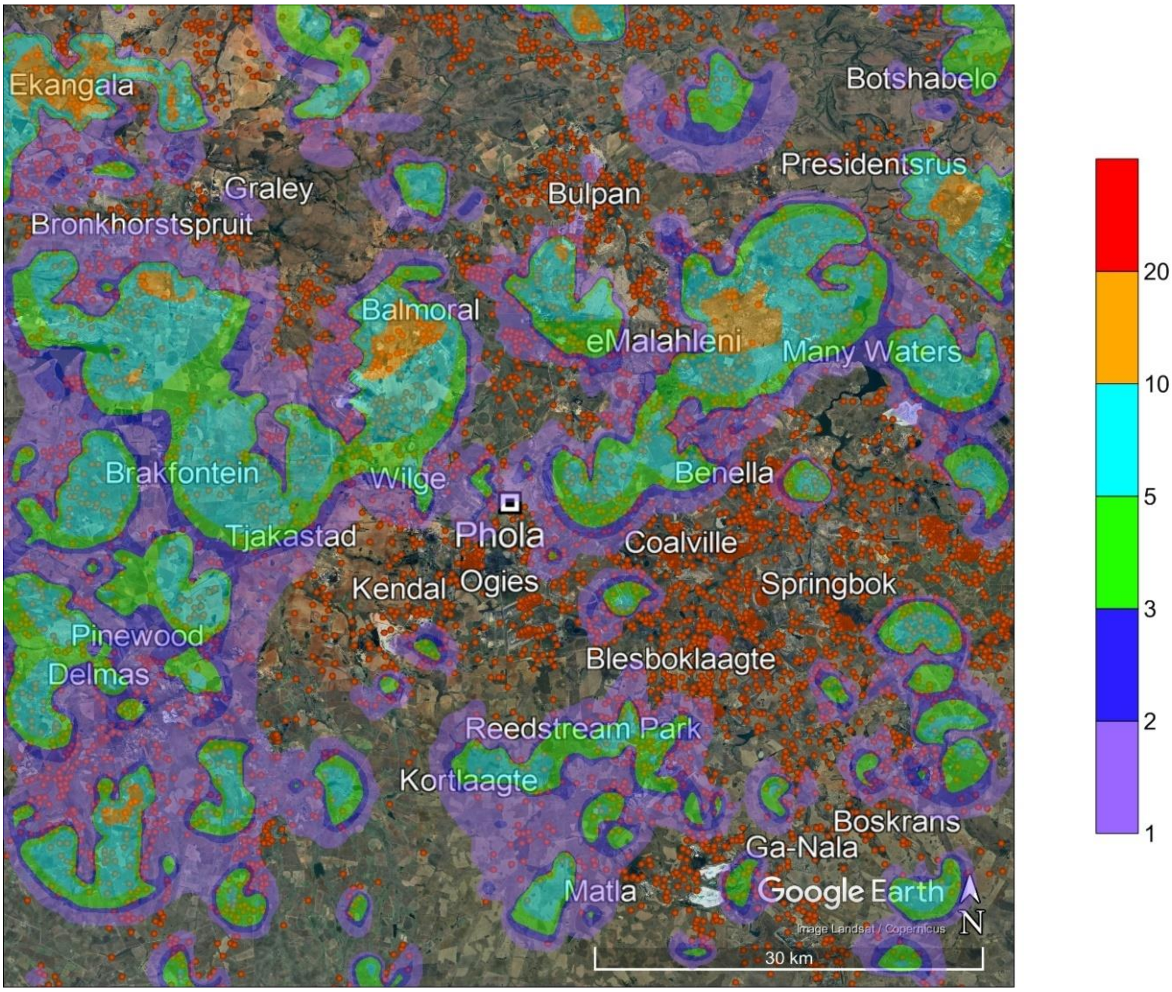


Figure 5-140: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m^3 for the Biomass Burning emission source category within the Greater Phola Airshed

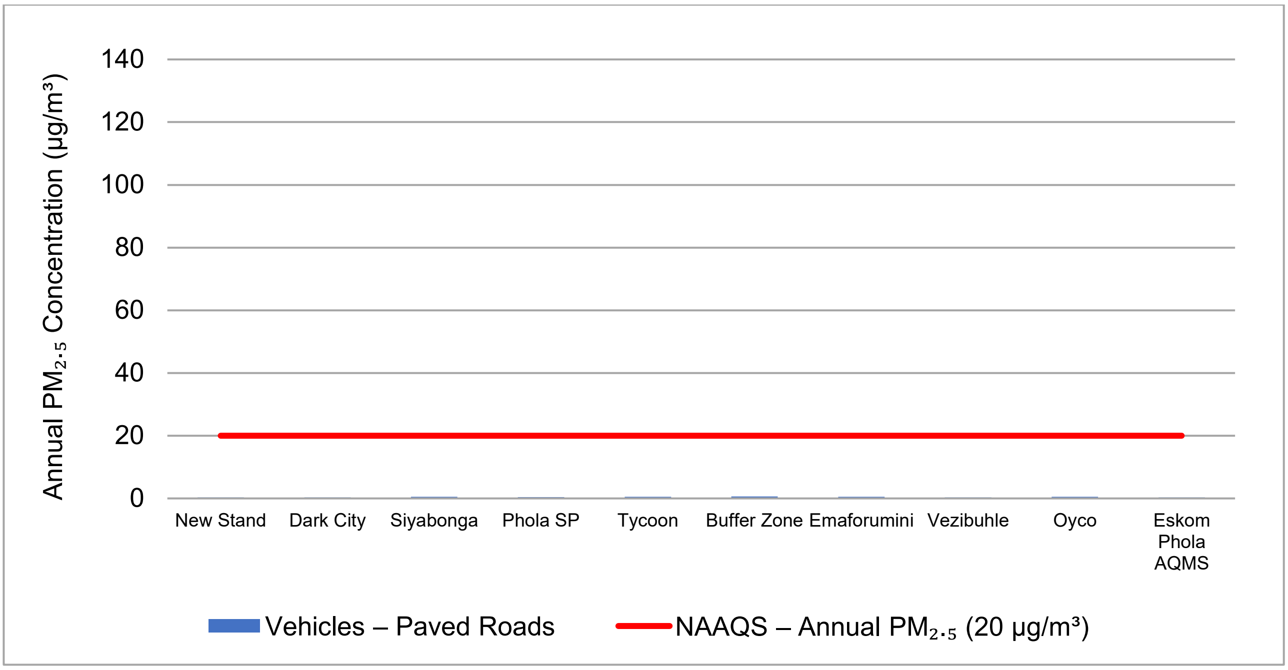


Figure 5-141: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Paved Roads emission source category

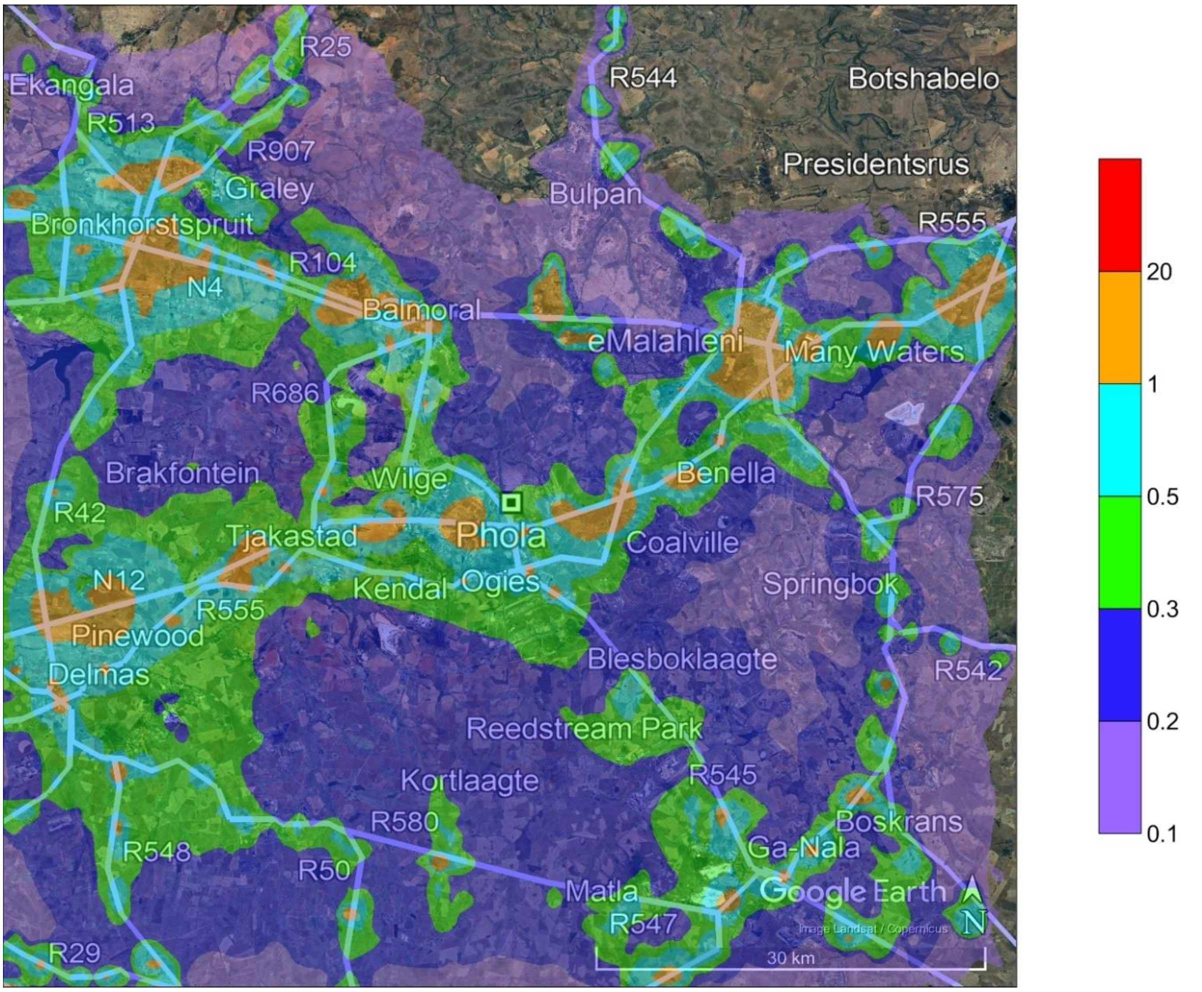


Figure 5-142: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Vehicles – Paved Roads emission source category within the Greater Phola Airshed

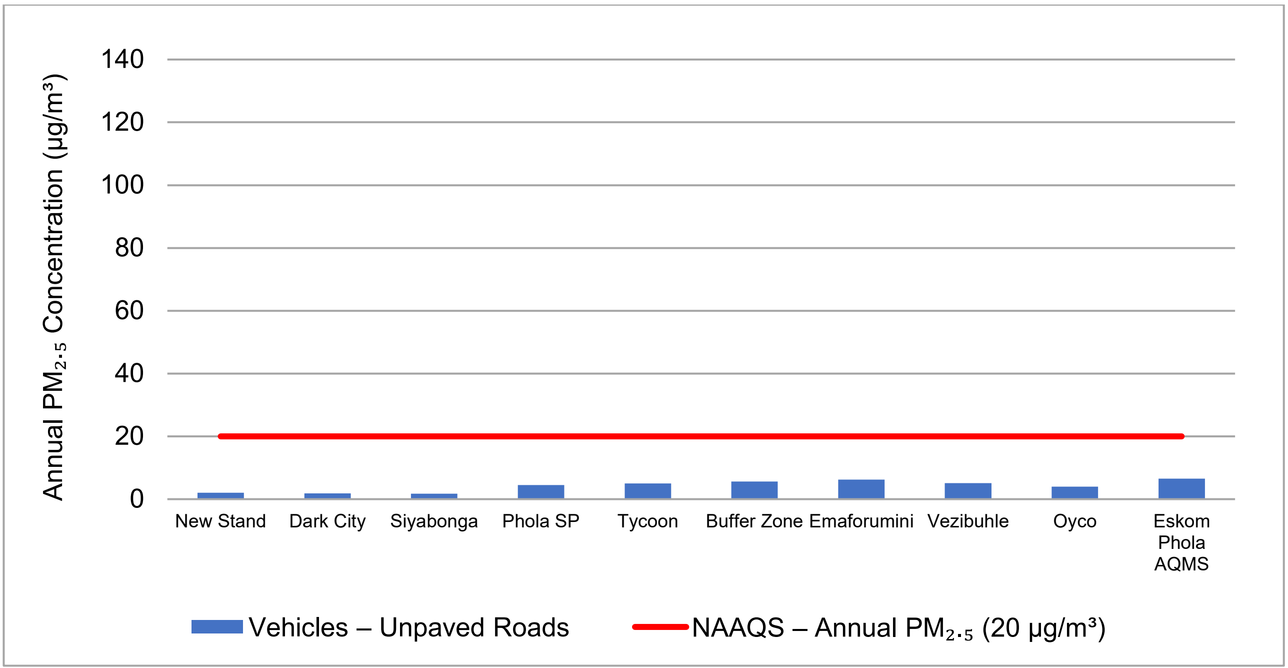


Figure 5-143: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Vehicles – Unpaved Roads emission source category

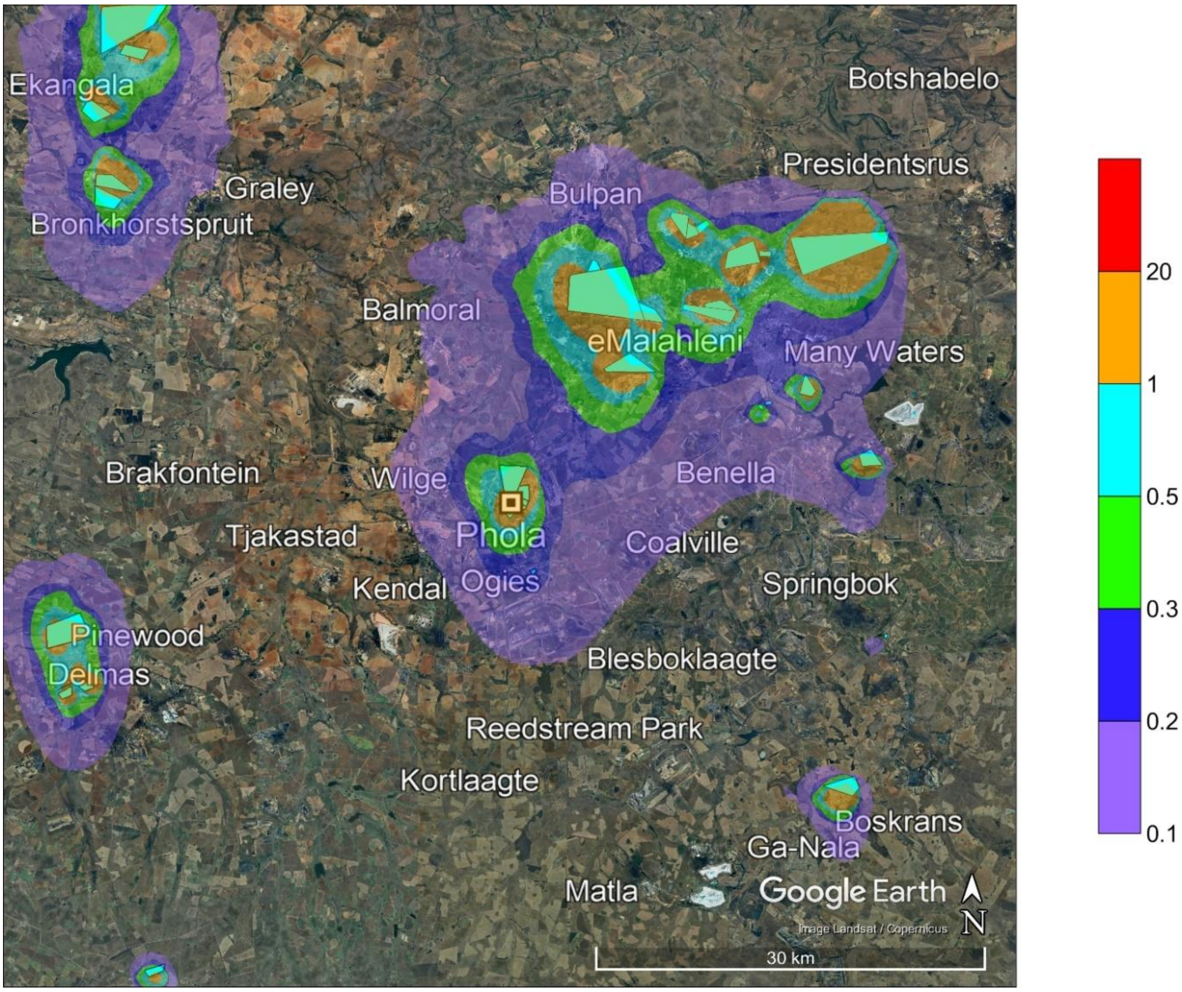


Figure 5-144: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

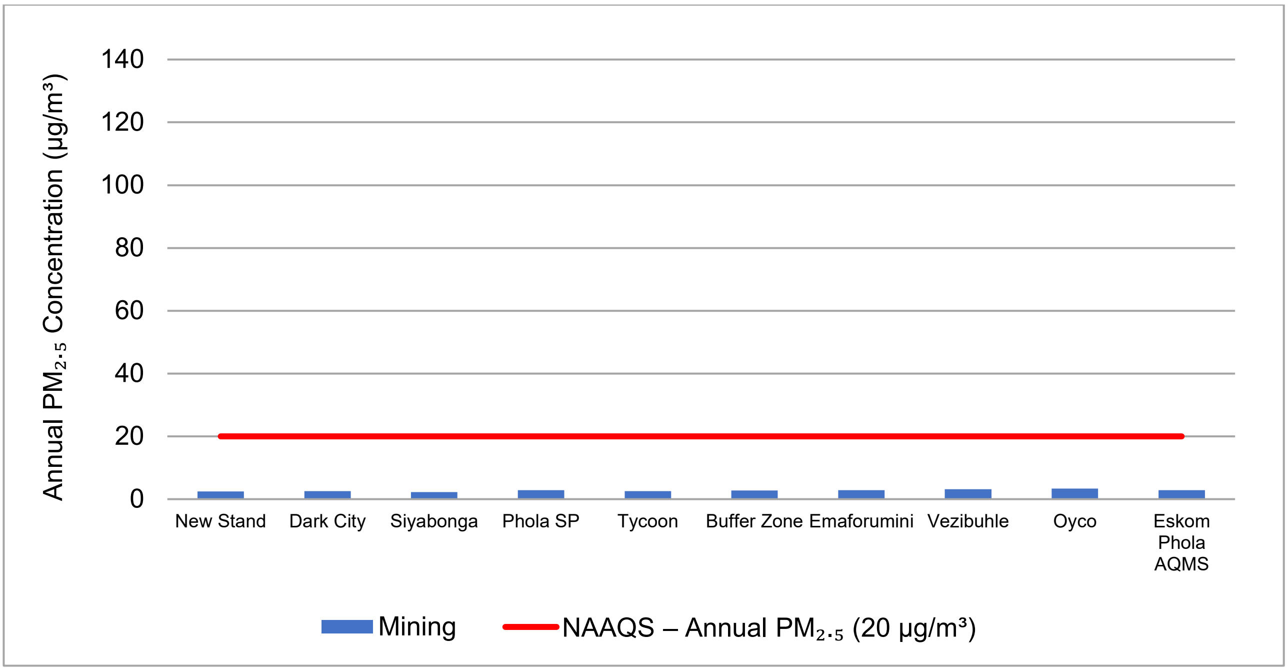


Figure 5-145: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the Mining emission source category

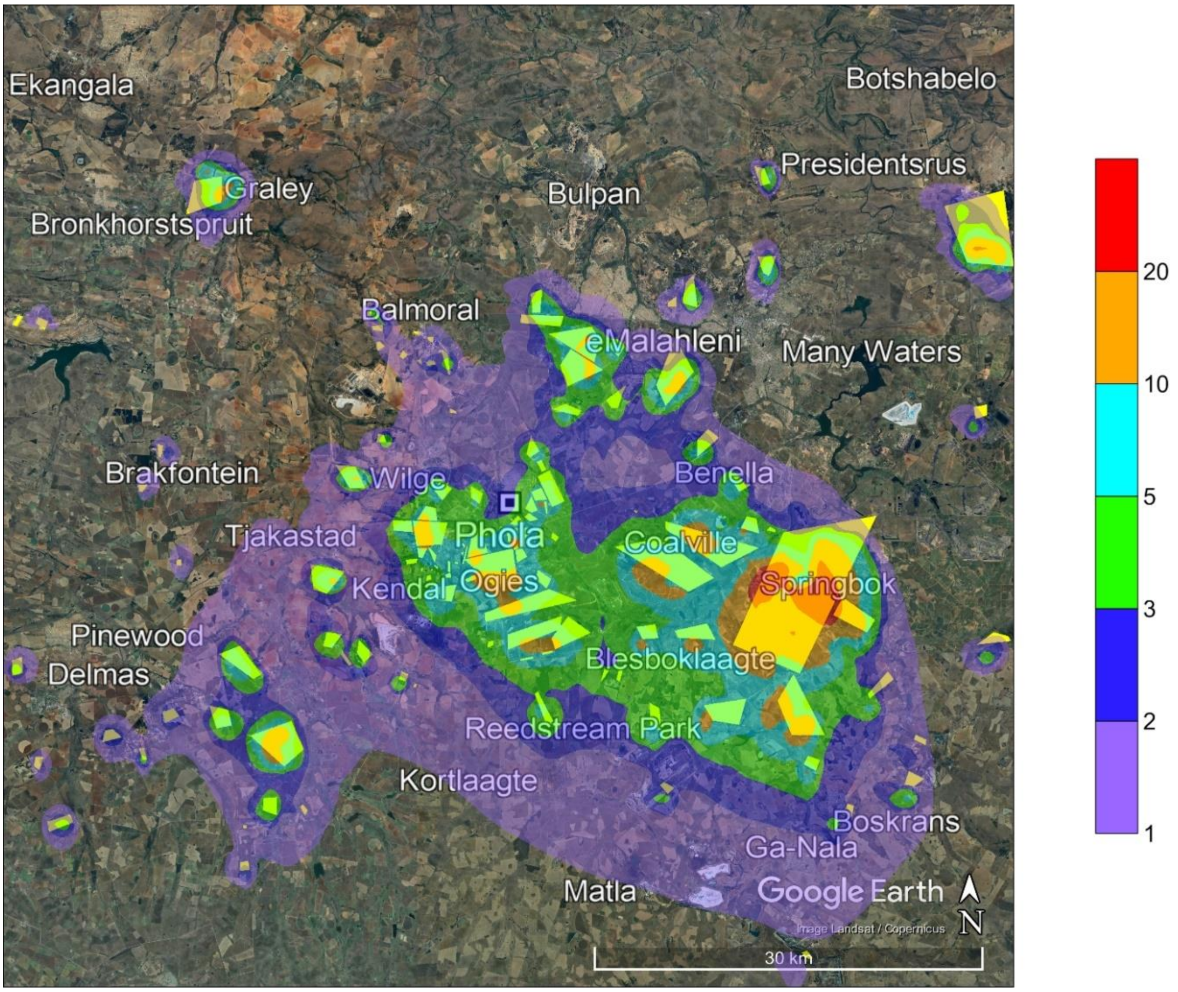


Figure 5-146: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the Mining emission source category within the Greater Phola Airshed

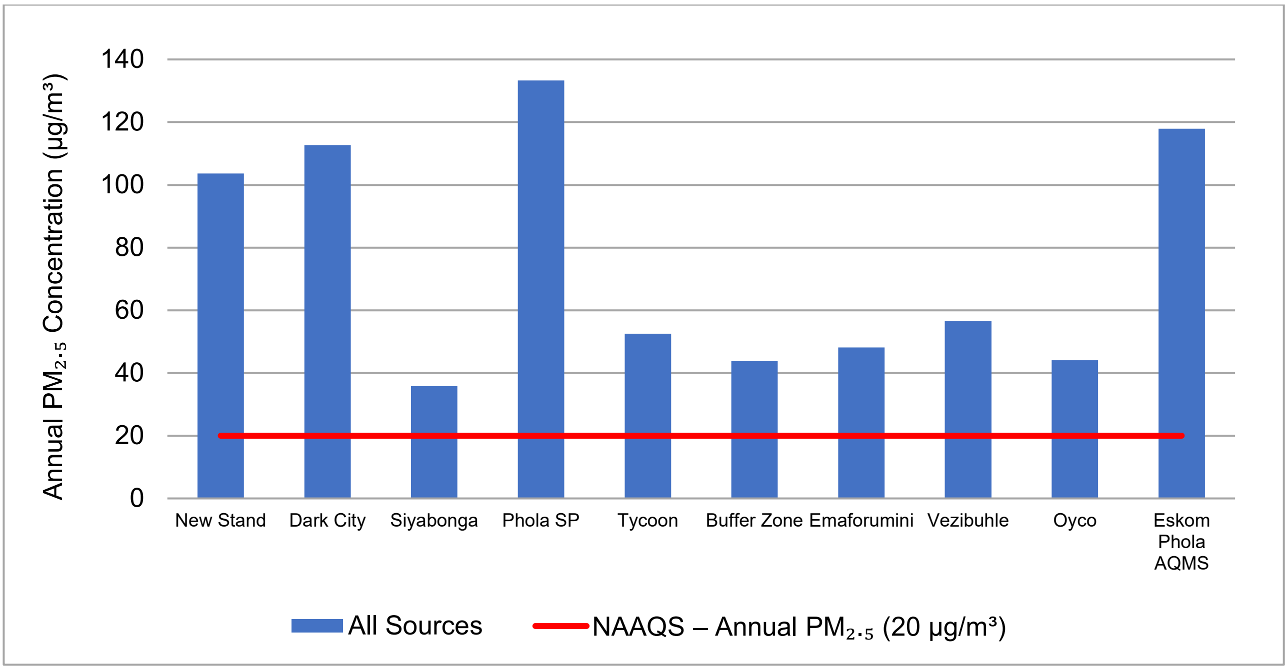


Figure 5-147: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the All Sources emission source category

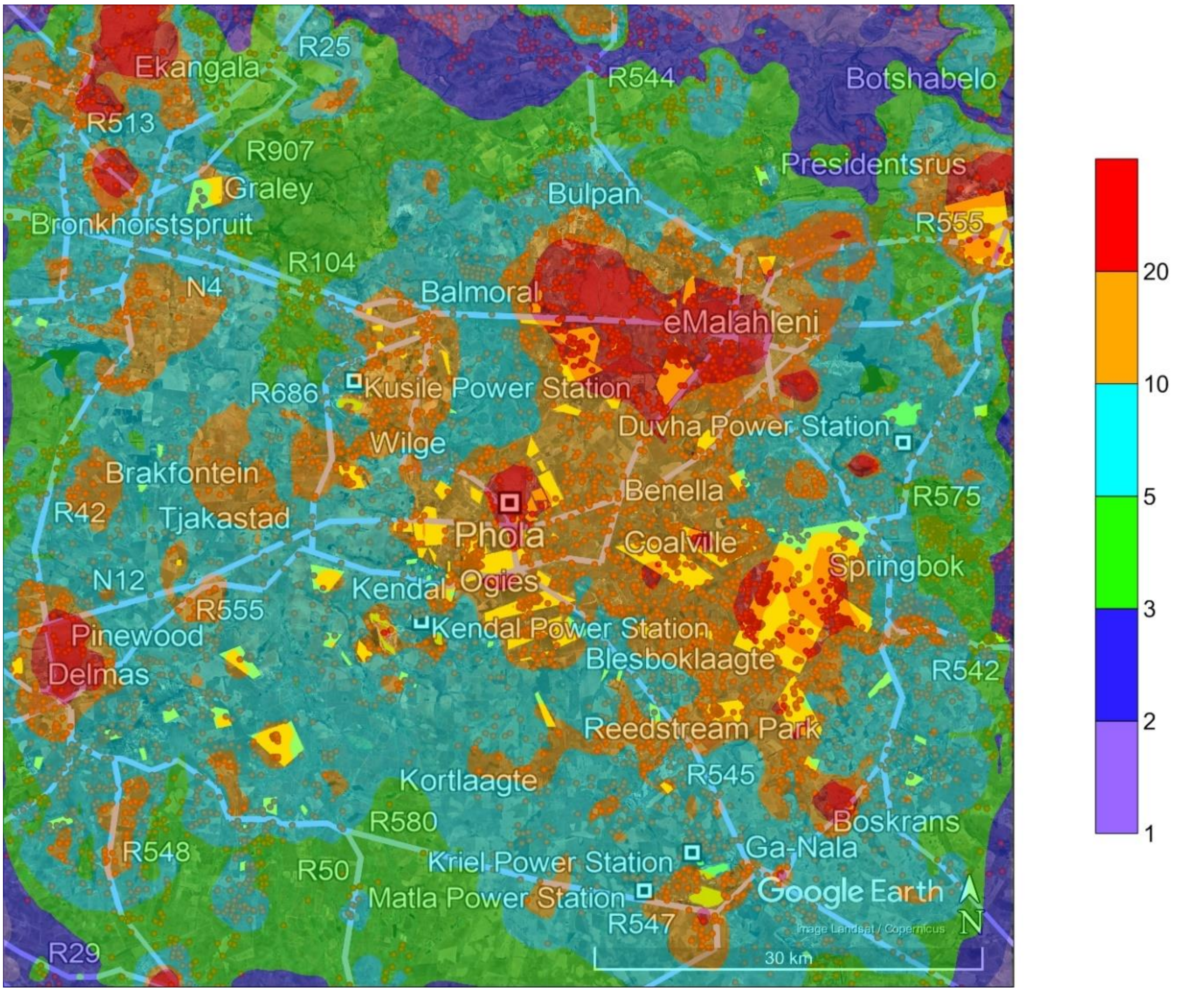


Figure 5-148: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ for the All Sources emission source category within the Greater Phola Airshed

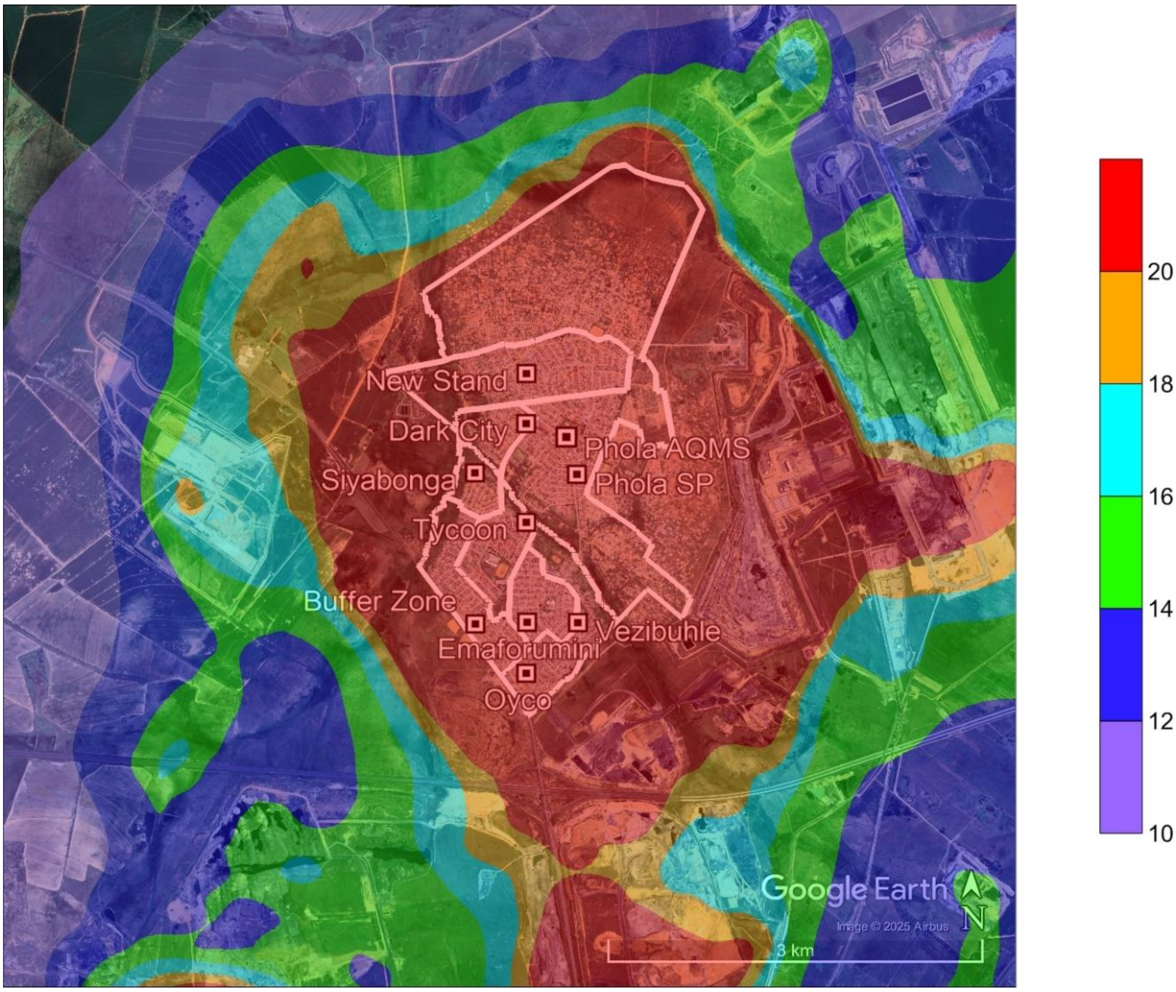


Figure 5-149: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m^3 for the All Sources emission source category within the Phola Airshed

5.4.3 $PM_{2.5}$ SOURCE CONTRIBUTION ANALYSIS

In this study, the $PM_{2.5}$ source contribution analysis is based on model predicted annual $PM_{2.5}$ ambient concentrations at the discrete receptors for the seven emission source categories which include power generation, residential fuel burning, waste burning, biomass burning, vehicles – paved roads, vehicles – unpaved roads and mining (Table 5-12). Table 5-12 is used to calculate the percent contribution of $PM_{2.5}$ at each discrete receptor as a function of the seven source categories, and is presented in Table 5-13.

Table 5-13: $PM_{2.5}$ source contribution (%) at discrete receptors for the seven emission source categories based on model predicted annual $PM_{2.5}$ ambient concentrations

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles – Paved Roads	Vehicles – Unpaved Roads	Mining	All Sources
New Stand	1.14	75.32	16.88	2.09	0.27	1.96	2.33	100.00
Dark City	1.06	76.27	16.79	1.71	0.28	1.66	2.23	100.00
Siyabonga	3.30	68.90	11.88	3.28	1.36	4.91	6.37	100.00
Phola SP	0.91	75.34	16.78	1.05	0.33	3.40	2.18	100.00
Tycoon	2.27	67.78	12.91	1.76	0.90	9.55	4.83	100.00
Buffer Zone	2.76	64.56	9.89	2.11	1.52	12.89	6.28	100.00
Emaforumini	2.51	65.52	10.31	1.81	1.00	12.82	6.03	100.00
Vezibuhle	2.15	68.38	12.76	1.51	0.64	9.01	5.57	100.00
Oyco	2.78	67.45	10.20	1.94	1.08	8.98	7.58	100.00
Eskom Phola AQMS	1.02	73.30	16.12	1.36	0.31	5.50	2.39	100.00

$PM_{2.5}$ ambient concentrations (in terms of $\mu g/m^3$) for each emission source category at each discrete receptor is presented in the form of a stacked bar graph in Figure 5-150. The total $PM_{2.5}$ ambient concentrations at each discrete receptor (which is made up of individual contributions representing each of the seven emission source categories) represents the All Sources emission source category. The $PM_{2.5}$ source contribution in terms of percentages is presented in the form of a stacked bar graph in Figure 5-151. The sum of individual contributions resulting from each emission source category makes up 100%.

The source contribution analysis indicates that residential fuel burning is the main contributor to ambient $PM_{2.5}$ levels in the Phola Airshed. It also indicates that waste burning, vehicles on unpaved roads and mining are relatively large contributors to the ambient $PM_{2.5}$ levels. Ambient contributions from power generation, biomass burning and vehicles on paved roads are much smaller in comparison.

Residential fuel burning sources account for approximately 64.56-76.27% of the total $PM_{2.5}$ ambient concentrations at the Phola discrete receptors. This is expected as these sources are in close proximity to the receptors.

Waste burning sources account for approximately 9.89-16.88% of the total $PM_{2.5}$ ambient concentrations, vehicle on unpaved roads account for approximately 1.66-12.89% of the total $PM_{2.5}$ ambient concentrations while mining sources account for approximately 2.18-7.58% of the total PM_{10} ambient concentrations at the Phola discrete receptors.

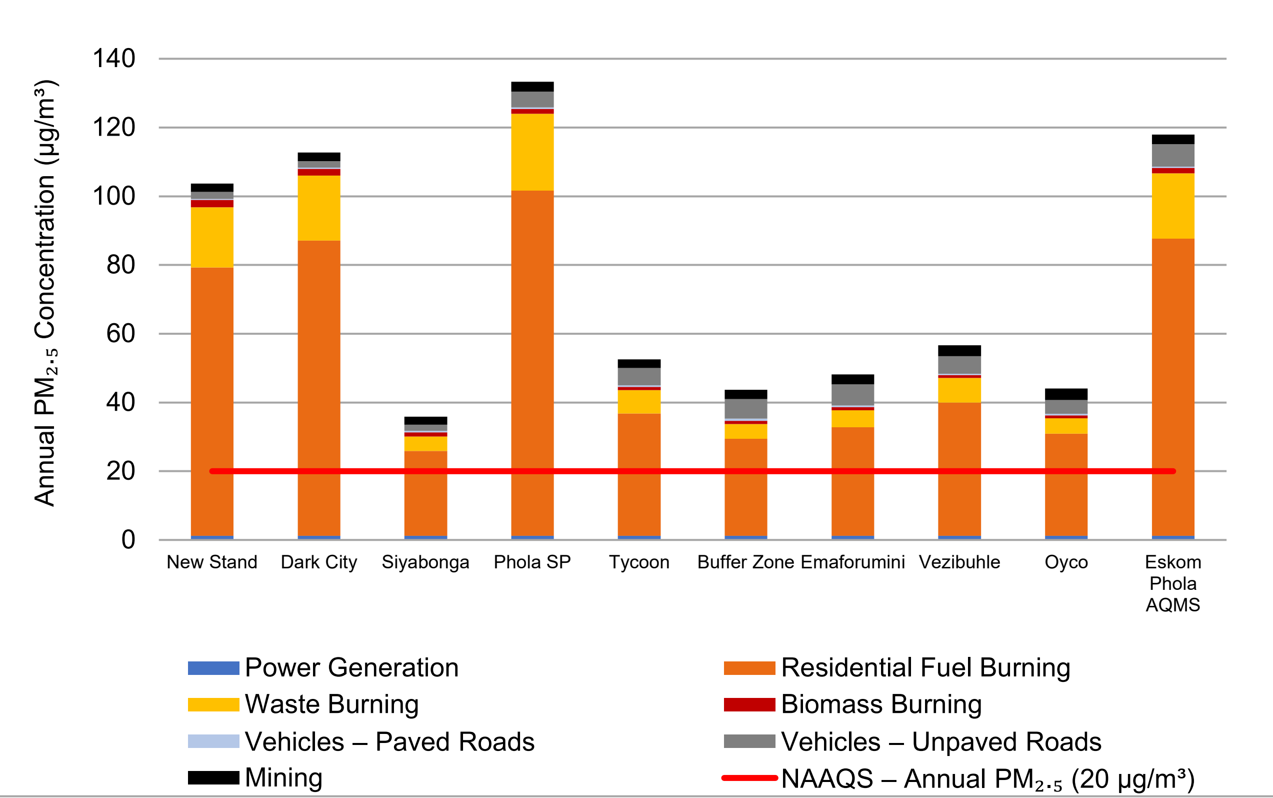


Figure 5-150: Stacked bar graph representing model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors for the six emission source categories

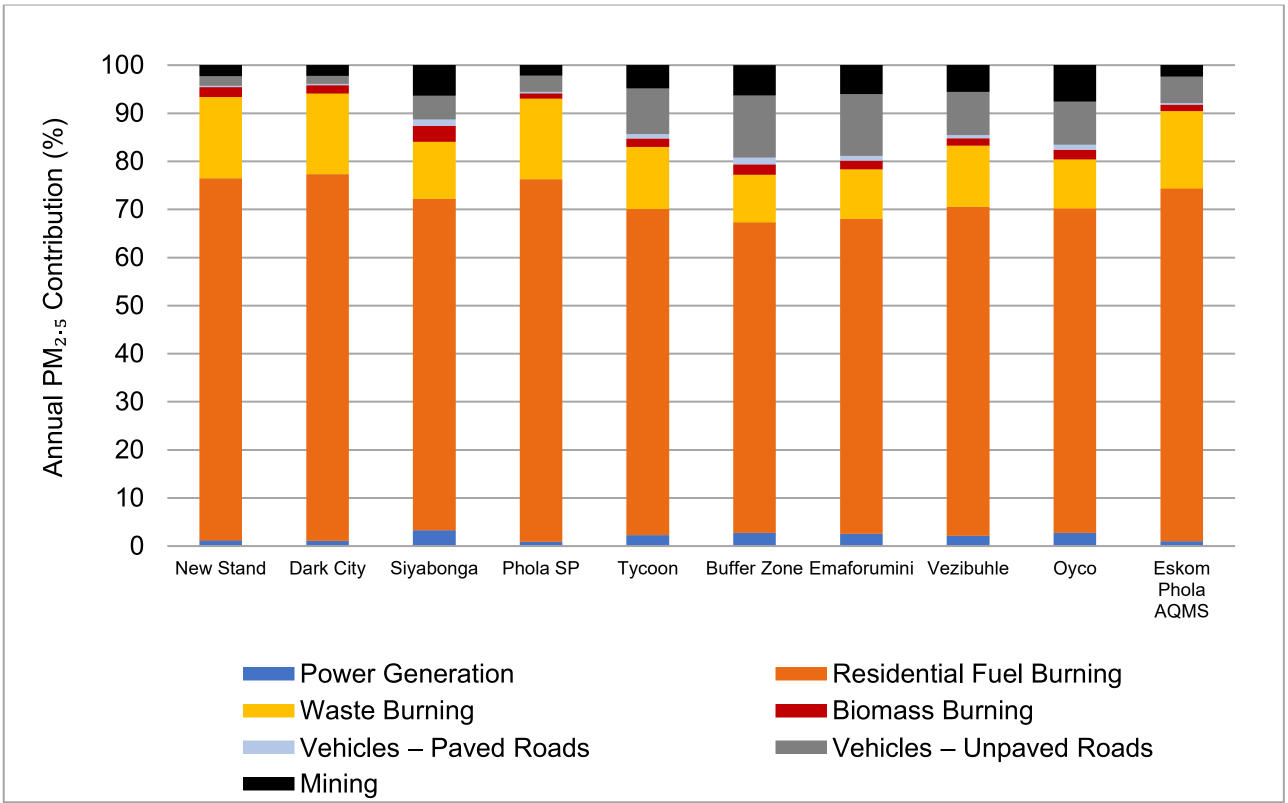


Figure 5-151: Stacked bar graph representing the percent contribution of $PM_{2.5}$ ambient concentrations at discrete receptors as a function of source category

5.5 Predicted dustfall rates

5.5.1 24-hour dustfall rates

Model predicted 24-hour dustfall rates at discrete receptors and at the point of maximum for the five emission source category is presented in Table 5-14. If applicable, exceedances of the National Dustfall Standard is highlighted in red.

Bar graphs for model predicted 24-hour dustfall rates at discrete receptors are presented in the following order:

- Figure 5-152 for the Power Generation emission source category
- Figure 5-154 for the Biomass Burning emission source category
- Figure 5-156 for the Vehicles – Unpaved Roads emission source category
- Figure 5-158 for the Mining emission source category
- Figure 5-160 for the All Sources emission source category

Contour plots for model predicted 24-hour dustfall rates for the Greater Phola Airshed are presented in the following order:

- Figure 5-153 for the Power Generation emission source category
- Figure 5-155 for the Biomass Burning emission source category
- Figure 5-157 for the Vehicles – Unpaved Roads emission source category
- Figure 5-159 for the Mining emission source category
- Figure 5-161 for the All Sources emission source category

Contour plots for model predicted 24-hour dustfall rates for the Phola Airshed is presented in Figure 5-162 for the All Sources emission source category.

With respect to contour plots for the Greater Phola and Phola Airshed, areas of exceedance of the Dustfall Standard is coloured in red.

Table 5-14: Model predicted 24-hour dustfall rates in mg/m^2/day at discrete receptors and at the point of maximum for the five emission source categories

Discrete Receptors	Power Generation	Biomass Burning	Vehicles - Unpaved Roads	Mining	All Sources
New Stand	10.80	2.43	45.20	21.10	62.40
Dark City	10.90	1.84	53.60	20.80	70.70
Siyabonga	11.00	0.96	37.10	23.60	52.00
Phola SP	10.90	1.30	123.00	25.80	139.00
Tycoon	11.10	0.86	83.00	25.00	94.80
Buffer Zone	11.80	0.82	125.00	28.60	140.00
Emaforumini	11.50	0.79	145.00	30.70	161.00
Vezibuhle	11.10	0.77	106.00	30.60	122.00
Oyco	11.80	0.80	94.70	37.50	113.00
Eskom Phola AQMS	10.90	1.51	187.00	24.80	203.00
Maximum	210.00	20.00	358.00	254.00	358.00
	National Dustfall Standard for residential area (600 mg/m^2/day)				
	National Dustfall Standard for non-residential area (1200 mg/m^2/day)				

According to Table 5-14, model predicted 24-hour dustfall rates are below the National Dustfall Standard for residential areas of 600 mg/m^2/day and the National Dustfall Standard for non-residential areas of 1 200 mg/m^2/day in the Phola Airshed and Greater Phola Airshed.

The highest dustfall rates are for the Vehicles - Unpaved Roads emission source category, followed by Mining, Power Generation and Biomass Burning in the Phola Airshed and Greater Phola Airshed.

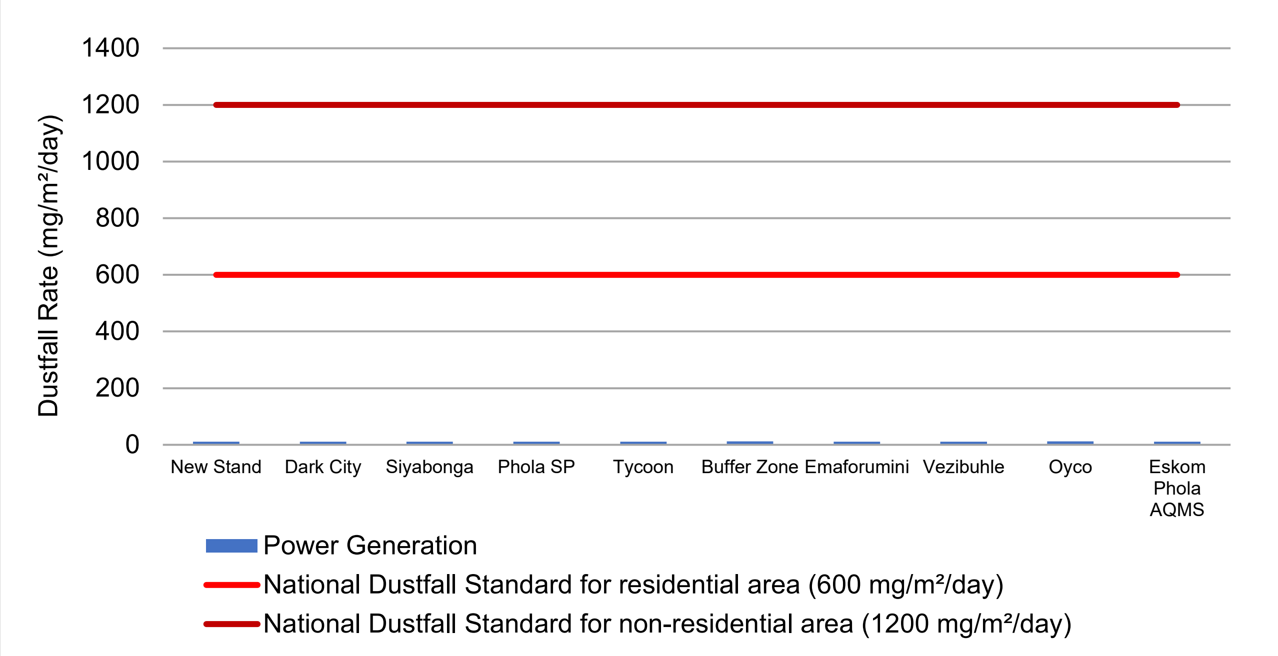


Figure 5-152: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors for the Power Generation emission source category

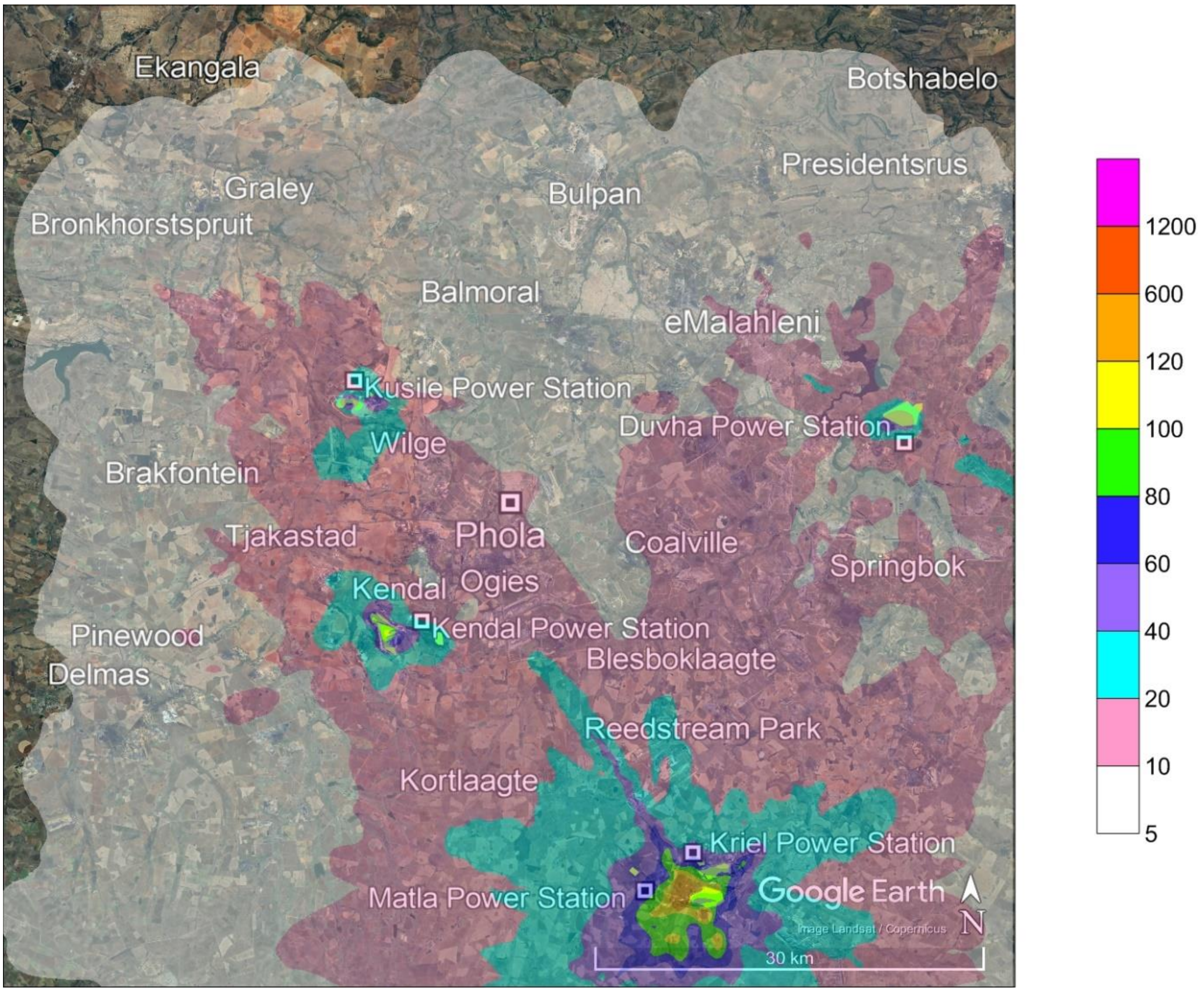


Figure 5-153: Model predicted 24-hour dustfall rates in mg/m²/day for the Power Generation emission source category within the Greater Phola Airshed

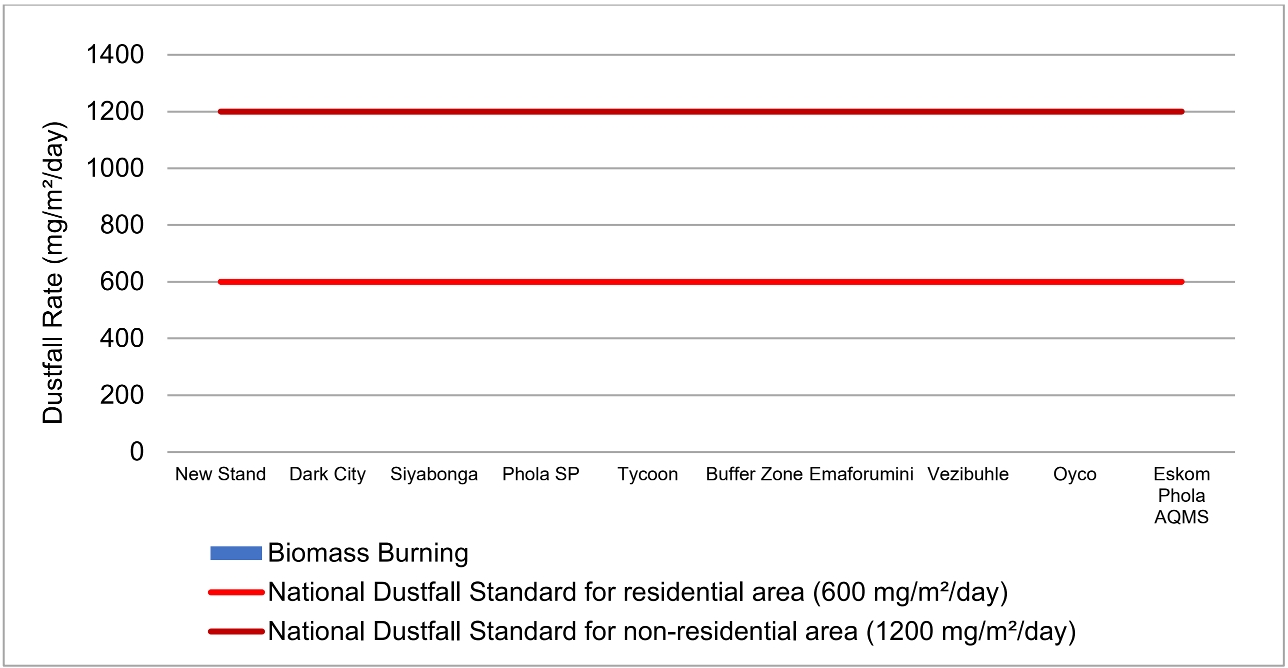


Figure 5-154: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors for the Biomass Burning emission source category

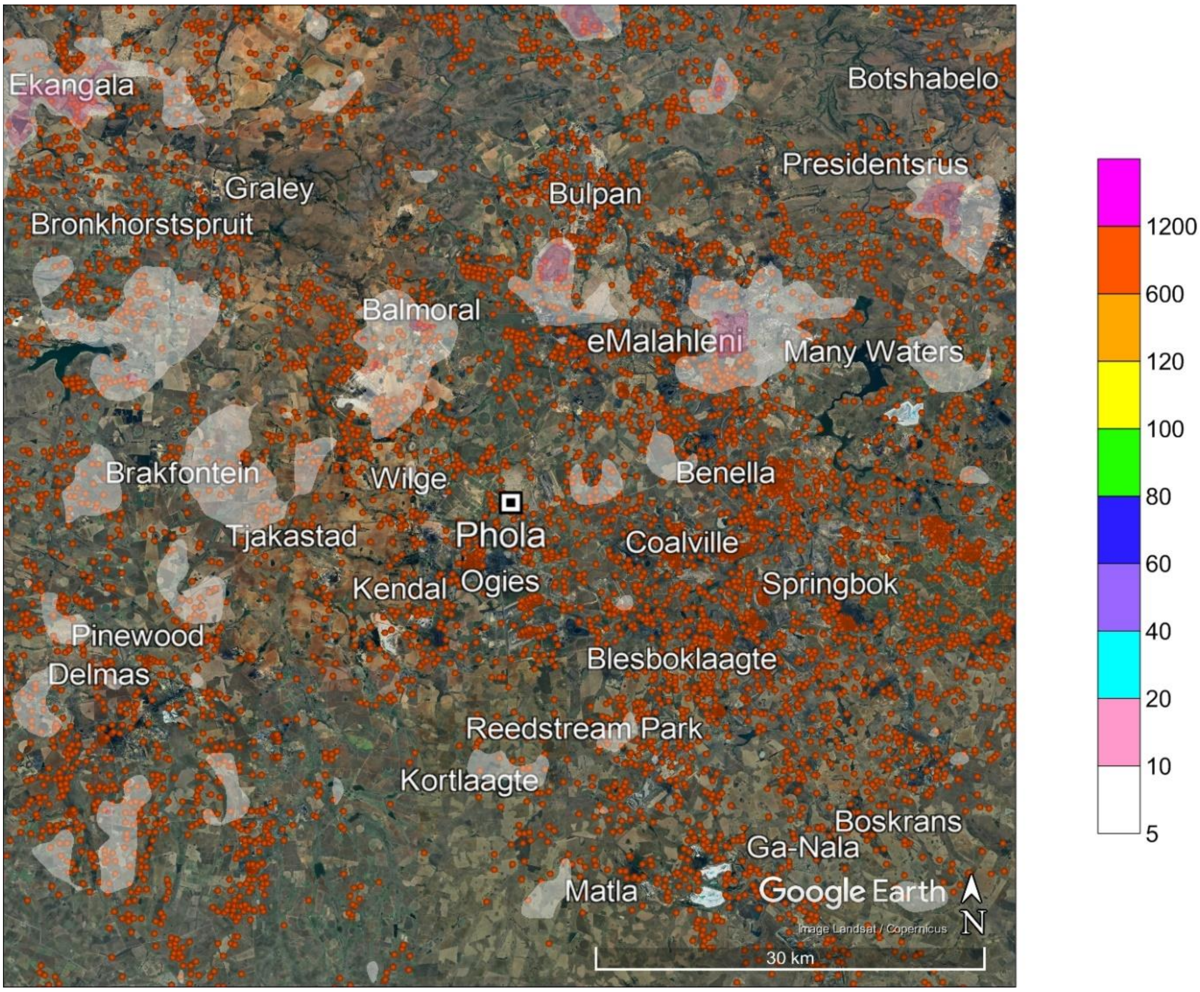


Figure 5-155: Model predicted 24-hour dustfall rates in mg/m²/day for the Biomass Burning emission source category within the Greater Phola Airshed

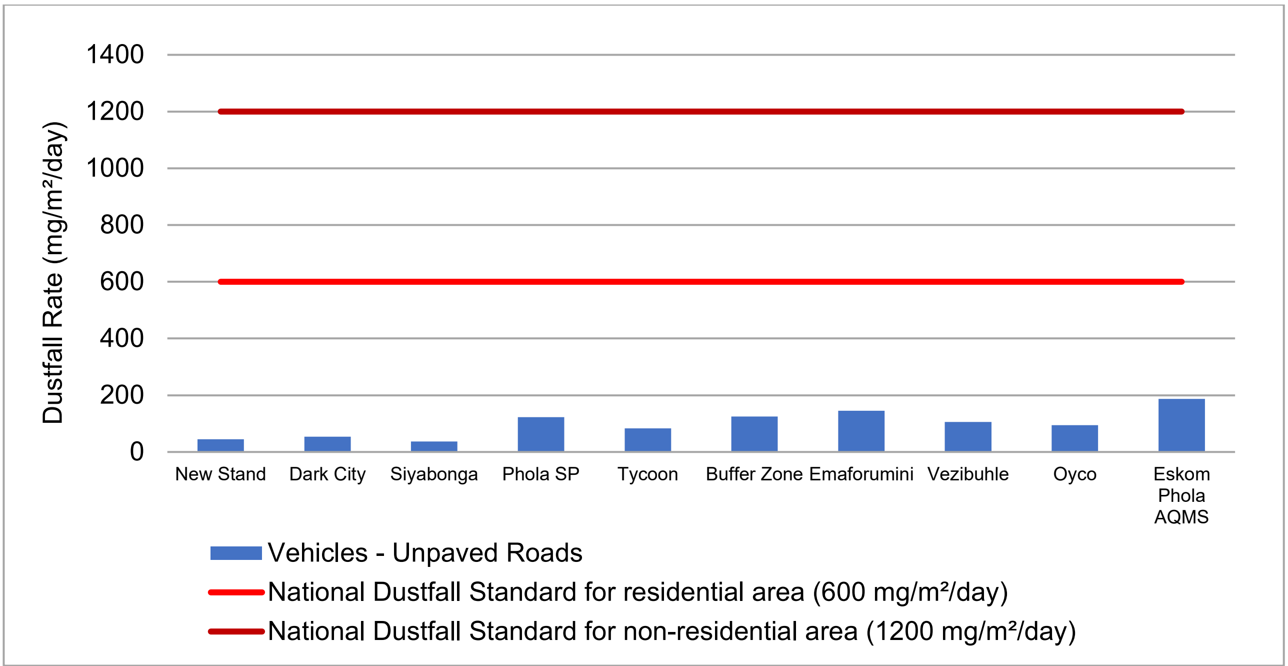


Figure 5-156: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors for the Vehicles – Unpaved Roads emission source category

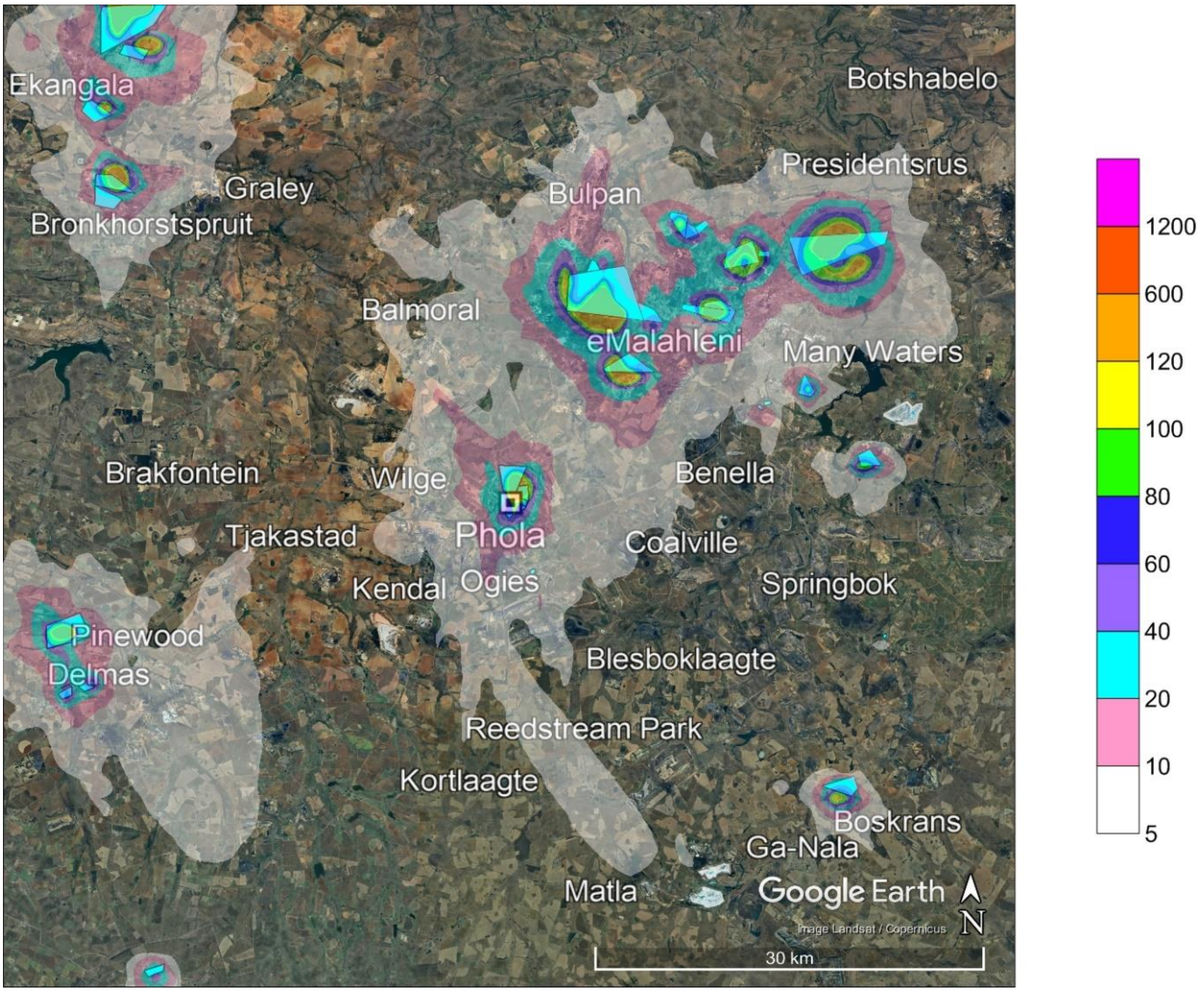


Figure 5-157: Model predicted 24-hour dustfall rates in mg/m²/day for the Vehicles – Unpaved Roads emission source category within the Greater Phola Airshed

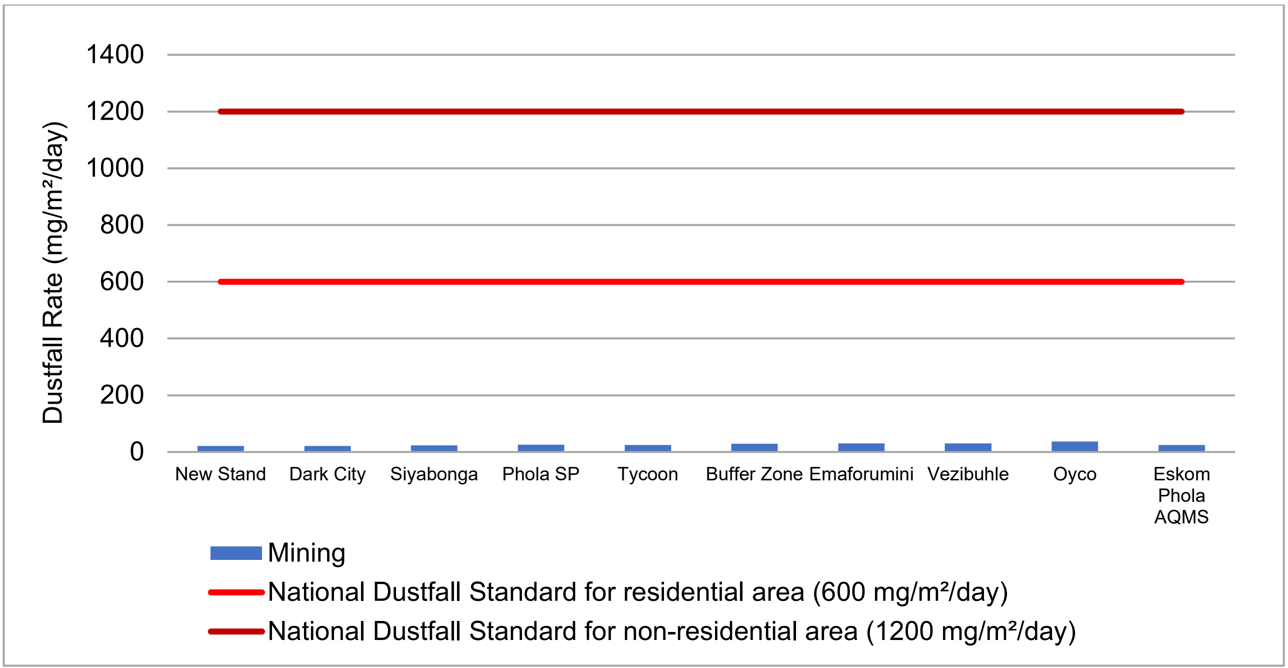


Figure 5-158: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors for the Mining emission source category

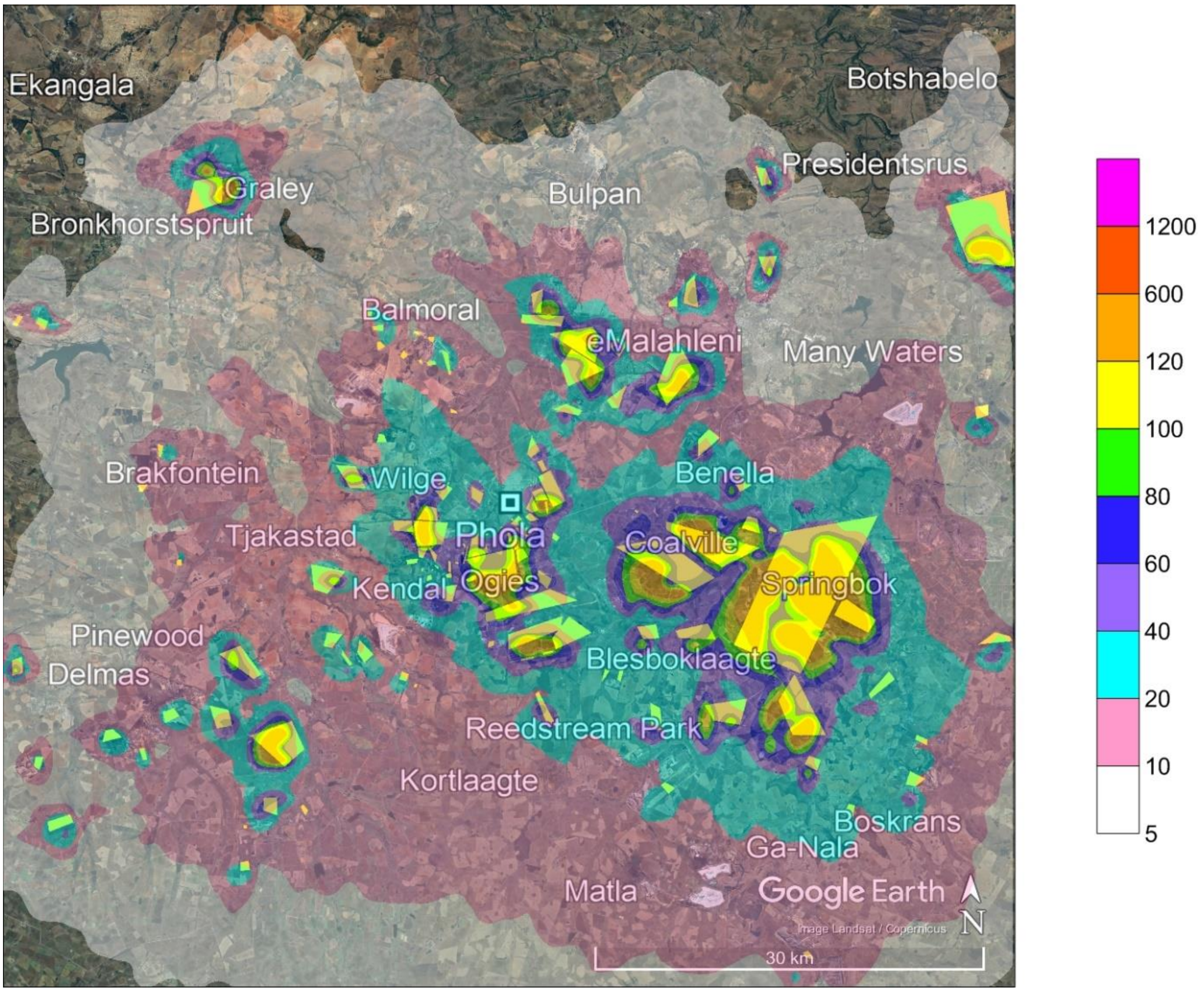


Figure 5-159: Model predicted 24-hour dustfall rates in mg/m²/day for the Mining emission source category within the Greater Phola Airshed

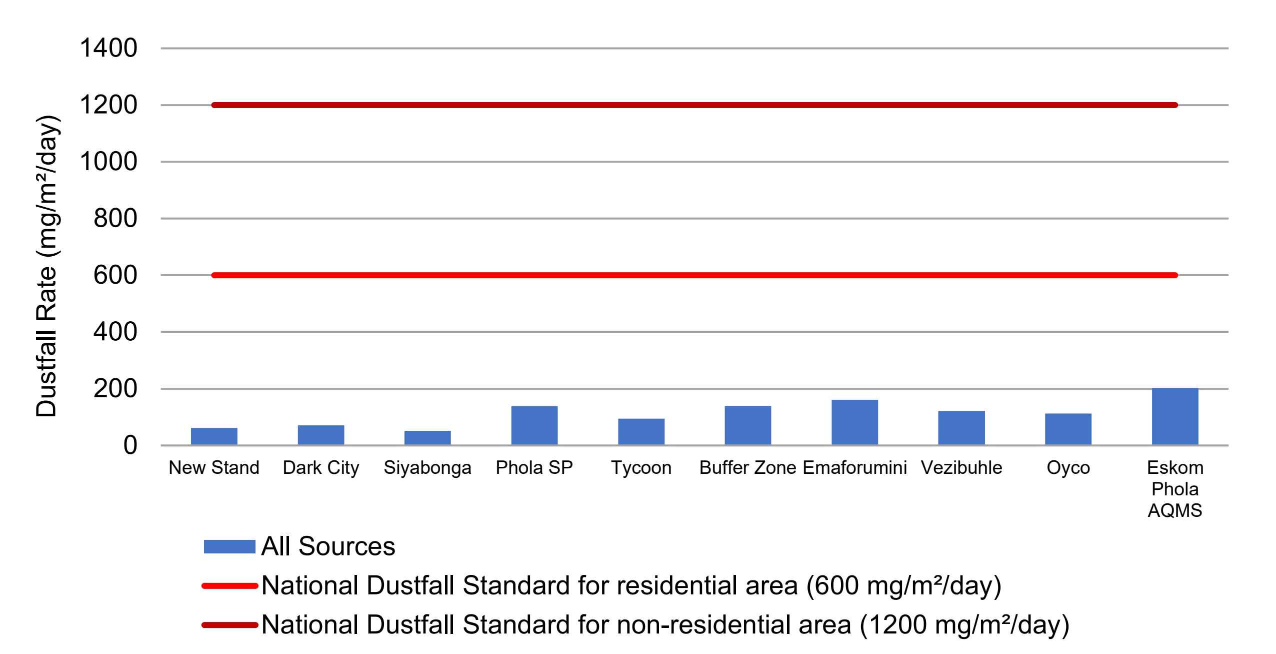


Figure 5-160: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors for the All Sources emission source category

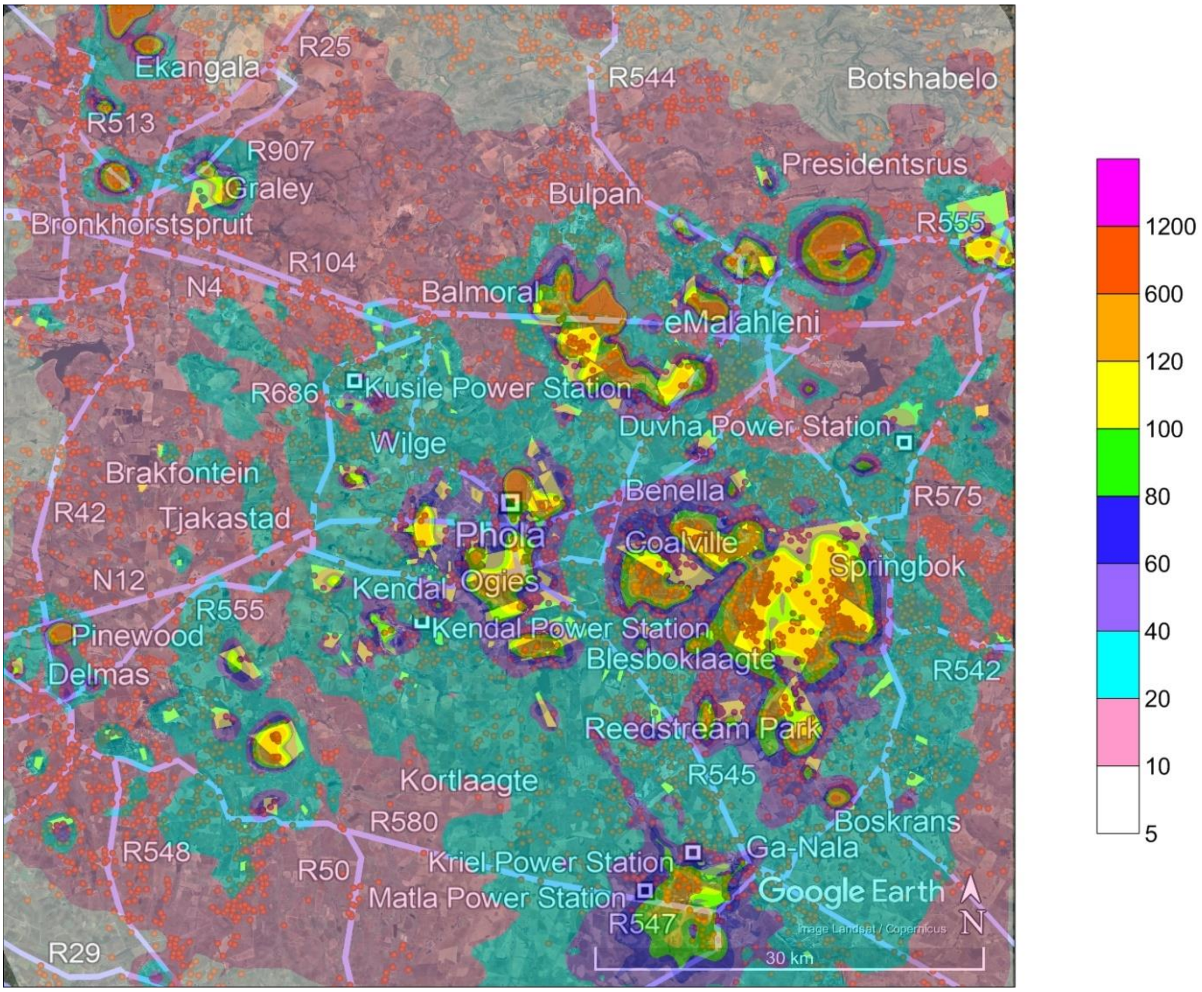


Figure 5-161: Model predicted 24-hour dustfall rates in mg/m²/day for the All Sources emission source category within the Greater Phola Airshed

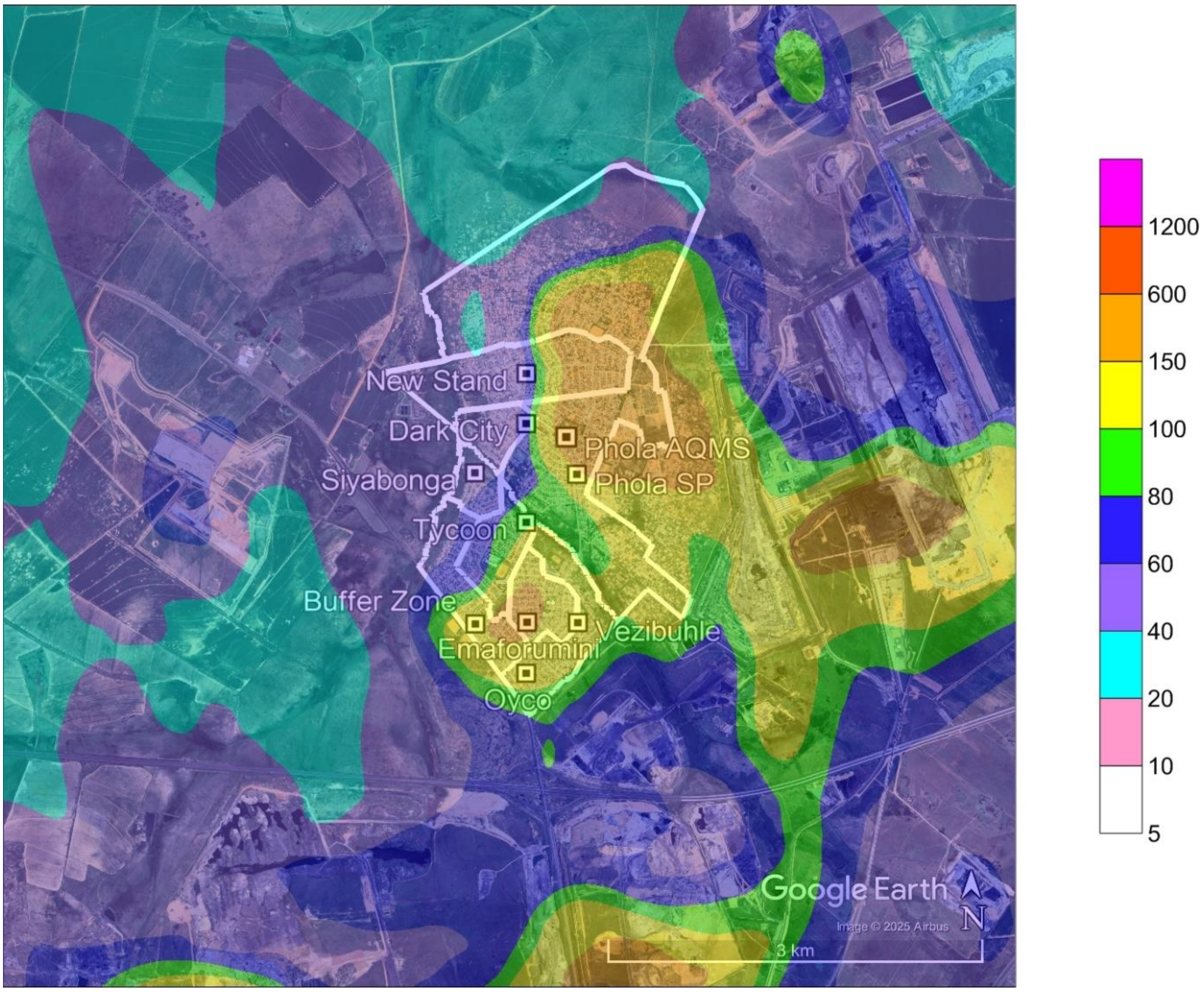


Figure 5-162: Model predicted 24-hour dustfall rates in mg/m²/day for the Vehicles – Unpaved Roads emission source category within the Phola Airshed

5.6 Comparison of the Phola Study with the Second-Generation AQMPs for the Vaal Triangle Airshed Priority Area (VTAPA Study) and the Highveld Priority Area (HPA Study)

The emission source categories common to the Eskom Phola Study and both of the Second-Generation Air Quality Management Plans (AQMPs) for the Vaal Triangle Airshed Priority Area (VTAPA Study) (DEA, 2020) and the Highveld Priority Area (HPA Study) (DEA, 2022) are industrial sources, residential fuel burning, waste burning, biomass burning, vehicle emissions and mining. The only industrial sources considered for the Eskom Phola Study was the Eskom Power Stations while the VTAPA and HPA Studies considered a large database of the main industrial sources. The emission estimation methodology used for residential fuel burning, waste burning, vehicle exhaust emissions and biomass burning are very similar across all three studies. Particulate emissions for unpaved road sources in the VTAPA and HPA Studies were limited to haul roads, while emissions for the Eskom Phola Study were calculated for unpaved roads in all residential areas, where applicable.

In the VTAPA and HPA Studies, the Weather research and forecasting (WRF) model (Advanced Research WRF (ARW) was used to generate meteorological data for input into the CAMx model, which is a photochemical model. In the Eskom Phola Study, TAPM was used to generate meteorological data for input into the CALPUFF model, which does not take photochemistry into account.

In terms of predicted ambient concentrations for the VTAPA and HPA Studies, several areas were impacted by high levels of SO_2, NO_2, PM_{10} and $PM_{2.5}$ and exceedances of these pollutants. In the Eskom Phola Study, high levels of SO_2, PM_{10} and $PM_{2.5}$ were also predicted, mainly around residential areas, with a number of exceedances for SO_2, PM_{10} and $PM_{2.5}$ for some of the emission scenarios. NO_2 was above the NAAQS in parts of the study area.

An important difference between the studies is that a source contribution analysis for discrete receptors was only undertaken for the Eskom Phola Study. This analysis has provided in-depth insight in terms of ranking of sources that have a significant contribution to ambient concentrations in the study area.

5.7 Air Quality Hotspots Identified in Phola

The health effects of airborne PM (PM_{10} & $PM_{2.5}$) have been extensively investigated (Dockery et al., 1993; Pope III et al., 2002; U.S. Environmental Protection Agency, 2004; Pope, 2007). PM has been strongly correlated to several adverse human health effects including exacerbation of chronic respiratory and cardiovascular diseases, decreased lung function. Thus, the prioritisation of air quality hotspots for Phola was ranked on the basis of PM air quality impacts. This ensures that the areas that potentially pose the greatest risk to human health and the environment are prioritised in the roll-out of Eskom's AQO program in Phola.

A total of seventy discrete receptors were used in this modelling study. Sixty-three (63) discrete receptors were used to obtain model predicted concentrations at regular intervals of 500 m across Phola and a little beyond (the remaining seven coincide with the various AQMSs). The discrete receptors were equally spaced to get an even distribution or variation of predicted concentrations across Phola. The PM concentrations were then ranked from highest to lowest for the "Residential Fuel Burning" emission source category, as this is the source category where air quality interventions will be targeted and managed.

Discrete receptors ranked with the top 25 highest concentrations are presented in Table 5-15 for PM_{10} and Table 5-16 for $PM_{2.5}$ for all emission source categories. The discrete receptors corresponding to the highest predicted particulate matter concentration were then grouped into hotspot zones based on impact and proximity to each other.

Subsequently a total of four air quality hotspots were identified in Phola (Figure 5-163). Its noted that these hotspots are located at New Stand and Phola SP. Consequently, the findings of the study suggest that the implementation of Eskom's AQO household intervention in Phola should prioritise the New Stand and Phola SP areas initially.

The central latitude and longitude (decimal degrees) for the four hotspot zones is as follows:

- Hotspot 1: -25.996437°; 29.040705°
- Hotspot 2: -25.988972°; 29.036659°
- Hotspot 3: -26.003939°; 29.044844°
- Hotspot 4: -25.983330°; 29.038692°

Model predicted 24-hour PM_{10} and $PM_{2.5}$ ambient concentration plots for the All Sources emission source category within the Phola Airshed are presented in Figure 5-164 and Figure 5-165 respectively.

Model predicted ambient concentration tables for SO_2, NO_2, PM_{10}, $PM_{2.5}$ and dustfall at all seventy (70) discrete receptors and at the point of maximum for the eight emission source categories are presented in Annexure 1.

Table 5-15: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories, exceedances of the NAAQS (75 µg/m³) are shown in red font

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources	Hotspot Zone	UTMx	UTMy
Receptor 38	17.88	294.78	57.95	3.31	1.72	117.71	31.73	456.68	Hotspot 1	704.049	7122.908
Receptor 20	17.86	280.61	44.49	5.78	1.38	50.22	26.71	386.37	Hotspot 2	703.661	7124.165
Receptor 25	17.79	279.46	45.17	5.12	1.42	45.37	27.21	368.41	Hotspot 2	703.658	7123.748
Receptor 21	18.33	275.93	46.52	4.97	1.47	189.73	29.60	490.23	Hotspot 2	704.077	7124.162
Receptor 45	17.76	269.06	53.58	2.38	1.56	117.81	34.03	445.50	Hotspot 3	704.465	7122.495
Receptor 31	17.64	265.22	44.05	4.75	1.52	48.90	28.22	354.69		703.649	7123.334
Receptor 26	17.45	264.80	43.01	4.11	1.50	185.10	30.22	485.21	Hotspot 2	704.069	7123.739
Eskom Phola AQMS	17.36	259.48	46.65	3.69	1.60	163.86	31.09	464.24		703.970	7123.219
Receptor 32	17.35	258.90	46.80	3.72	1.54	168.59	30.79	461.23	Hotspot 1	704.063	7123.336
Receptor 39	17.79	256.90	47.23	2.88	1.51	124.27	35.36	412.09	Hotspot 1	704.470	7122.914
Receptor 15	17.91	246.68	40.03	8.26	1.36	71.25	27.25	353.97	Hotspot 4	704.086	7124.570
Receptor 46	17.82	235.70	44.17	2.65	1.52	83.54	45.35	369.43	Hotspot 3	704.874	7122.489
Receptor 40	17.75	232.72	42.58	2.97	1.50	144.09	43.35	425.12		704.880	7122.907
Receptor 22	18.01	232.37	36.28	5.28	1.36	157.25	30.95	394.54		704.489	7124.149
Receptor 33	17.95	229.61	42.94	3.30	1.49	157.70	33.82	412.24	Hotspot 1	704.470	7123.330
Receptor 52	18.08	225.41	43.57	2.17	1.48	96.56	33.75	361.81	Hotspot 3	704.456	7122.083
Receptor 27	17.52	223.38	37.43	4.01	1.43	164.56	32.67	423.12		704.482	7123.734
Receptor 37	17.07	216.03	38.01	3.25	1.61	62.99	28.62	310.25		703.640	7122.921
SAWS eMalahleni AQMS	14.31	210.78	27.25	3.62	0.97	10.79	11.12	257.08		719.076	7136.018
Receptor 16	18.22	207.07	32.07	7.20	1.31	97.93	28.22	343.30	Hotspot 4	704.492	7124.559
Receptor 34	18.36	199.31	36.01	3.54	1.52	159.13	41.90	405.85		704.891	7123.323
Receptor 53	18.51	196.55	38.64	2.50	1.57	85.21	47.80	330.71	Hotspot 3	704.873	7122.082
Receptor 14	17.48	190.12	33.40	5.39	1.27	31.49	25.08	255.64	Hotspot 4	703.674	7124.580
Receptor 58	18.82	163.90	30.01	2.12	1.47	62.35	35.71	274.29		704.451	7121.669
Receptor 28	18.28	158.51	25.98	3.98	1.39	116.51	37.55	332.43		704.898	7123.715

Table 5-16: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories, exceedances of the NAAQS (40 µg/m³) are shown in red font

Discrete Receptors	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources	Hotspot Zone	UTMx	UTMy
Receptor 38	11.91	**274.35**	**57.72**	3.18	1.72	11.81	8.46	**337.44**	Hotspot 1	704.049	7122.908
Receptor 20	11.71	**261.14**	**44.31**	5.55	1.38	5.04	7.12	**309.04**	Hotspot 2	703.661	7124.165
Receptor 25	11.70	**260.07**	**45.00**	4.93	1.42	4.56	7.25	**300.82**	Hotspot 2	703.658	7123.748
Receptor 21	11.77	**256.79**	**46.34**	4.77	1.47	19.04	7.89	**318.61**	Hotspot 2	704.077	7124.162
Receptor 45	11.63	**250.40**	**53.37**	2.29	1.56	11.82	9.07	**319.27**	Hotspot 3	704.465	7122.495
Receptor 31	11.65	**246.83**	**43.88**	4.57	1.52	4.91	7.52	**286.79**		703.649	7123.334
Receptor 26	11.58	**246.44**	**42.84**	3.95	1.50	18.57	8.06	**299.87**	Hotspot 2	704.069	7123.739
Eskom Phola AQMS	11.51	**241.49**	**46.47**	3.55	1.60	16.44	8.29	**300.06**		703.970	7123.219
Receptor 32	11.50	**240.95**	**46.61**	3.58	1.54	16.91	8.21	**290.88**	Hotspot 1	704.063	7123.336
Receptor 39	11.76	**239.09**	**47.04**	2.77	1.51	12.47	9.43	**293.88**	Hotspot 1	704.470	7122.914
Receptor 15	11.79	**229.58**	39.87	7.94	1.36	7.15	7.26	**274.55**	Hotspot 4	704.086	7124.570
Receptor 46	11.61	**219.35**	**43.99**	2.55	1.52	8.38	12.09	**275.90**	Hotspot 3	704.874	7122.489
Receptor 40	11.67	**216.58**	**42.41**	2.85	1.50	14.46	11.56	**268.95**		704.880	7122.907
Receptor 22	11.94	**216.25**	36.14	5.07	1.36	15.78	8.25	**271.57**		704.489	7124.149
Receptor 33	11.91	**213.70**	**42.77**	3.17	1.49	15.82	9.02	**261.65**	Hotspot 1	704.470	7123.330
Receptor 52	11.86	**209.78**	**43.40**	2.09	1.48	9.69	9.00	**258.34**	Hotspot 3	704.456	7122.083
Receptor 27	11.66	**207.89**	37.28	3.85	1.43	16.51	8.71	**264.26**		704.482	7123.734
Receptor 37	11.52	**201.06**	37.86	3.12	1.61	6.32	7.63	**238.66**		703.640	7122.921
SAWS eMalahleni AQMS	9.48	**196.19**	27.14	3.48	0.97	1.09	2.96	**231.46**		719.076	7136.018
Receptor 16	12.13	**192.71**	31.94	6.92	1.31	9.83	7.52	**231.91**	Hotspot 4	704.492	7124.559
Receptor 34	11.98	**185.49**	35.87	3.40	1.52	15.96	11.17	**233.09**		704.891	7123.323
Receptor 53	11.81	**182.93**	38.49	2.41	1.57	8.55	12.74	**242.71**	Hotspot 3	704.873	7122.082
Receptor 14	11.72	**176.95**	33.27	5.18	1.27	3.16	6.69	**219.33**	Hotspot 4	703.674	7124.580
Receptor 58	12.21	**152.55**	29.89	2.04	1.47	6.26	9.52	**197.09**		704.451	7121.669
Receptor 28	12.07	**147.53**	25.88	3.82	1.39	11.69	10.01	**199.84**		704.898	7123.715

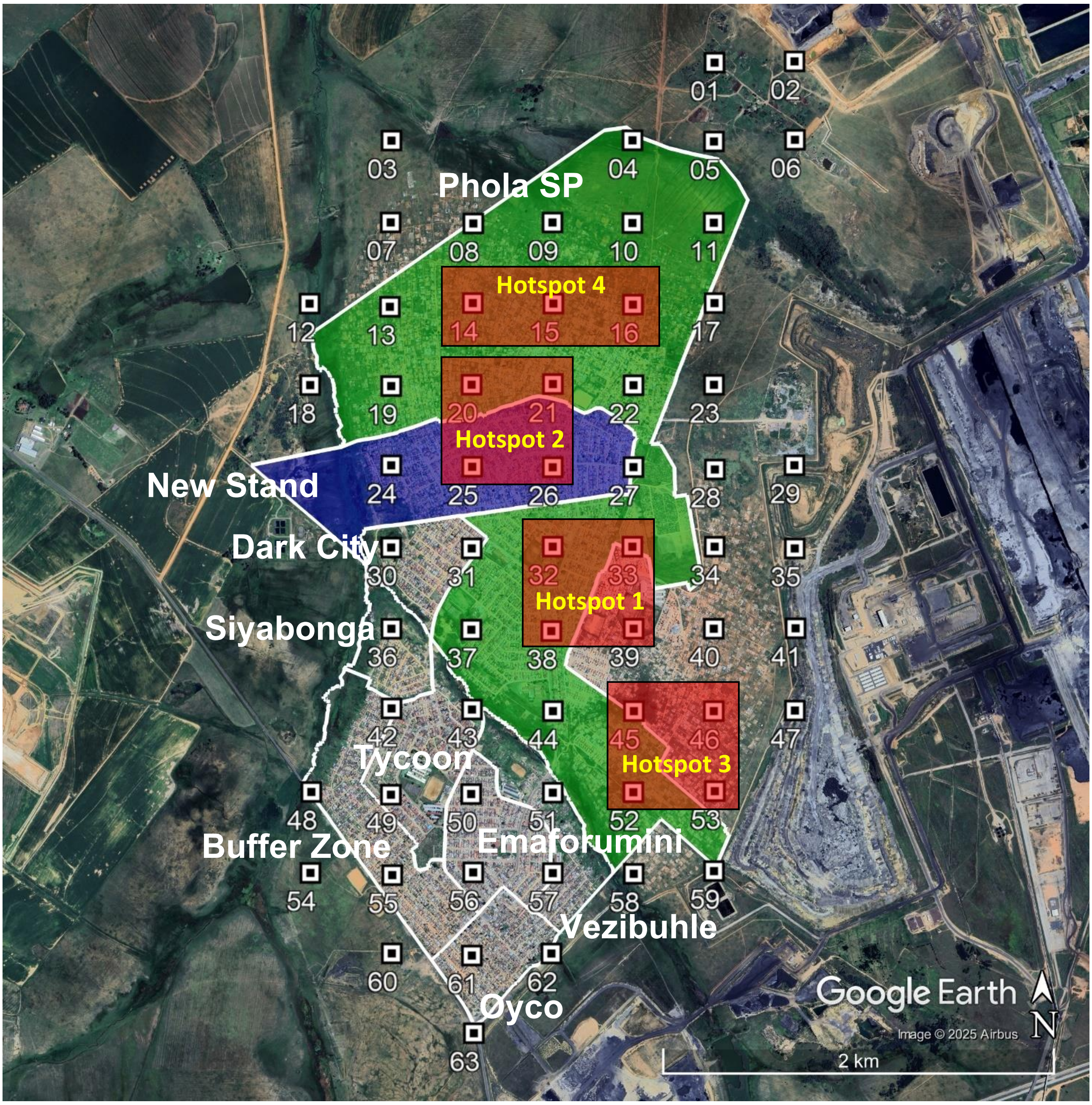


Figure 5-163: Air quality hotspots identified for Phola

Figure 5-164: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m^3 for the All Sources emission source category within the Phola Airshed

Figure 5-165: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m^3 for the All Sources emission source category within the Phola Airshed

6. MODEL VALIDATION

The importance of model validation is crucial for ensuring the accuracy and reliability of models. A model validation exercise can help to identify any potential errors or limitations that may impact their accuracy, reliability and performance. Although atmospheric dispersion models are indispensable in air quality assessment studies, their limitations should always be taken into account. In this study, the model predicted concentrations for the All-Sources emission source category (cumulative baseline emissions from all specified sources within the modelling domain) were compared with measured ambient data recorded at the Eskom Phola AQMS.

6.1 Predicted and Measured Concentrations at the Phola AQMS

The predicted 99th percentile of the 1-hour SO_2 and NO_2, and 24-hour SO_2, PM_{10} and $PM_{2.5}$ concentrations at the Phola AQMS are compared with the maximum measured concentrations at the Phola AQMS (Table 6-1, Figure 6-1). Exceedances of the limit value of the NAAQS are shown in red font.

1-hour SO_2: Modelled and measured values are both in exceedance of the NAAQS, however model predicted concentrations are approximately three times lower that the measured concentration resulting in an under-prediction.

1-hour NO_2: The modelled values are in exceedance of the NAAQS and approximately two times higher than the measured concentration resulting in an over-prediction.

24-hour SO_2: Modelled and measured values are both in exceedance of the NAAQS, however model predicted concentrations are approximately two times lower than the measured concentration resulting in an under-prediction.

24-hour PM_{10} and $PM_{2.5}$: Modelled and measured values are both in exceedance of the NAAQS, however model predicted concentrations are much higher than the measured concentration resulting in an over-prediction

The extent to which a user has reliable information on emissions data, meteorological data and the correct model physics set-up will influence the accuracy of the model predicted concentrations. It is evident that the model has both under-predicted and over-predicted concentrations. It must be remembered that the data availability at the Phola AQMS was approximately 41% for the hourly concentrations and approximately 39% for the daily concentrations. In the case of SO_2, it is possible that the measured concentrations may have some high outlying values, resulting in very high concentrations. With a larger and more complete AQMS dataset available, it is possible that a better comparison would have been possible, particularly for NO_2 and particulates, where potentially high measured concentrations are missing. In terms of the above points, it is the opinion of the modelling team that the model has performed satisfactorily.

Section 7 outlines the underlying limitations of this study which may have bearing on the simulated results.

Table 6-1: Comparison of predicted and measured concentrations at the Phola AQMS in µg/m³

Pollutant	NAAQS	Model Predicted	Measured
1-hour SO_2	350	**616.74**	**1830.46**
1-hour NO_2	200	**243.67**	136.25
24-hour SO_2	125	**207.38**	**387.06**
24-hour PM_{10}	75	**464.24**	**140.00**
24-hour $PM_{2.5}$	40	**300.06**	**57.00**

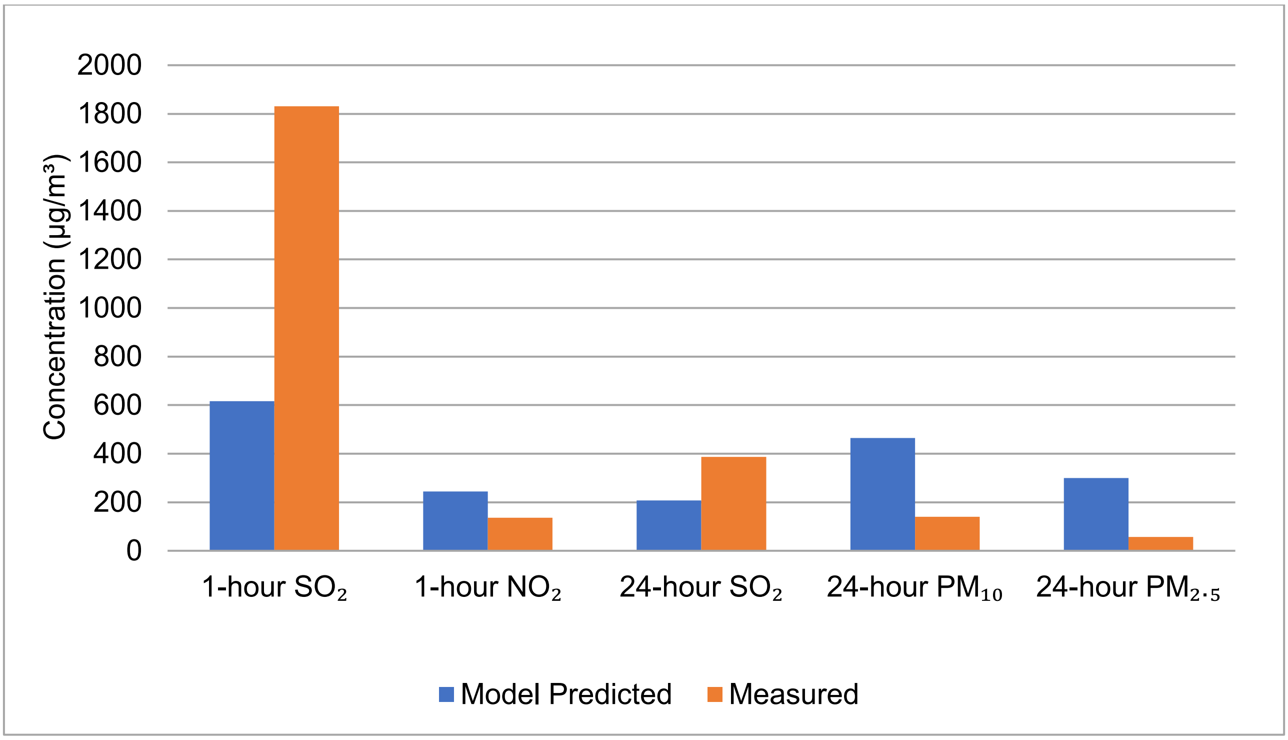


Figure 6-1: Comparative IOA statistics between monitored data and model predictions

7. LIMITATIONS, POTENTIAL BIASES, UNCERTAINTIES & DATA GAPS

7.1 LIMITATIONS OF STUDY

For this baseline modelling assessment study, the following limitations must be noted:

i. Atmospheric Emission License (AEL) data serve as the principle information source for activity data in order to estimate emissions from industrial sources. Although ARM submitted a request to the Department of Environment, Forestry and Fisheries (DEFF) requesting the AEL data for industrial sources within the modelling domain, DEFF was unable to provide the data. DEFF responded stating that they will not be able to disclose the data due to data policy privacy issues. Thus the cumulative impact of other industrial sources are not included in the model simulation which will result in an under-prediction of pollutant ambient concentrations for this emission source category.

ii. The South African National Atmospheric Emission Inventory System (NAEIS) contains emissions information for mines, controlled emitters and facilities identified in accordance with the local by-laws. DEFF was not able to provide ARM with the NAEIS emissions data due to data policy privacy issues. Thus the cumulative impact of controlled emitters and facilities identified in accordance with the local by-laws have therefore been excluded from this study, which results in an under-prediction of the simulated pollutants. For the mining sector, ARM was able to develop its own emission factors (see Section 4) which is based on mine footprints.

iii. The data required to model “local unpaved roads” dust emissions are currently not available for Phola and other parts of the modelling domain. The information required to model these local roads include the location of unpaved roads, silt content of each road, number of vehicles, vehicle types, empty and full weight of cars, buses, heavy-duty vehicles and taxis using these roads. In order to develop an emission inventory for this emissions source category (Vehicles – Unpaved Roads), a number of assumptions had to be made based on best judgement. These are discussed under assumptions in Section 4. Thus the model predicted results may be under-predicted for some pollutants.

iv. Residential fuel burning and waste burning for the modelling was estimated based on energy use data at the Sub Place level for Phola using Stats SA Census data. There is currently no finer resolution residential fuel burning or waste burning data for Phola. The model simulated results are therefore constrained by the granularity of this data. Thus the model predicted results may be under-predicted for some pollutants.

7.2 Limitations and Potential Biases of the CALPUFF Model

Although the CALPUFF dispersion modelling system is very sophisticated and supports a wide range of modelling scenarios, it does have some limitations. One limitation of the system is that there is a finite number of sources that can be specified in the model input parameters. For example, CALPUFF can only accommodate a finite number of sources for each source type in a single model run. Each executable (e.g., CALMET, CALPUFF, CALPOST) has a corresponding parameterization file which defines these limits. If a project has one of these parameters which exceeds the model limit, the model executables need be recompiled in FORTRAN to accept higher limits; or multiple model runs can be built, and then CALSUM can be used to combine model runs together. Another limitation of the CALPUFF air dispersion model is that it can only be executed on a single processor (i.e., serially). Again, CALPUFF can be run with a single source to run faster, and then CALSUM can be used to combine single runs to assess the cumulative impacts.

The CALPUFF model is an objective dispersion modelling tool that uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source and thereby predict ambient concentrations, based on emissions and meteorological inputs. The model does not favour and is not biased by any source or source type, and relies on the input parameters provided.

7.3 Uncertainties in the CALPUFF Model

Dispersion models are used to predict ambient concentrations based on certain measured parameters, such as wind speed, wind direction, temperature, relative humidity, pressure, solar radiation; and emission rates. Variations in model parameters that are not measured and which are inherent in the model (including complex atmospheric processes that are, by their nature, highly variable), can have an influence on the predicted concentrations. Uncertainties can also result from inadequate model physics and model formulations which are used to predict the ambient concentrations, as well as inaccuracies in model algorithms and input values. These include meteorological data and emission data which is unrepresentative, poor source characterisation in the model and errors in the concentrations measured at AQMS that are used for comparison with model predictions.

The primary areas of uncertainty relevant to this modelling study include uncertainties in the TAPM modelled meteorological data fields (i.e. how accurately the actual wind fields and other meteorological parameters are represented in the modelling), source emissions data and ambient air quality monitoring data. These data elements represent the most important sources of uncertainty in the model inputs. There may be some differences between the TAPM predicted wind speeds and temperature fields and values recorded at available observational stations, and in the modelling domain. These differences would be expected to increase the levels of uncertainty in the modelling results. In terms of the uncertainty in measured ambient concentrations, it is assumed that Eskom has minimized the associated uncertainty by conducting regular assessments and calibration of the ambient monitoring stations used in the analysis. The uncertainty of model predicted concentrations will scale directly with uncertainty in the emission estimates. Emission rates for the power generation emission source category in this study are based on actual emissions provided by Eskom, and are considered to be accurate. Emission rates in this study for all other emission source categories are based on robust methodologies and are also considered to be accurate.

Uncertainties can be minimised by using accurate input data, preparing the input files correctly, double checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics. The accuracy of model predictions in this assessment was done by ensuring that all uncertainties in the input data and model parameterisation were kept to a minimum.

7.4 Data Gaps

The exclusion of a source category can have a significant or insignificant impact on the results of a study depending on the magnitude and importance of the source category.

When compared with the VTAPA and HPA Study, the emission source categories common across all three studies include:

- Industrial Sources
- Residential Fuel Burning
- Waste Burning
- Biomass Burning
- Vehicle Emissions
- Mining Sources
- Wind Blown Dust from Exposed Topsoil Areas

When compared with the VTAPA Study and HPA Study, emissions source categories not included in the Phola Study are:

- Biogenic VOC's
- Agricultural Ammonia
- Spontaneous Combustion

v. As mentioned in Section 7.1, although ARM submitted a request to the DEFF requesting the AEL data for industrial sources and NAEIS data containing emissions information for mines, controlled emitters and facilities identified in accordance with the local by-laws within the modelling domain, DEFF was unable to provide the data due to data policy privacy issues.

Thus, cumulative impact of other industrial sources, controlled emitters and facilities have therefore been excluded from this study, which results in an under-prediction of pollutant ambient concentrations. For the mining sector, ARM was able to develop its own emission factors (see Section 4) which is based on mine footprints.

Regardless of this, the emission source categories for the Phola Study are considered to be adequate, as all important sources have been included in the study. For industrial emissions, there are very few industrial sources in the modelling domain. Eskom power station stacks and fugitive emissions from the associated coal yard and ash dump for the Duvha Power Station, Kendal Power Station, Kriel Power Station, Kusile Power Station and Matla Power Station , which are included in the modelling, are some of the main industrial sources in the modelling domain.

Emissions from spontaneous combustion (burning and smouldering of coal dumps) are relatively small in comparison to the total emissions calculated for both the VTAPA and HPA studies; and impacts in the ambient environment is also considered to be localised. The inclusion of these source categories in the model will not have a significant impact on the results.

Biogenic VOC’s and agricultural ammonia are not relevant to the Phola Study.

8. CONCLUSION AND RECOMMENDATIONS

In this study, the CALPUFF suite of models was used to predict the dispersion of the following pollutants: SO_2, SO_4, NO_X, HNO_3, NO_3, PM_{10}, $PM_{2.5}$ and TPM (to calculate particulate/dust deposition rates) using the MESOPUFF II Scheme chemical transformation method. This baseline modelling study has taken a conservative approach (Scire, 2014) whereby the total concentrations of particulate matter (PM_{10} or $PM_{2.5}$) was computed as the sum of primary particulate matter concentrations (PM_{10} or $PM_{2.5}$) plus the contribution of concentrations from secondary particulate matter, including ammonium nitrate and ammonium sulphate. Results of the modelling were evaluated against the applicable NAAQS and dustfall rates.

The model simulated results indicate that there are exceedances of the NAAQS for SO_2, NO_2 and particulate matter (PM_{10} or $PM_{2.5}$) in the Phola Airshed. An analysis of the source contribution analysis indicates that residential fuel burning and vehicles on unpaved roads have the most significant air quality impact on ambient PM_{10} levels in the Phola Airshed while residential fuel burning have the most significant air quality impact on ambient $PM_{2.5}$ levels in the Phola Airshed.

Hence there is an opportunity herein to reduce human exposure to harmful levels of particulate air pollution by reducing emissions from residential burning in Phola. Thus, supporting the roll-out of Eskom's PMV air quality offset intervention project in Phola. ARM recommends that Eskom considers further investigating the potential PM_{10} air quality impact of unpaved roads in the Phola airshed. Addressing this issue may result in an overall improvement of general ambient air quality in the affected areas. Its noted that Eskom has piloted an ash polymer road at Kusile with good success. This could potentially be an affordable AQO intervention to stabilise the road and prevent dust. However the economic feasibility & viability of this potential AQO intervention will need to be tested by Eskom.

The prioritisation of air quality hotspots for Phola was ranked on the basis of PM air quality impacts. This ensures that the areas that potentially pose the greatest risk to human health and the environment are prioritised in the roll-out of Eskom's AQO program in Phola. Subsequently a total of four air quality hotspots were identified in Phola. Based on these study results, ARM recommends that Eskom considers the rollout of Eskom's AQO household intervention in Phola should prioritise the New Stand and Phola SP areas initially.

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ANNEXURE 1: MODELLED AMBIENT CONCENTRATIONS AT DIESCRETE RECEPTORS FOR SO_2, NO_2, PM_{10}, $PM_{2.5}$ AND DUSTFALL

Table A-1: Model predicted 1-hour SO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour SO_2 (350 µg/m^3)							
Receptor 01	704.929	7125.782	83.45	152.23	0.18	1.31	0.39	0.00	0.00	170.29
Receptor 02	705.339	7125.782	83.95	117.06	0.15	1.11	0.40	0.00	0.00	151.00
Receptor 03	703.270	7125.411	85.01	116.96	0.38	0.42	0.37	0.00	0.00	141.35
Receptor 04	704.503	7125.394	84.28	207.89	0.69	1.34	0.38	0.00	0.00	221.80
Receptor 05	704.920	7125.381	84.34	173.01	0.23	1.45	0.39	0.00	0.00	185.91
Receptor 06	705.334	7125.383	83.66	119.28	0.16	1.15	0.40	0.00	0.00	146.74
Receptor 07	703.260	7124.996	88.04	130.34	0.44	0.41	0.40	0.00	0.00	153.43
Receptor 08	703.683	7124.984	86.63	184.46	0.63	0.50	0.41	0.00	0.00	202.39
Receptor 09	704.087	7124.982	86.53	209.92	0.60	0.54	0.40	0.00	0.00	222.91
Receptor 10	704.496	7124.974	85.40	293.04	1.15	1.48	0.41	0.00	0.00	299.86
Receptor 11	704.913	7124.969	84.95	225.95	0.90	1.31	0.42	0.00	0.00	241.82
Receptor 12	702.839	7124.589	89.46	160.15	0.56	0.49	0.47	0.00	0.00	174.51
Receptor 13	703.249	7124.567	88.77	174.74	0.65	0.46	0.45	0.00	0.00	184.60
Receptor 14	703.674	7124.580	88.37	421.13	1.85	1.06	0.47	0.00	0.00	433.93
Receptor 15	704.086	7124.570	88.07	550.10	2.46	1.48	0.49	0.01	0.00	555.08
Receptor 16	704.492	7124.559	86.37	442.99	1.93	1.33	0.47	0.01	0.00	449.04
Receptor 17	704.910	7124.560	84.87	302.91	1.37	1.23	0.46	0.01	0.00	311.99
Receptor 18	702.836	7124.176	90.24	175.84	0.67	0.43	0.50	0.00	0.00	189.70
Receptor 19	703.250	7124.164	88.82	186.77	0.68	0.47	0.49	0.00	0.00	197.38
Receptor 20	703.661	7124.165	88.50	550.41	2.40	1.22	0.56	0.01	0.00	558.17
Receptor 21	704.077	7124.162	89.00	686.01	3.02	1.02	0.55	0.03	0.00	694.52
Receptor 22	704.489	7124.149	87.43	480.68	2.15	1.12	0.51	0.02	0.00	489.28
Receptor 23	704.900	7124.145	86.91	341.99	1.51	1.15	0.49	0.02	0.00	349.46

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour SO_2 (350 µg/m³)							
Receptor 24	703.244	7123.762	89.91	228.60	0.82	0.62	0.58	0.00	0.00	238.33
Receptor 25 (New Stand)	703.658	7123.748	89.14	586.01	2.57	1.12	0.63	0.01	0.00	593.53
Receptor 26	704.069	7123.739	87.91	566.99	2.54	0.89	0.62	0.03	0.00	571.44
Receptor 27	704.482	7123.734	87.95	472.67	2.14	0.90	0.57	0.02	0.00	477.44
Receptor 28	704.898	7123.715	87.69	368.88	1.56	0.98	0.54	0.02	0.00	375.06
Receptor 29	705.305	7123.730	86.39	287.45	1.23	0.93	0.53	0.01	0.00	294.77
Receptor 30	703.237	7123.345	89.43	179.42	0.68	0.52	0.65	0.00	0.00	192.22
Receptor 31 (Dark City)	703.649	7123.334	90.33	597.16	2.65	1.02	0.74	0.01	0.00	605.46
Receptor 32	704.063	7123.336	89.16	576.99	2.57	0.80	0.70	0.02	0.00	579.96
Receptor 33	704.470	7123.330	88.84	540.17	2.42	0.80	0.63	0.02	0.00	544.72
Receptor 34	704.891	7123.323	88.74	502.31	2.23	0.87	0.68	0.02	0.00	506.32
Receptor 35	705.301	7123.308	87.66	358.51	1.52	0.88	0.65	0.01	0.00	365.81
Receptor 36 (Siyabonga)	703.232	7122.933	91.30	215.31	0.83	0.53	1.14	0.01	0.00	230.39
Receptor 37	703.640	7122.921	91.47	491.56	2.22	0.68	0.92	0.01	0.00	498.28
Receptor 38 (Phola SP)	704.049	7122.908	91.05	730.02	3.35	0.71	0.93	0.01	0.00	733.72
Receptor 39	704.470	7122.914	90.07	662.20	2.94	0.67	0.72	0.02	0.00	667.71
Receptor 40	704.880	7122.907	89.85	616.43	2.78	0.78	0.65	0.02	0.00	619.54
Receptor 41	705.299	7122.902	87.74	402.91	1.84	0.84	0.68	0.01	0.00	409.62
Receptor 42	703.226	7122.528	91.19	221.49	0.91	0.49	1.61	0.01	0.00	232.71
Receptor 43 (Tycoon)	703.637	7122.516	91.44	275.35	1.04	0.45	1.08	0.01	0.00	286.40
Receptor 44	704.051	7122.501	92.48	390.17	1.56	0.47	0.76	0.01	0.00	400.84
Receptor 45	704.465	7122.495	90.32	662.06	3.07	0.53	0.83	0.02	0.00	669.34
Receptor 46	704.874	7122.489	88.96	592.91	2.77	0.66	0.71	0.01	0.00	604.92
Receptor 47	705.289	7122.485	88.64	382.47	1.83	0.81	0.67	0.01	0.00	393.80
Receptor 48	702.809	7122.110	92.79	190.19	0.69	0.48	5.36	0.01	0.00	198.94
Receptor 49	703.216	7122.090	92.63	210.04	0.78	0.43	1.38	0.01	0.00	223.18
Receptor 50	703.627	7122.087	92.73	279.94	0.96	0.43	1.30	0.02	0.00	287.72
Receptor 51	704.044	7122.087	92.26	266.90	0.83	0.42	0.81	0.02	0.00	272.96
Receptor 52	704.456	7122.083	92.09	488.51	2.27	0.48	0.76	0.01	0.00	505.10

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour SO_2 (350 µg/m³)							
Receptor 53	704.873	7122.082	89.89	498.55	2.38	0.61	0.77	0.01	0.00	512.72
Receptor 54	702.798	7121.700	94.86	208.12	0.72	0.45	2.25	0.01	0.00	222.22
Receptor 55 (Buffer Zone)	703.217	7121.682	94.70	297.84	0.91	0.43	1.92	0.02	0.00	305.09
Receptor 56 (Emaforumini)	703.631	7121.689	94.43	309.88	0.93	0.42	1.25	0.02	0.00	313.19
Receptor 57 (Vezibuhle)	704.038	7121.679	93.21	275.80	1.07	0.43	0.85	0.02	0.00	287.01
Receptor 58	704.451	7121.669	92.14	354.64	1.67	0.46	0.80	0.01	0.00	367.39
Receptor 59	704.862	7121.677	91.16	315.94	1.53	0.48	0.81	0.01	0.00	326.36
Receptor 60	703.208	7121.284	95.16	249.98	0.81	0.41	1.59	0.01	0.00	258.94
Receptor 61 (Oyco)	703.617	7121.267	94.71	291.81	0.82	0.41	1.32	0.01	0.00	295.27
Receptor 62	704.024	7121.271	92.93	236.78	0.79	0.41	0.86	0.01	0.00	246.26
Receptor 63	703.621	7120.873	93.61	246.73	0.72	0.44	1.18	0.01	0.00	254.11
Eskom Chicken Farm AQMS	694.498	7125.216	100.15	25.90	0.05	1.75	0.67	0.00	0.00	109.94
Eskom Elandsfontein AQMS	741.853	7094.089	72.50	10.34	0.01	0.22	0.12	0.00	0.00	72.65
Eskom Kendal AQMS	698.242	7112.343	101.98	23.66	0.03	0.61	0.44	0.00	0.00	107.04
Eskom Kriel Village AQMS	724.814	7094.533	138.97	49.34	0.11	0.38	0.60	0.00	0.00	151.15
Eskom Masakhane AQMS	731.596	7125.309	61.88	340.89	1.03	0.40	0.28	0.02	0.00	346.64
Eskom Phola AQMS	703.970	7123.219	89.35	612.19	2.73	0.80	0.82	0.02	0.00	616.74
SAWS eMalahleni AQMS	719.076	7136.018	58.48	521.16	1.44	0.72	0.75	0.00	0.00	525.81
Maximum			151.32	4131.70	15.37	9.74	52.98	0.05	0.00	4143.70

Table A-2: Model predicted 24-hour SO_2 ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour SO_2 (125 µg/m³)							
Receptor 01	704.929	7125.782	32.65	44.10	0.13	0.69	0.18	0.00	0.00	55.54
Receptor 02	705.339	7125.782	32.78	35.42	0.10	0.52	0.18	0.00	0.00	55.52
Receptor 03	703.270	7125.411	36.08	30.87	0.10	0.21	0.17	0.00	0.00	56.99
Receptor 04	704.503	7125.394	32.60	68.62	0.23	0.75	0.17	0.00	0.00	84.45
Receptor 05	704.920	7125.381	31.94	56.10	0.15	0.76	0.17	0.00	0.00	65.32
Receptor 06	705.334	7125.383	33.57	37.28	0.09	0.53	0.18	0.00	0.00	54.96
Receptor 07	703.260	7124.996	34.68	35.49	0.13	0.20	0.18	0.00	0.00	61.11
Receptor 08	703.683	7124.984	34.11	51.80	0.19	0.24	0.18	0.00	0.00	71.23
Receptor 09	704.087	7124.982	33.72	60.27	0.21	0.27	0.17	0.00	0.00	74.28
Receptor 10	704.496	7124.974	33.12	108.42	0.37	0.82	0.18	0.00	0.00	118.98
Receptor 11	704.913	7124.969	33.23	81.76	0.27	0.72	0.18	0.00	0.00	90.59
Receptor 12	702.839	7124.589	37.97	42.07	0.14	0.24	0.22	0.00	0.00	63.88
Receptor 13	703.249	7124.567	35.11	47.59	0.16	0.23	0.21	0.00	0.00	66.60
Receptor 14	703.674	7124.580	35.41	144.71	0.68	0.52	0.20	0.00	0.00	150.83
Receptor 15	704.086	7124.570	34.64	188.09	0.81	0.80	0.22	0.00	0.00	191.25
Receptor 16	704.492	7124.559	33.75	157.76	0.65	0.70	0.21	0.01	0.00	167.86
Receptor 17	704.910	7124.560	34.17	99.03	0.45	0.63	0.20	0.01	0.00	111.84
Receptor 18	702.836	7124.176	36.42	49.34	0.18	0.22	0.23	0.00	0.00	67.66
Receptor 19	703.250	7124.164	35.88	49.60	0.18	0.23	0.22	0.00	0.00	68.42
Receptor 20	703.661	7124.165	35.33	214.10	0.90	0.56	0.25	0.00	0.00	221.91
Receptor 21	704.077	7124.162	35.76	210.50	0.94	0.48	0.25	0.01	0.00	221.09
Receptor 22	704.489	7124.149	34.50	177.13	0.73	0.51	0.23	0.01	0.00	183.20
Receptor 23	704.900	7124.145	33.72	119.17	0.54	0.47	0.22	0.01	0.00	130.67
Receptor 24	703.244	7123.762	36.29	61.43	0.26	0.29	0.25	0.00	0.00	74.65
Receptor 25 (New Stand)	703.658	7123.748	35.94	213.10	0.91	0.50	0.28	0.00	0.00	223.48
Receptor 26	704.069	7123.739	35.48	201.79	0.87	0.40	0.28	0.01	0.00	211.62
Receptor 27	704.482	7123.734	34.89	170.24	0.75	0.38	0.25	0.01	0.00	185.14

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour SO_2 (125 µg/m³)							
Receptor 28	704.898	7123.715	34.17	120.61	0.52	0.38	0.24	0.01	0.00	135.94
Receptor 29	705.305	7123.730	34.45	83.18	0.39	0.39	0.22	0.00	0.00	97.94
Receptor 30	703.237	7123.345	35.11	46.97	0.18	0.26	0.29	0.00	0.00	62.58
Receptor 31 (Dark City)	703.649	7123.334	36.58	202.20	0.89	0.46	0.34	0.00	0.00	219.53
Receptor 32	704.063	7123.336	36.12	197.39	0.94	0.36	0.31	0.01	0.00	204.10
Receptor 33	704.470	7123.330	35.56	174.97	0.87	0.31	0.28	0.01	0.00	185.43
Receptor 34	704.891	7123.323	34.89	151.82	0.73	0.34	0.27	0.01	0.00	160.97
Receptor 35	705.301	7123.308	34.12	93.83	0.46	0.35	0.25	0.01	0.00	112.83
Receptor 36 (Siyabonga)	703.232	7122.933	34.88	57.15	0.22	0.26	0.54	0.00	0.00	74.18
Receptor 37	703.640	7122.921	33.80	164.58	0.77	0.31	0.41	0.00	0.00	172.08
Receptor 38 (Phola SP)	704.049	7122.908	36.68	224.70	1.17	0.32	0.45	0.01	0.00	240.49
Receptor 39	704.470	7122.914	36.23	195.47	0.95	0.27	0.31	0.01	0.00	203.93
Receptor 40	704.880	7122.907	34.39	177.26	0.86	0.28	0.28	0.01	0.00	182.53
Receptor 41	705.299	7122.902	34.27	105.49	0.52	0.33	0.26	0.01	0.00	122.69
Receptor 42	703.226	7122.528	35.94	59.93	0.25	0.25	0.77	0.00	0.00	73.45
Receptor 43 (Tycoon)	703.637	7122.516	34.95	73.08	0.33	0.22	0.50	0.01	0.00	89.61
Receptor 44	704.051	7122.501	35.32	117.17	0.58	0.22	0.31	0.01	0.00	130.51
Receptor 45	704.465	7122.495	33.48	205.05	1.08	0.23	0.36	0.01	0.00	215.31
Receptor 46	704.874	7122.489	33.99	179.80	0.89	0.25	0.30	0.01	0.00	187.01
Receptor 47	705.289	7122.485	34.12	98.08	0.51	0.30	0.27	0.00	0.00	117.28
Receptor 48	702.809	7122.110	36.46	50.49	0.16	0.24	2.30	0.00	0.00	61.80
Receptor 49	703.216	7122.090	36.73	52.76	0.20	0.23	0.67	0.00	0.00	63.97
Receptor 50	703.627	7122.087	36.00	73.61	0.30	0.21	0.59	0.01	0.00	81.82
Receptor 51	704.044	7122.087	34.64	64.33	0.27	0.20	0.34	0.01	0.00	79.35
Receptor 52	704.456	7122.083	33.92	171.53	0.88	0.21	0.34	0.01	0.00	185.61
Receptor 53	704.873	7122.082	34.63	149.71	0.78	0.24	0.33	0.01	0.00	161.01
Receptor 54	702.798	7121.700	36.52	52.66	0.19	0.23	1.20	0.00	0.00	64.52
Receptor 55 (Buffer Zone)	703.217	7121.682	36.51	68.08	0.25	0.22	0.94	0.01	0.00	78.00
Receptor 56 (Emaforumini)	703.631	7121.689	36.01	76.00	0.27	0.21	0.55	0.01	0.00	85.56

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour SO_2 (125 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	35.26	87.59	0.38	0.20	0.36	0.01	0.00	106.15
Receptor 58	704.451	7121.669	35.36	124.74	0.61	0.20	0.34	0.00	0.00	138.26
Receptor 59	704.862	7121.677	34.57	94.56	0.46	0.21	0.35	0.01	0.00	111.13
Receptor 60	703.208	7121.284	38.77	59.04	0.21	0.21	0.74	0.01	0.00	68.25
Receptor 61 (Oyco)	703.617	7121.267	36.69	68.72	0.25	0.20	0.55	0.01	0.00	84.78
Receptor 62	704.024	7121.271	35.68	66.51	0.24	0.19	0.37	0.01	0.00	74.46
Receptor 63	703.621	7120.873	37.14	58.43	0.20	0.20	0.51	0.00	0.00	68.92
Eskom Chicken Farm AQMS	694.498	7125.216	45.29	11.84	0.02	0.84	0.25	0.00	0.00	47.72
Eskom Elandsfontein AQMS	741.853	7094.089	25.68	3.50	0.00	0.11	0.07	0.00	0.00	26.33
Eskom Kendal AQMS	698.242	7112.343	51.94	10.49	0.01	0.27	0.17	0.00	0.00	55.56
Eskom Kriel Village AQMS	724.814	7094.533	55.68	17.77	0.06	0.18	0.26	0.00	0.00	62.14
Eskom Masakhane AQMS	731.596	7125.309	25.91	111.96	0.34	0.17	0.15	0.01	0.00	113.58
Eskom Phola AQMS	703.970	7123.219	36.42	197.74	0.94	0.36	0.35	0.01	0.00	207.38
SAWS eMalahleni AQMS	719.076	7136.018	27.83	160.38	0.55	0.35	0.30	0.00	0.00	171.63
Maximum			79.68	1389.50	5.06	3.93	23.55	0.03	0.00	1394.10

Table A-3: Model predicted annual SO_2 ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual SO_2 (50 µg/m³)							
Receptor 01	704.929	7125.782	4.14	5.72	0.01	0.36	0.07	0.00	0.00	10.30
Receptor 02	705.339	7125.782	4.13	4.82	0.01	0.24	0.07	0.00	0.00	9.27
Receptor 03	703.270	7125.411	4.18	7.73	0.03	0.09	0.06	0.00	0.00	12.09
Receptor 04	704.503	7125.394	4.17	19.85	0.09	0.39	0.07	0.00	0.00	24.57
Receptor 05	704.920	7125.381	4.17	7.60	0.02	0.39	0.07	0.00	0.00	12.25
Receptor 06	705.334	7125.383	4.16	5.21	0.01	0.28	0.07	0.00	0.00	9.73
Receptor 07	703.260	7124.996	4.22	9.51	0.04	0.10	0.07	0.00	0.00	13.93
Receptor 08	703.683	7124.984	4.22	13.82	0.06	0.12	0.07	0.00	0.00	18.29
Receptor 09	704.087	7124.982	4.22	16.11	0.07	0.13	0.07	0.00	0.00	20.60
Receptor 10	704.496	7124.974	4.21	33.85	0.16	0.37	0.07	0.00	0.00	38.67
Receptor 11	704.913	7124.969	4.21	21.40	0.09	0.33	0.07	0.00	0.00	26.10
Receptor 12	702.839	7124.589	4.28	11.47	0.05	0.11	0.07	0.00	0.00	15.97
Receptor 13	703.249	7124.567	4.27	15.06	0.07	0.11	0.07	0.00	0.00	19.58
Receptor 14	703.674	7124.580	4.28	47.99	0.27	0.23	0.07	0.00	0.00	52.84
Receptor 15	704.086	7124.570	4.28	65.65	0.36	0.35	0.08	0.00	0.00	70.71
Receptor 16	704.492	7124.559	4.27	52.57	0.28	0.32	0.07	0.00	0.00	57.51
Receptor 17	704.910	7124.560	4.25	33.83	0.17	0.27	0.07	0.00	0.00	38.61
Receptor 18	702.836	7124.176	4.32	15.69	0.07	0.10	0.08	0.00	0.00	20.25
Receptor 19	703.250	7124.164	4.32	16.97	0.07	0.11	0.07	0.00	0.00	21.54
Receptor 20	703.661	7124.165	4.33	58.65	0.33	0.26	0.08	0.00	0.00	63.64
Receptor 21	704.077	7124.162	4.33	64.78	0.36	0.22	0.08	0.01	0.00	69.78
Receptor 22	704.489	7124.149	4.31	52.21	0.29	0.22	0.08	0.01	0.00	57.12
Receptor 23	704.900	7124.145	4.30	36.72	0.20	0.19	0.08	0.00	0.00	41.49
Receptor 24	703.244	7123.762	4.37	21.74	0.10	0.13	0.08	0.00	0.00	26.42
Receptor 25 (New Stand)	703.658	7123.748	4.37	64.13	0.36	0.22	0.08	0.00	0.00	69.16
Receptor 26	704.069	7123.739	4.37	71.05	0.40	0.18	0.08	0.01	0.00	76.08
Receptor 27	704.482	7123.734	4.36	61.87	0.34	0.16	0.08	0.01	0.00	66.82

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual SO_2 (50 µg/m³)							
Receptor 28	704.898	7123.715	4.35	39.08	0.21	0.14	0.08	0.00	0.00	43.85
Receptor 29	705.305	7123.730	4.32	26.69	0.14	0.13	0.08	0.00	0.00	31.37
Receptor 30	703.237	7123.345	4.41	16.71	0.07	0.12	0.10	0.00	0.00	21.41
Receptor 31 (Dark City)	703.649	7123.334	4.42	70.61	0.38	0.19	0.11	0.00	0.00	75.72
Receptor 32	704.063	7123.336	4.41	71.96	0.39	0.16	0.09	0.00	0.00	77.02
Receptor 33	704.470	7123.330	4.40	66.23	0.36	0.14	0.09	0.00	0.00	71.21
Receptor 34	704.891	7123.323	4.39	62.35	0.33	0.12	0.09	0.01	0.00	67.29
Receptor 35	705.301	7123.308	4.36	32.32	0.17	0.13	0.09	0.00	0.00	37.07
Receptor 36 (Siyabonga)	703.232	7122.933	4.45	20.19	0.09	0.12	0.24	0.00	0.00	25.09
Receptor 37	703.640	7122.921	4.45	56.01	0.30	0.14	0.16	0.00	0.00	61.06
Receptor 38 (Phola SP)	704.049	7122.908	4.44	82.51	0.45	0.14	0.19	0.00	0.00	87.74
Receptor 39	704.470	7122.914	4.43	79.81	0.43	0.10	0.09	0.00	0.00	84.86
Receptor 40	704.880	7122.907	4.41	69.08	0.36	0.11	0.09	0.00	0.00	74.06
Receptor 41	705.299	7122.902	4.39	37.36	0.19	0.12	0.09	0.00	0.00	42.15
Receptor 42	703.226	7122.528	4.50	22.35	0.10	0.11	0.37	0.00	0.00	27.43
Receptor 43 (Tycoon)	703.637	7122.516	4.48	29.19	0.14	0.09	0.23	0.00	0.00	34.13
Receptor 44	704.051	7122.501	4.46	44.31	0.22	0.09	0.12	0.00	0.00	49.20
Receptor 45	704.465	7122.495	4.44	68.85	0.37	0.09	0.13	0.00	0.00	73.90
Receptor 46	704.874	7122.489	4.43	61.27	0.33	0.10	0.09	0.00	0.00	66.23
Receptor 47	705.289	7122.485	4.41	34.53	0.18	0.12	0.09	0.00	0.00	39.33
Receptor 48	702.809	7122.110	4.56	13.31	0.06	0.11	0.72	0.00	0.00	18.76
Receptor 49	703.216	7122.090	4.55	17.36	0.07	0.10	0.26	0.00	0.00	22.34
Receptor 50	703.627	7122.087	4.53	26.72	0.11	0.09	0.27	0.01	0.00	31.73
Receptor 51	704.044	7122.087	4.49	24.74	0.10	0.09	0.13	0.00	0.00	29.56
Receptor 52	704.456	7122.083	4.47	53.98	0.28	0.09	0.10	0.00	0.00	58.94
Receptor 53	704.873	7122.082	4.47	50.00	0.26	0.10	0.10	0.00	0.00	54.93
Receptor 54	702.798	7121.700	4.61	14.15	0.06	0.10	0.45	0.00	0.00	19.37
Receptor 55 (Buffer Zone)	703.217	7121.682	4.59	23.10	0.09	0.09	0.36	0.00	0.00	28.24
Receptor 56 (Emaforumini)	703.631	7121.689	4.57	25.85	0.10	0.09	0.23	0.00	0.00	30.84

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual SO_2 (50 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	4.54	31.72	0.15	0.08	0.14	0.00	0.00	36.64
Receptor 58	704.451	7121.669	4.52	39.60	0.20	0.09	0.11	0.00	0.00	44.52
Receptor 59	704.862	7121.677	4.51	32.34	0.15	0.09	0.10	0.00	0.00	37.20
Receptor 60	703.208	7121.284	4.63	18.83	0.07	0.09	0.28	0.00	0.00	23.91
Receptor 61 (Oyco)	703.617	7121.267	4.61	24.31	0.09	0.09	0.22	0.00	0.00	29.31
Receptor 62	704.024	7121.271	4.59	22.96	0.09	0.08	0.12	0.00	0.00	27.85
Receptor 63	703.621	7120.873	4.65	21.31	0.08	0.09	0.18	0.00	0.00	26.30
Eskom Chicken Farm AQMS	694.498	7125.216	4.50	1.50	0.00	0.34	0.09	0.00	0.00	6.44
Eskom Elandsfontein AQMS	741.853	7094.089	4.30	0.57	0.00	0.03	0.01	0.00	0.00	4.91
Eskom Kendal AQMS	698.242	7112.343	5.19	1.24	0.00	0.12	0.06	0.00	0.00	6.61
Eskom Kriel Village AQMS	724.814	7094.533	7.45	2.74	0.01	0.07	0.09	0.00	0.00	10.35
Eskom Masakhane AQMS	731.596	7125.309	3.21	42.28	0.15	0.06	0.04	0.00	0.00	45.76
Eskom Phola AQMS	703.970	7123.219	4.43	71.01	0.39	0.16	0.13	0.00	0.00	76.13
SAWS eMalahleni AQMS	719.076	7136.018	2.99	46.12	0.17	0.12	0.10	0.00	0.00	49.50
Maximum			8.07	494.01	2.35	1.59	4.56	0.01	0.00	499.53

Table A-4: Model predicted 1-hour NO_2 ambient concentrations (99th percentile) in µg/m^3 at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour NO_2 (200 µg/m^3)							
Receptor 01	704.929	7125.782	30.88	54.07	0.61	0.22	19.85	0.74	0.00	70.83
Receptor 02	705.339	7125.782	30.32	41.25	0.49	0.18	19.80	0.62	0.00	61.62
Receptor 03	703.270	7125.411	31.19	41.75	1.50	0.07	18.88	0.48	0.00	59.68
Receptor 04	704.503	7125.394	30.98	74.86	2.66	0.23	19.48	0.74	0.00	90.56
Receptor 05	704.920	7125.381	30.78	60.84	0.79	0.24	19.88	0.76	0.00	78.26
Receptor 06	705.334	7125.383	31.02	42.65	0.53	0.19	20.37	0.72	0.00	61.28
Receptor 07	703.260	7124.996	31.21	46.80	1.71	0.06	20.76	0.50	0.00	65.63
Receptor 08	703.683	7124.984	31.23	66.29	2.49	0.08	20.99	0.66	0.00	84.13
Receptor 09	704.087	7124.982	31.06	75.54	2.33	0.09	20.44	0.72	0.00	92.34
Receptor 10	704.496	7124.974	30.92	106.32	4.45	0.25	21.04	0.88	0.00	118.32
Receptor 11	704.913	7124.969	30.98	81.27	3.49	0.22	21.27	0.99	0.00	99.27
Receptor 12	702.839	7124.589	32.03	57.68	2.22	0.08	23.80	0.62	0.00	78.34
Receptor 13	703.249	7124.567	31.45	62.95	2.55	0.07	23.00	0.61	0.00	79.23
Receptor 14	703.674	7124.580	31.36	152.87	7.14	0.17	24.19	0.95	0.00	165.54
Receptor 15	704.086	7124.570	31.42	199.63	9.56	0.25	25.10	2.06	0.00	215.74
Receptor 16	704.492	7124.559	31.24	161.02	7.50	0.22	24.11	2.96	0.00	175.40
Receptor 17	704.910	7124.560	31.27	109.59	5.38	0.21	23.34	2.76	0.00	125.03
Receptor 18	702.836	7124.176	31.75	63.48	2.64	0.07	25.79	0.59	0.00	83.07
Receptor 19	703.250	7124.164	32.08	67.28	2.69	0.07	25.07	0.56	0.00	83.84
Receptor 20	703.661	7124.165	32.21	198.50	9.25	0.20	29.05	1.56	0.00	213.20
Receptor 21	704.077	7124.162	31.69	250.48	11.82	0.17	28.21	5.52	0.00	268.96
Receptor 22	704.489	7124.149	31.19	175.81	8.28	0.19	26.68	4.99	0.00	189.80
Receptor 23	704.900	7124.145	31.16	123.83	5.76	0.19	25.21	3.50	0.00	138.29
Receptor 24	703.244	7123.762	32.12	82.76	3.26	0.10	29.76	0.68	0.00	99.80
Receptor 25 (New Stand)	703.658	7123.748	31.99	213.01	9.89	0.19	32.58	1.30	0.00	227.11
Receptor 26	704.069	7123.739	31.88	206.20	9.88	0.14	31.81	5.59	0.00	223.55
Receptor 27	704.482	7123.734	31.67	172.04	8.18	0.15	29.38	5.03	0.00	186.53

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour NO_2 (200 µg/m³)							
Receptor 28	704.898	7123.715	31.46	133.71	5.91	0.16	28.02	3.84	0.00	144.58
Receptor 29	705.305	7123.730	31.35	103.56	4.74	0.15	27.22	1.14	0.00	114.07
Receptor 30	703.237	7123.345	32.48	64.53	2.66	0.09	33.49	0.70	0.00	88.15
Receptor 31 (Dark City)	703.649	7123.334	32.37	216.91	10.22	0.17	37.41	1.33	0.00	233.05
Receptor 32	704.063	7123.336	32.00	209.91	9.86	0.13	36.52	4.95	0.00	220.03
Receptor 33	704.470	7123.330	32.09	195.78	9.21	0.13	32.50	4.83	0.00	205.65
Receptor 34	704.891	7123.323	31.73	183.36	8.57	0.14	34.35	4.73	0.00	197.18
Receptor 35	705.301	7123.308	31.90	129.59	5.88	0.14	33.31	2.36	0.00	142.34
Receptor 36 (Siyabonga)	703.232	7122.933	32.79	78.10	3.29	0.09	58.73	1.31	0.00	116.81
Receptor 37	703.640	7122.921	32.61	178.21	8.49	0.11	47.30	2.18	0.00	203.15
Receptor 38 (Phola SP)	704.049	7122.908	32.39	265.47	12.69	0.12	48.15	3.02	0.00	294.55
Receptor 39	704.470	7122.914	32.38	241.12	11.30	0.10	37.21	4.01	0.00	254.57
Receptor 40	704.880	7122.907	32.20	223.74	10.71	0.12	33.67	4.21	0.00	237.29
Receptor 41	705.299	7122.902	32.08	145.66	7.14	0.14	35.14	2.22	0.00	160.82
Receptor 42	703.226	7122.528	32.92	80.21	3.62	0.08	83.69	1.79	0.00	135.44
Receptor 43 (Tycoon)	703.637	7122.516	33.12	100.42	4.05	0.07	55.46	2.89	0.00	135.78
Receptor 44	704.051	7122.501	33.02	142.28	6.08	0.07	38.57	2.35	0.00	156.00
Receptor 45	704.465	7122.495	32.36	240.42	11.76	0.08	43.11	3.28	0.00	262.67
Receptor 46	704.874	7122.489	32.31	214.71	10.77	0.10	36.86	2.25	0.00	232.29
Receptor 47	705.289	7122.485	31.80	138.66	7.06	0.13	34.63	1.16	0.00	153.51
Receptor 48	702.809	7122.110	33.66	68.40	2.70	0.08	281.23	1.52	0.00	289.95
Receptor 49	703.216	7122.090	33.63	76.19	3.04	0.07	71.78	1.67	0.00	118.88
Receptor 50	703.627	7122.087	33.28	102.31	3.73	0.07	67.53	4.27	0.00	138.94
Receptor 51	704.044	7122.087	33.13	96.97	3.33	0.06	41.47	3.53	0.00	115.36
Receptor 52	704.456	7122.083	32.95	177.64	8.78	0.07	39.16	2.82	0.00	195.25
Receptor 53	704.873	7122.082	32.30	180.90	9.19	0.09	39.66	2.35	0.00	196.31
Receptor 54	702.798	7121.700	34.28	74.71	2.79	0.07	117.16	2.17	0.00	143.32
Receptor 55 (Buffer Zone)	703.217	7121.682	34.08	108.53	3.60	0.07	100.04	3.87	0.00	157.98
Receptor 56 (Emaforumini)	703.631	7121.689	33.31	112.98	3.74	0.07	63.94	3.64	0.00	139.97

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 1-hour NO_2 (200 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	33.46	100.54	4.17	0.07	43.68	3.30	0.00	120.30
Receptor 58	704.451	7121.669	33.05	129.17	6.43	0.07	41.40	1.91	0.00	143.80
Receptor 59	704.862	7121.677	32.50	114.31	5.89	0.07	42.37	2.06	0.00	133.13
Receptor 60	703.208	7121.284	34.13	91.10	3.19	0.06	83.51	2.38	0.00	129.94
Receptor 61 (Oyco)	703.617	7121.267	33.51	106.50	3.18	0.06	68.77	2.54	0.00	130.05
Receptor 62	704.024	7121.271	33.45	86.19	3.10	0.06	45.03	2.17	0.00	104.80
Receptor 63	703.621	7120.873	33.76	89.86	2.84	0.07	62.45	1.72	0.00	117.63
Eskom Chicken Farm AQMS	694.498	7125.216	40.78	8.69	0.15	0.29	34.19	0.19	0.00	51.26
Eskom Elandsfontein AQMS	741.853	7094.089	46.03	3.43	0.02	0.04	5.93	0.03	0.00	46.55
Eskom Kendal AQMS	698.242	7112.343	46.14	7.72	0.08	0.10	21.29	0.21	0.00	52.63
Eskom Kriel Village AQMS	724.814	7094.533	93.53	16.92	0.41	0.06	30.53	0.09	0.00	97.55
Eskom Masakhane AQMS	731.596	7125.309	25.34	124.20	4.00	0.06	14.14	3.40	0.00	133.21
Eskom Phola AQMS	703.970	7123.219	32.32	223.08	10.44	0.13	42.79	4.85	0.00	243.67
SAWS eMalahleni AQMS	719.076	7136.018	19.72	187.81	5.62	0.12	40.22	0.36	0.00	198.67
Maximum			108.58	1512.10	61.14	1.66	2914.50	10.90	0.00	2922.00

Table A-5: Model predicted annual NO_2 ambient concentrations in µg/m^3 at discrete receptors and at the point of maximum for the seven emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual NO_2 (40 µg/m³)							
Receptor 01	704.929	7125.782	1.61	1.96	0.04	0.06	3.39	0.05	0.00	7.11
Receptor 02	705.339	7125.782	1.60	1.63	0.03	0.04	3.44	0.04	0.00	6.79
Receptor 03	703.270	7125.411	1.65	2.70	0.10	0.01	3.05	0.06	0.00	7.56
Receptor 04	704.503	7125.394	1.63	7.10	0.36	0.07	3.27	0.06	0.00	12.50
Receptor 05	704.920	7125.381	1.62	2.64	0.07	0.07	3.35	0.05	0.00	7.81
Receptor 06	705.334	7125.383	1.62	1.77	0.03	0.05	3.45	0.05	0.00	6.97
Receptor 07	703.260	7124.996	1.66	3.34	0.14	0.02	3.20	0.07	0.00	8.43
Receptor 08	703.683	7124.984	1.66	4.91	0.23	0.02	3.31	0.09	0.00	10.22
Receptor 09	704.087	7124.982	1.65	5.74	0.28	0.02	3.30	0.08	0.00	11.07
Receptor 10	704.496	7124.974	1.65	12.21	0.64	0.06	3.40	0.09	0.00	18.05
Receptor 11	704.913	7124.969	1.64	7.67	0.37	0.05	3.47	0.07	0.00	13.27
Receptor 12	702.839	7124.589	1.68	4.06	0.17	0.02	3.59	0.09	0.00	9.61
Receptor 13	703.249	7124.567	1.68	5.36	0.25	0.02	3.51	0.09	0.00	10.92
Receptor 14	703.674	7124.580	1.68	17.33	1.05	0.04	3.61	0.13	0.00	23.84
Receptor 15	704.086	7124.570	1.68	23.76	1.42	0.06	3.74	0.35	0.00	31.01
Receptor 16	704.492	7124.559	1.67	19.01	1.10	0.05	3.68	0.77	0.00	26.28
Receptor 17	704.910	7124.560	1.67	12.19	0.68	0.05	3.69	0.57	0.00	18.84
Receptor 18	702.836	7124.176	1.70	5.60	0.26	0.02	3.76	0.10	0.00	11.43
Receptor 19	703.250	7124.164	1.69	6.05	0.27	0.02	3.68	0.10	0.00	11.82
Receptor 20	703.661	7124.165	1.70	21.20	1.27	0.04	3.96	0.25	0.00	28.42
Receptor 21	704.077	7124.162	1.70	23.44	1.41	0.04	3.99	1.53	0.00	32.10
Receptor 22	704.489	7124.149	1.69	18.86	1.12	0.04	3.90	1.26	0.00	26.87
Receptor 23	704.900	7124.145	1.68	13.22	0.76	0.03	3.87	0.74	0.00	20.31
Receptor 24	703.244	7123.762	1.71	7.79	0.37	0.02	4.05	0.16	0.00	14.09
Receptor 25 (New Stand)	703.658	7123.748	1.71	23.19	1.39	0.04	4.18	0.30	0.00	30.81
Receptor 26	704.069	7123.739	1.71	25.71	1.55	0.03	4.22	1.18	0.00	34.41
Receptor 27	704.482	7123.734	1.71	22.37	1.34	0.03	4.10	1.11	0.00	30.65

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual NO_2 (40 µg/m³)							
Receptor 28	704.898	7123.715	1.70	14.08	0.80	0.02	4.10	0.71	0.00	21.41
Receptor 29	705.305	7123.730	1.69	9.58	0.55	0.02	4.05	0.09	0.00	15.98
Receptor 30	703.237	7123.345	1.72	5.96	0.25	0.02	5.28	0.16	0.00	13.39
Receptor 31 (Dark City)	703.649	7123.334	1.73	25.56	1.50	0.03	5.54	0.28	0.00	34.63
Receptor 32	704.063	7123.336	1.72	26.04	1.53	0.03	4.52	0.97	0.00	34.81
Receptor 33	704.470	7123.330	1.72	23.96	1.38	0.02	4.36	0.96	0.00	32.39
Receptor 34	704.891	7123.323	1.72	22.57	1.29	0.02	4.61	1.10	0.00	31.30
Receptor 35	705.301	7123.308	1.71	11.63	0.65	0.02	4.53	0.33	0.00	18.87
Receptor 36 (Siyabonga)	703.232	7122.933	1.73	7.23	0.33	0.02	12.40	0.26	0.00	21.97
Receptor 37	703.640	7122.921	1.73	20.23	1.15	0.02	8.41	0.37	0.00	31.93
Receptor 38 (Phola SP)	704.049	7122.908	1.73	29.85	1.76	0.02	9.88	0.67	0.00	43.92
Receptor 39	704.470	7122.914	1.73	28.90	1.66	0.02	4.62	0.75	0.00	37.67
Receptor 40	704.880	7122.907	1.72	25.03	1.40	0.02	4.57	0.92	0.00	33.66
Receptor 41	705.299	7122.902	1.71	13.47	0.75	0.02	4.73	0.43	0.00	21.11
Receptor 42	703.226	7122.528	1.75	8.02	0.38	0.02	19.07	0.40	0.00	29.63
Receptor 43 (Tycoon)	703.637	7122.516	1.74	10.49	0.53	0.01	11.65	0.75	0.00	25.17
Receptor 44	704.051	7122.501	1.73	15.97	0.87	0.01	6.09	0.47	0.00	25.14
Receptor 45	704.465	7122.495	1.73	24.91	1.43	0.01	6.83	0.76	0.00	35.68
Receptor 46	704.874	7122.489	1.73	22.18	1.27	0.02	4.72	0.44	0.00	30.36
Receptor 47	705.289	7122.485	1.72	12.45	0.70	0.02	4.67	0.12	0.00	19.68
Receptor 48	702.809	7122.110	1.76	4.73	0.22	0.02	37.69	0.28	0.00	44.69
Receptor 49	703.216	7122.090	1.76	6.20	0.26	0.01	13.49	0.33	0.00	22.06
Receptor 50	703.627	7122.087	1.75	9.60	0.44	0.01	14.03	1.20	0.00	27.03
Receptor 51	704.044	7122.087	1.74	8.87	0.39	0.01	6.84	0.87	0.00	18.73
Receptor 52	704.456	7122.083	1.74	19.51	1.09	0.01	5.30	0.53	0.00	28.19
Receptor 53	704.873	7122.082	1.74	18.08	1.03	0.01	5.01	0.48	0.00	26.35
Receptor 54	702.798	7121.700	1.77	5.03	0.23	0.02	23.10	0.38	0.00	30.53
Receptor 55 (Buffer Zone)	703.217	7121.682	1.77	8.29	0.34	0.01	18.76	0.84	0.00	30.01
Receptor 56 (Emaforumini)	703.631	7121.689	1.76	9.28	0.39	0.01	11.74	0.92	0.00	24.11

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual NO_2 (40 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	1.76	11.41	0.56	0.01	6.96	0.76	0.00	21.47
Receptor 58	704.451	7121.669	1.75	14.28	0.76	0.01	5.50	0.31	0.00	22.62
Receptor 59	704.862	7121.677	1.75	11.65	0.60	0.01	5.25	0.35	0.00	19.61
Receptor 60	703.208	7121.284	1.78	6.74	0.26	0.01	14.64	0.50	0.00	23.93
Receptor 61 (Oyco)	703.617	7121.267	1.77	8.72	0.35	0.01	11.12	0.59	0.00	22.56
Receptor 62	704.024	7121.271	1.77	8.23	0.35	0.01	6.39	0.43	0.00	17.18
Receptor 63	703.621	7120.873	1.78	7.63	0.30	0.01	9.29	0.26	0.00	19.28
Eskom Chicken Farm AQMS	694.498	7125.216	1.80	0.47	0.01	0.06	4.59	0.01	0.00	6.94
Eskom Elandsfontein AQMS	741.853	7094.089	2.18	0.17	0.00	0.00	0.65	0.00	0.00	3.00
Eskom Kendal AQMS	698.242	7112.343	1.96	0.38	0.00	0.02	2.94	0.01	0.00	5.31
Eskom Kriel Village AQMS	724.814	7094.533	4.10	0.91	0.02	0.01	4.55	0.01	0.00	9.60
Eskom Masakhane AQMS	731.596	7125.309	1.12	15.35	0.59	0.01	2.11	0.90	0.00	20.08
Eskom Phola AQMS	703.970	7123.219	1.73	25.69	1.50	0.03	6.82	0.96	0.00	36.73
SAWS eMalahleni AQMS	719.076	7136.018	0.93	16.66	0.65	0.02	5.40	0.07	0.00	23.72
Maximum			4.76	180.46	9.33	0.27	247.17	2.74	0.00	255.80

Table A-6: Model predicted 24-hour PM_{10} ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour PM_{10} (75 µg/m³)							
Receptor 01	704.929	7125.782	17.34	58.37	6.40	7.17	1.24	22.53	27.62	104.15
Receptor 02	705.339	7125.782	17.56	47.13	4.72	5.41	1.24	19.48	32.32	97.37
Receptor 03	703.270	7125.411	16.87	41.22	4.90	2.15	1.15	14.48	21.14	85.91
Receptor 04	704.503	7125.394	17.53	90.56	11.23	7.77	1.17	20.88	25.46	144.32
Receptor 05	704.920	7125.381	17.47	74.18	7.53	7.85	1.19	21.10	26.34	124.56
Receptor 06	705.334	7125.383	17.12	49.57	4.40	5.50	1.24	23.91	28.81	99.48
Receptor 07	703.260	7124.996	16.52	47.48	6.56	2.14	1.17	16.53	21.81	93.72
Receptor 08	703.683	7124.984	16.80	68.49	9.61	2.54	1.14	21.45	22.75	123.20
Receptor 09	704.087	7124.982	17.26	79.59	10.55	2.80	1.19	22.24	23.98	134.25
Receptor 10	704.496	7124.974	17.97	142.49	18.27	8.53	1.20	26.12	25.96	201.48
Receptor 11	704.913	7124.969	17.68	107.73	13.49	7.46	1.22	29.08	27.37	168.47
Receptor 12	702.839	7124.589	16.96	55.86	6.96	2.55	1.27	18.96	23.54	108.70
Receptor 13	703.249	7124.567	17.09	63.21	8.19	2.38	1.24	21.04	23.67	112.54
Receptor 14	703.674	7124.580	17.48	190.12	33.40	5.39	1.27	31.49	25.08	255.64
Receptor 15	704.086	7124.570	17.91	246.68	40.03	8.26	1.36	71.25	27.25	353.97
Receptor 16	704.492	7124.559	18.22	207.07	32.07	7.20	1.31	97.93	28.22	343.30
Receptor 17	704.910	7124.560	17.95	130.34	22.43	6.49	1.27	97.27	30.55	261.28
Receptor 18	702.836	7124.176	16.63	65.64	8.99	2.27	1.26	19.48	24.02	114.82
Receptor 19	703.250	7124.164	17.06	65.82	8.88	2.40	1.30	19.06	24.07	112.12
Receptor 20	703.661	7124.165	17.86	280.61	44.49	5.78	1.38	50.22	26.71	386.37
Receptor 21	704.077	7124.162	18.33	275.93	46.52	4.97	1.47	189.73	29.60	490.23
Receptor 22	704.489	7124.149	18.01	232.37	36.28	5.28	1.36	157.25	30.95	394.54
Receptor 23	704.900	7124.145	18.19	156.55	26.77	4.91	1.33	112.12	32.60	293.71
Receptor 24	703.244	7123.762	17.48	81.26	12.75	3.03	1.33	22.52	25.49	134.05
Receptor 25 (New Stand)	703.658	7123.748	17.79	279.46	45.17	5.12	1.42	45.37	27.21	368.41
Receptor 26	704.069	7123.739	17.45	264.80	43.01	4.11	1.50	185.10	30.22	485.21
Receptor 27	704.482	7123.734	17.52	223.38	37.43	4.01	1.43	164.56	32.67	423.12

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour PM_{10} (75 µg/m³)							
Receptor 28	704.898	7123.715	18.28	158.51	25.98	3.98	1.39	116.51	37.55	332.43
Receptor 29	705.305	7123.730	18.04	109.48	19.43	4.03	1.34	50.42	41.47	183.42
Receptor 30	703.237	7123.345	17.26	62.59	9.17	2.75	1.34	23.09	24.98	116.39
Receptor 31 (Dark City)	703.649	7123.334	17.64	265.22	44.05	4.75	1.52	48.90	28.22	354.69
Receptor 32	704.063	7123.336	17.35	258.90	46.80	3.72	1.54	168.59	30.79	461.23
Receptor 33	704.470	7123.330	17.95	229.61	42.94	3.30	1.49	157.70	33.82	412.24
Receptor 34	704.891	7123.323	18.36	199.31	36.01	3.54	1.52	159.13	41.90	405.85
Receptor 35	705.301	7123.308	18.20	123.39	22.99	3.60	1.45	82.59	46.59	250.52
Receptor 36 (Siyabonga)	703.232	7122.933	17.26	75.56	10.90	2.71	1.67	42.14	26.18	138.86
Receptor 37	703.640	7122.921	17.07	216.03	38.01	3.25	1.61	62.99	28.62	310.25
Receptor 38 (Phola SP)	704.049	7122.908	17.88	294.78	57.95	3.31	1.72	117.71	31.73	456.68
Receptor 39	704.470	7122.914	17.79	256.90	47.23	2.88	1.51	124.27	35.36	412.09
Receptor 40	704.880	7122.907	17.75	232.72	42.58	2.97	1.50	144.09	43.35	425.12
Receptor 41	705.299	7122.902	18.39	138.66	25.71	3.40	1.48	78.23	53.43	269.25
Receptor 42	703.226	7122.528	17.05	79.23	12.17	2.60	1.96	59.92	27.07	158.88
Receptor 43 (Tycoon)	703.637	7122.516	17.46	96.55	16.39	2.31	1.67	99.58	28.27	224.44
Receptor 44	704.051	7122.501	17.55	154.41	28.92	2.27	1.46	71.96	29.39	265.00
Receptor 45	704.465	7122.495	17.76	269.06	53.58	2.38	1.56	117.81	34.03	445.50
Receptor 46	704.874	7122.489	17.82	235.70	44.17	2.65	1.52	83.54	45.35	369.43
Receptor 47	705.289	7122.485	18.04	128.94	25.20	3.12	1.46	52.77	58.66	229.38
Receptor 48	702.809	7122.110	17.24	67.25	8.15	2.52	3.98	43.94	26.85	132.82
Receptor 49	703.216	7122.090	17.61	69.94	10.01	2.38	1.82	52.68	26.63	140.14
Receptor 50	703.627	7122.087	18.48	97.19	14.97	2.23	1.77	150.25	29.29	263.09
Receptor 51	704.044	7122.087	18.59	84.89	13.58	2.11	1.46	110.01	29.17	218.42
Receptor 52	704.456	7122.083	18.08	225.41	43.57	2.17	1.48	96.56	33.75	361.81
Receptor 53	704.873	7122.082	18.51	196.55	38.64	2.50	1.57	85.21	47.80	330.71
Receptor 54	702.798	7121.700	18.13	70.08	9.71	2.42	2.61	67.93	29.06	145.32
Receptor 55 (Buffer Zone)	703.217	7121.682	18.73	89.91	12.62	2.29	2.26	135.03	29.28	229.17
Receptor 56 (Emaforumini)	703.631	7121.689	19.24	100.23	13.40	2.16	1.73	140.41	30.33	254.92

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour PM_{10} (75 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	19.05	115.32	19.09	2.08	1.49	104.84	33.36	263.48
Receptor 58	704.451	7121.669	18.82	163.90	30.01	2.12	1.47	62.35	35.71	274.29
Receptor 59	704.862	7121.677	18.64	124.43	22.63	2.18	1.56	73.08	43.72	242.51
Receptor 60	703.208	7121.284	19.81	78.05	10.31	2.16	1.98	83.03	30.83	169.30
Receptor 61 (Oyco)	703.617	7121.267	19.79	90.80	12.42	2.10	1.75	93.48	33.97	203.44
Receptor 62	704.024	7121.271	19.33	87.88	12.14	2.01	1.51	76.79	35.81	192.14
Receptor 63	703.621	7120.873	19.93	77.31	9.99	2.10	1.75	52.47	37.76	157.31
Eskom Chicken Farm AQMS	694.498	7125.216	30.11	16.28	0.97	8.69	1.41	4.51	24.25	52.25
Eskom Elandsfontein AQMS	741.853	7094.089	12.40	4.96	0.20	1.16	0.76	1.15	9.74	25.10
Eskom Kendal AQMS	698.242	7112.343	42.15	14.51	0.69	2.86	1.49	4.72	24.19	58.31
Eskom Kriel Village AQMS	724.814	7094.533	38.77	23.98	2.97	1.91	1.50	2.31	21.62	58.48
Eskom Masakhane AQMS	731.596	7125.309	19.22	146.59	16.82	1.79	0.95	109.53	18.83	267.51
Eskom Phola AQMS	703.970	7123.219	17.36	259.48	46.65	3.69	1.60	163.86	31.09	464.24
SAWS eMalahleni AQMS	719.076	7136.018	14.31	210.78	27.25	3.62	0.97	10.79	11.12	257.08
Maximum			383.62	1819.54	249.88	40.69	35.06	401.51	273.09	2037.67

Table A-7: Model predicted annual PM_{10} ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual PM_{10} 40 µg/m³)							
Receptor 01	704.929	7125.782	2.04	7.63	0.63	3.75	0.26	3.60	11.36	29.27
Receptor 02	705.339	7125.782	2.06	6.45	0.49	2.49	0.26	3.11	16.03	30.89
Receptor 03	703.270	7125.411	1.97	10.25	1.36	0.99	0.23	3.91	6.38	25.10
Receptor 04	704.503	7125.394	2.02	26.07	4.64	4.06	0.25	4.28	8.52	49.83
Receptor 05	704.920	7125.381	2.04	10.08	0.94	4.07	0.25	3.68	10.26	31.33
Receptor 06	705.334	7125.383	2.05	6.96	0.55	2.93	0.26	3.52	12.89	29.15
Receptor 07	703.260	7124.996	2.00	12.58	1.87	1.02	0.24	4.98	6.71	29.39
Receptor 08	703.683	7124.984	2.03	18.21	3.05	1.26	0.25	5.87	7.33	38.00
Receptor 09	704.087	7124.982	2.03	21.19	3.62	1.39	0.25	5.63	7.76	41.88
Receptor 10	704.496	7124.974	2.06	44.35	8.15	3.82	0.25	6.43	8.86	73.93
Receptor 11	704.913	7124.969	2.06	28.09	4.68	3.39	0.26	4.66	10.36	53.51
Receptor 12	702.839	7124.589	2.04	15.14	2.25	1.10	0.26	6.48	7.11	34.38
Receptor 13	703.249	7124.567	2.04	19.83	3.27	1.12	0.25	6.45	7.30	40.27
Receptor 14	703.674	7124.580	2.08	62.83	13.29	2.36	0.26	9.20	8.15	98.18
Receptor 15	704.086	7124.570	2.11	85.87	17.89	3.57	0.27	23.74	9.04	142.50
Receptor 16	704.492	7124.559	2.11	68.79	13.85	3.30	0.27	51.36	9.84	149.53
Receptor 17	704.910	7124.560	2.12	44.33	8.63	2.80	0.27	38.40	11.38	107.93
Receptor 18	702.836	7124.176	2.05	20.64	3.31	1.06	0.26	6.98	7.28	41.58
Receptor 19	703.250	7124.164	2.05	22.32	3.56	1.13	0.26	6.74	7.54	43.59
Receptor 20	703.661	7124.165	2.12	76.74	16.14	2.67	0.28	17.04	8.77	123.76
Receptor 21	704.077	7124.162	2.15	84.74	17.88	2.31	0.28	102.50	9.80	219.66
Receptor 22	704.489	7124.149	2.15	68.33	14.21	2.28	0.28	84.57	10.75	182.57
Receptor 23	704.900	7124.145	2.16	48.10	9.70	2.00	0.28	49.84	12.12	124.19
Receptor 24	703.244	7123.762	2.08	28.55	4.71	1.35	0.27	10.57	8.08	55.61
Receptor 25 (New Stand)	703.658	7123.748	2.12	83.90	17.57	2.26	0.28	20.23	9.05	135.40
Receptor 26	704.069	7123.739	2.15	92.93	19.62	1.87	0.29	79.10	10.23	206.18
Receptor 27	704.482	7123.734	2.17	80.94	16.95	1.65	0.29	74.24	11.45	187.68

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual PM_{10} 40 µg/m³)							
Receptor 28	704.898	7123.715	2.19	51.19	10.19	1.41	0.29	47.76	13.54	126.56
Receptor 29	705.305	7123.730	2.19	35.01	7.01	1.40	0.29	6.45	15.40	67.74
Receptor 30	703.237	7123.345	2.09	21.98	3.26	1.22	0.30	10.77	8.07	47.70
Receptor 31 (Dark City)	703.649	7123.334	2.14	92.37	18.99	2.01	0.32	18.67	9.41	143.90
Receptor 32	704.063	7123.336	2.16	94.13	19.43	1.65	0.30	65.23	10.55	193.45
Receptor 33	704.470	7123.330	2.18	86.64	17.58	1.40	0.30	64.09	12.07	184.25
Receptor 34	704.891	7123.323	2.24	81.56	16.30	1.23	0.33	73.77	15.52	190.95
Receptor 35	705.301	7123.308	2.23	42.35	8.30	1.32	0.32	22.44	18.89	95.86
Receptor 36 (Siyabonga)	703.232	7122.933	2.12	26.53	4.27	1.22	0.49	17.53	8.56	60.73
Receptor 37	703.640	7122.921	2.15	73.31	14.72	1.42	0.39	25.07	9.58	126.64
Receptor 38 (Phola SP)	704.049	7122.908	2.18	107.94	22.46	1.46	0.44	45.22	10.92	190.61
Receptor 39	704.470	7122.914	2.19	104.39	21.08	1.08	0.30	50.10	12.62	191.78
Receptor 40	704.880	7122.907	2.23	90.36	17.78	1.11	0.31	61.58	16.16	189.53
Receptor 41	705.299	7122.902	2.25	48.92	9.54	1.26	0.33	28.54	20.62	111.45
Receptor 42	703.226	7122.528	2.13	29.35	4.86	1.10	0.66	27.02	8.95	74.08
Receptor 43 (Tycoon)	703.637	7122.516	2.15	38.28	6.81	0.96	0.47	50.05	9.52	108.25
Receptor 44	704.051	7122.501	2.15	58.04	11.12	0.95	0.33	31.40	10.25	114.24
Receptor 45	704.465	7122.495	2.19	90.09	18.18	0.97	0.36	51.08	12.35	175.23
Receptor 46	704.874	7122.489	2.23	80.16	16.15	1.04	0.31	29.75	16.58	146.22
Receptor 47	705.289	7122.485	2.24	45.24	8.93	1.20	0.31	8.41	22.93	89.26
Receptor 48	702.809	7122.110	2.14	17.55	2.81	1.11	1.14	19.00	9.18	52.92
Receptor 49	703.216	7122.090	2.14	22.84	3.44	0.99	0.52	22.46	9.29	61.68
Receptor 50	703.627	7122.087	2.16	35.06	5.69	0.93	0.54	80.12	9.99	134.48
Receptor 51	704.044	7122.087	2.16	32.47	5.12	0.89	0.35	58.39	10.35	109.74
Receptor 52	704.456	7122.083	2.20	70.66	13.93	0.93	0.32	35.70	12.12	135.85
Receptor 53	704.873	7122.082	2.25	65.43	13.11	1.01	0.32	31.86	17.56	131.53
Receptor 54	702.798	7121.700	2.17	18.64	3.01	1.03	0.78	25.46	10.12	61.21
Receptor 55 (Buffer Zone)	703.217	7121.682	2.17	30.33	4.34	0.96	0.66	56.19	10.30	104.95
Receptor 56 (Emaforumini)	703.631	7121.689	2.18	33.92	4.99	0.91	0.48	61.60	10.89	114.97

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual PM_{10} 40 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	2.20	41.59	7.25	0.89	0.36	50.83	11.82	114.94
Receptor 58	704.451	7121.669	2.21	51.88	9.73	0.90	0.32	21.09	13.03	99.17
Receptor 59	704.862	7121.677	2.23	42.39	7.65	0.92	0.32	23.49	15.80	92.80
Receptor 60	703.208	7121.284	2.19	24.76	3.39	0.92	0.57	33.83	11.31	76.97
Receptor 61 (Oyco)	703.617	7121.267	2.21	31.91	4.51	0.89	0.48	39.42	12.51	91.92
Receptor 62	704.024	7121.271	2.20	30.16	4.49	0.86	0.35	28.94	13.33	80.33
Receptor 63	703.621	7120.873	2.24	27.99	3.95	0.89	0.44	17.45	15.32	68.28
Eskom Chicken Farm AQMS	694.498	7125.216	3.55	2.07	0.17	3.54	0.33	1.01	6.19	16.85
Eskom Elandsfontein AQMS	741.853	7094.089	2.07	0.79	0.05	0.28	0.09	0.20	1.49	4.97
Eskom Kendal AQMS	698.242	7112.343	6.83	1.72	0.10	1.24	0.29	0.77	10.08	21.02
Eskom Kriel Village AQMS	724.814	7094.533	4.42	3.70	0.30	0.69	0.30	0.59	5.68	15.68
Eskom Masakhane AQMS	731.596	7125.309	2.77	55.24	7.35	0.65	0.16	59.97	2.52	128.67
Eskom Phola AQMS	703.970	7123.219	2.17	92.90	19.09	1.67	0.36	64.70	10.57	191.46
SAWS eMalahleni AQMS	719.076	7136.018	1.51	60.40	8.33	1.26	0.26	4.54	2.92	79.22
Maximum			57.33	644.92	116.05	16.43	7.00	186.84	123.56	782.45

Table A-8: Model predicted 24-hour $PM_{2.5}$ ambient concentrations (99th percentile) in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour $PM_{2.5}$ (40 µg/m³)							
Receptor 01	704.929	7125.782	11.74	54.36	6.38	6.90	1.24	2.27	7.36	77.89
Receptor 02	705.339	7125.782	11.67	43.91	4.70	5.20	1.24	1.96	8.62	66.15
Receptor 03	703.270	7125.411	11.15	38.41	4.89	2.07	1.15	1.46	5.63	56.25
Receptor 04	704.503	7125.394	11.69	84.31	11.18	7.47	1.17	2.10	6.79	117.30
Receptor 05	704.920	7125.381	11.72	69.07	7.50	7.55	1.19	2.12	7.02	95.79
Receptor 06	705.334	7125.383	11.64	46.18	4.39	5.29	1.24	2.40	7.68	66.83
Receptor 07	703.260	7124.996	11.19	44.24	6.54	2.06	1.17	1.66	5.81	61.75
Receptor 08	703.683	7124.984	11.41	63.78	9.57	2.44	1.14	2.16	6.06	88.01
Receptor 09	704.087	7124.982	11.66	74.11	10.51	2.70	1.19	2.24	6.39	97.10
Receptor 10	704.496	7124.974	12.00	132.62	18.20	8.20	1.20	2.63	6.92	165.55
Receptor 11	704.913	7124.969	11.88	100.29	13.43	7.17	1.22	2.92	7.30	131.78
Receptor 12	702.839	7124.589	11.43	52.03	6.94	2.45	1.27	1.91	6.28	74.24
Receptor 13	703.249	7124.567	11.51	58.87	8.16	2.29	1.24	2.12	6.31	81.35
Receptor 14	703.674	7124.580	11.72	176.95	33.27	5.18	1.27	3.16	6.69	219.33
Receptor 15	704.086	7124.570	11.79	229.58	39.87	7.94	1.36	7.15	7.26	274.55
Receptor 16	704.492	7124.559	12.13	192.71	31.94	6.92	1.31	9.83	7.52	231.91
Receptor 17	704.910	7124.560	12.03	121.32	22.34	6.24	1.27	9.76	8.14	167.40
Receptor 18	702.836	7124.176	11.45	61.13	8.96	2.19	1.26	1.96	6.40	82.55
Receptor 19	703.250	7124.164	11.52	61.30	8.85	2.31	1.30	1.92	6.42	83.31
Receptor 20	703.661	7124.165	11.71	261.14	44.31	5.55	1.38	5.04	7.12	309.04
Receptor 21	704.077	7124.162	11.77	256.79	46.34	4.77	1.47	19.04	7.89	318.61
Receptor 22	704.489	7124.149	11.94	216.25	36.14	5.07	1.36	15.78	8.25	271.57
Receptor 23	704.900	7124.145	12.13	145.71	26.67	4.72	1.33	11.25	8.69	185.00
Receptor 24	703.244	7123.762	11.63	75.67	12.69	2.91	1.33	2.27	6.80	99.98
Receptor 25 (New Stand)	703.658	7123.748	11.70	260.07	45.00	4.93	1.42	4.56	7.25	300.82
Receptor 26	704.069	7123.739	11.58	246.44	42.84	3.95	1.50	18.57	8.06	299.87
Receptor 27	704.482	7123.734	11.66	207.89	37.28	3.85	1.43	16.51	8.71	264.26

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour $PM_{2.5}$ (40 µg/m³)							
Receptor 28	704.898	7123.715	12.07	147.53	25.88	3.82	1.39	11.69	10.01	199.84
Receptor 29	705.305	7123.730	11.89	101.92	19.35	3.87	1.34	5.06	11.05	135.46
Receptor 30	703.237	7123.345	11.61	58.30	9.13	2.64	1.34	2.32	6.66	80.60
Receptor 31 (Dark City)	703.649	7123.334	11.65	246.83	43.88	4.57	1.52	4.91	7.52	286.79
Receptor 32	704.063	7123.336	11.50	240.95	46.61	3.58	1.54	16.91	8.21	290.88
Receptor 33	704.470	7123.330	11.91	213.70	42.77	3.17	1.49	15.82	9.02	261.65
Receptor 34	704.891	7123.323	11.98	185.49	35.87	3.40	1.52	15.96	11.17	233.09
Receptor 35	705.301	7123.308	11.97	114.86	22.90	3.46	1.45	8.29	12.42	152.66
Receptor 36 (Siyabonga)	703.232	7122.933	11.54	70.36	10.86	2.61	1.67	4.23	6.98	95.83
Receptor 37	703.640	7122.921	11.52	201.06	37.86	3.12	1.61	6.32	7.63	238.66
Receptor 38 (Phola SP)	704.049	7122.908	11.91	274.35	57.72	3.18	1.72	11.81	8.46	337.44
Receptor 39	704.470	7122.914	11.76	239.09	47.04	2.77	1.51	12.47	9.43	293.88
Receptor 40	704.880	7122.907	11.67	216.58	42.41	2.85	1.50	14.46	11.56	268.95
Receptor 41	705.299	7122.902	12.15	129.06	25.61	3.27	1.48	7.85	14.24	177.87
Receptor 42	703.226	7122.528	11.54	73.78	12.13	2.50	1.96	6.02	7.22	101.48
Receptor 43 (Tycoon)	703.637	7122.516	11.66	89.90	16.32	2.22	1.67	9.99	7.53	125.40
Receptor 44	704.051	7122.501	11.74	143.73	28.81	2.18	1.46	7.22	7.83	185.54
Receptor 45	704.465	7122.495	11.63	250.40	53.37	2.29	1.56	11.82	9.07	319.27
Receptor 46	704.874	7122.489	11.61	219.35	43.99	2.55	1.52	8.38	12.09	275.90
Receptor 47	705.289	7122.485	11.73	120.02	25.10	3.00	1.46	5.30	15.64	167.35
Receptor 48	702.809	7122.110	11.66	62.63	8.12	2.42	3.98	4.41	7.16	85.97
Receptor 49	703.216	7122.090	11.71	65.14	9.97	2.29	1.82	5.29	7.10	89.50
Receptor 50	703.627	7122.087	12.10	90.48	14.91	2.15	1.77	15.07	7.81	126.62
Receptor 51	704.044	7122.087	12.18	79.04	13.53	2.03	1.46	11.04	7.78	112.75
Receptor 52	704.456	7122.083	11.86	209.78	43.40	2.09	1.48	9.69	9.00	258.34
Receptor 53	704.873	7122.082	11.81	182.93	38.49	2.41	1.57	8.55	12.74	242.71
Receptor 54	702.798	7121.700	12.17	65.26	9.67	2.32	2.61	6.82	7.75	89.62
Receptor 55 (Buffer Zone)	703.217	7121.682	12.37	83.72	12.57	2.20	2.26	13.55	7.80	116.58
Receptor 56 (Emaforumini)	703.631	7121.689	12.50	93.31	13.35	2.08	1.73	14.09	8.08	127.16

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour $PM_{2.5}$ (40 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	12.38	107.35	19.01	2.00	1.49	10.52	8.89	141.45
Receptor 58	704.451	7121.669	12.21	152.55	29.89	2.04	1.47	6.26	9.52	197.09
Receptor 59	704.862	7121.677	12.07	115.83	22.54	2.10	1.56	7.33	11.66	156.76
Receptor 60	703.208	7121.284	12.87	72.68	10.27	2.07	1.98	8.33	8.22	98.09
Receptor 61 (Oyco)	703.617	7121.267	12.81	84.54	12.38	2.02	1.75	9.38	9.06	114.73
Receptor 62	704.024	7121.271	12.55	81.83	12.09	1.93	1.51	7.71	9.55	110.38
Receptor 63	703.621	7120.873	12.95	71.99	9.95	2.02	1.75	5.27	10.07	97.70
Eskom Chicken Farm AQMS	694.498	7125.216	16.96	15.19	0.97	8.35	1.41	0.46	6.46	32.14
Eskom Elandsfontein AQMS	741.853	7094.089	7.17	4.63	0.20	1.12	0.76	0.12	2.60	13.98
Eskom Kendal AQMS	698.242	7112.343	22.07	13.55	0.68	2.75	1.49	0.48	6.45	31.98
Eskom Kriel Village AQMS	724.814	7094.533	18.90	22.36	2.96	1.84	1.50	0.24	5.76	37.92
Eskom Masakhane AQMS	731.596	7125.309	10.80	136.41	16.75	1.72	0.95	10.99	5.02	164.38
Eskom Phola AQMS	703.970	7123.219	11.51	241.49	46.47	3.55	1.60	16.44	8.29	300.06
SAWS eMalahleni AQMS	719.076	7136.018	9.48	196.19	27.14	3.48	0.97	1.09	2.96	231.46
Maximum			156.91	1693.14	248.89	39.12	35.06	40.30	72.79	1876.17

Table A-9: Model predicted annual $PM_{2.5}$ ambient concentrations in µg/m³ at discrete receptors and at the point of maximum for the eight emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual $PM_{2.5}$ (20 µg/m³)							
Receptor 01	704.929	7125.782	1.15	7.11	0.62	3.61	0.26	0.36	3.03	16.13
Receptor 02	705.339	7125.782	1.15	6.01	0.49	2.40	0.26	0.31	4.27	14.90
Receptor 03	703.270	7125.411	1.12	9.55	1.35	0.95	0.23	0.39	1.70	15.29
Receptor 04	704.503	7125.394	1.14	24.26	4.62	3.90	0.25	0.43	2.27	36.87
Receptor 05	704.920	7125.381	1.15	9.39	0.94	3.91	0.25	0.37	2.74	18.74
Receptor 06	705.334	7125.383	1.15	6.48	0.54	2.81	0.26	0.35	3.43	15.04
Receptor 07	703.260	7124.996	1.13	11.71	1.86	0.98	0.24	0.50	1.79	18.21
Receptor 08	703.683	7124.984	1.14	16.95	3.03	1.21	0.25	0.59	1.95	25.13
Receptor 09	704.087	7124.982	1.15	19.73	3.60	1.34	0.25	0.57	2.07	28.70
Receptor 10	704.496	7124.974	1.16	41.27	8.12	3.67	0.25	0.65	2.36	57.48
Receptor 11	704.913	7124.969	1.16	26.14	4.66	3.26	0.26	0.47	2.76	38.71
Receptor 12	702.839	7124.589	1.15	14.09	2.24	1.06	0.26	0.65	1.90	21.34
Receptor 13	703.249	7124.567	1.15	18.46	3.26	1.08	0.25	0.65	1.95	26.79
Receptor 14	703.674	7124.580	1.17	58.46	13.24	2.27	0.26	0.92	2.17	78.50
Receptor 15	704.086	7124.570	1.18	79.90	17.82	3.43	0.27	2.38	2.41	107.39
Receptor 16	704.492	7124.559	1.18	64.01	13.80	3.17	0.27	5.15	2.62	90.20
Receptor 17	704.910	7124.560	1.18	41.25	8.60	2.70	0.27	3.85	3.03	60.88
Receptor 18	702.836	7124.176	1.15	19.21	3.30	1.02	0.26	0.70	1.94	27.59
Receptor 19	703.250	7124.164	1.15	20.77	3.54	1.09	0.26	0.68	2.01	29.51
Receptor 20	703.661	7124.165	1.18	71.41	16.07	2.57	0.28	1.71	2.34	95.56
Receptor 21	704.077	7124.162	1.20	78.85	17.81	2.22	0.28	10.28	2.61	113.25
Receptor 22	704.489	7124.149	1.20	63.58	14.15	2.20	0.28	8.48	2.86	92.75
Receptor 23	704.900	7124.145	1.20	44.75	9.66	1.93	0.28	5.00	3.23	66.04
Receptor 24	703.244	7123.762	1.17	26.57	4.69	1.29	0.27	1.06	2.15	37.22
Receptor 25 (New Stand)	703.658	7123.748	1.18	78.07	17.50	2.17	0.28	2.03	2.41	103.65
Receptor 26	704.069	7123.739	1.20	86.46	19.54	1.80	0.29	7.93	2.73	119.95
Receptor 27	704.482	7123.734	1.20	75.31	16.89	1.59	0.29	7.45	3.05	105.77

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual $PM_{2.5}$ (20 µg/m³)							
Receptor 28	704.898	7123.715	1.22	47.63	10.15	1.35	0.29	4.79	3.61	69.04
Receptor 29	705.305	7123.730	1.21	32.58	6.98	1.35	0.29	0.65	4.10	47.16
Receptor 30	703.237	7123.345	1.17	20.46	3.25	1.18	0.30	1.08	2.15	29.59
Receptor 31 (Dark City)	703.649	7123.334	1.19	85.95	18.92	1.93	0.32	1.87	2.51	112.69
Receptor 32	704.063	7123.336	1.20	87.58	19.35	1.59	0.30	6.54	2.81	119.38
Receptor 33	704.470	7123.330	1.21	80.62	17.51	1.35	0.30	6.43	3.22	110.63
Receptor 34	704.891	7123.323	1.24	75.89	16.24	1.19	0.33	7.40	4.14	106.41
Receptor 35	705.301	7123.308	1.23	39.41	8.27	1.27	0.32	2.25	5.03	57.79
Receptor 36 (Siyabonga)	703.232	7122.933	1.18	24.69	4.26	1.18	0.49	1.76	2.28	35.84
Receptor 37	703.640	7122.921	1.20	68.22	14.66	1.36	0.39	2.51	2.55	90.90
Receptor 38 (Phola SP)	704.049	7122.908	1.21	100.43	22.37	1.40	0.44	4.54	2.91	133.30
Receptor 39	704.470	7122.914	1.22	97.13	21.00	1.04	0.30	5.02	3.36	129.09
Receptor 40	704.880	7122.907	1.23	84.08	17.71	1.07	0.31	6.18	4.31	114.88
Receptor 41	705.299	7122.902	1.24	45.53	9.50	1.21	0.33	2.86	5.50	66.16
Receptor 42	703.226	7122.528	1.19	27.32	4.84	1.06	0.66	2.71	2.39	40.16
Receptor 43 (Tycoon)	703.637	7122.516	1.20	35.63	6.79	0.92	0.47	5.02	2.54	52.56
Receptor 44	704.051	7122.501	1.20	54.01	11.08	0.91	0.33	3.15	2.73	73.41
Receptor 45	704.465	7122.495	1.22	83.83	18.10	0.94	0.36	5.12	3.29	112.86
Receptor 46	704.874	7122.489	1.23	74.59	16.09	1.00	0.31	2.98	4.42	100.62
Receptor 47	705.289	7122.485	1.24	42.10	8.90	1.15	0.31	0.84	6.11	60.65
Receptor 48	702.809	7122.110	1.19	16.33	2.80	1.06	1.14	1.91	2.45	26.87
Receptor 49	703.216	7122.090	1.19	21.26	3.43	0.95	0.52	2.25	2.48	32.08
Receptor 50	703.627	7122.087	1.20	32.62	5.67	0.90	0.54	8.03	2.66	51.62
Receptor 51	704.044	7122.087	1.20	30.22	5.10	0.86	0.35	5.86	2.76	46.34
Receptor 52	704.456	7122.083	1.22	65.75	13.88	0.89	0.32	3.58	3.23	88.86
Receptor 53	704.873	7122.082	1.24	60.89	13.05	0.97	0.32	3.20	4.68	84.34
Receptor 54	702.798	7121.700	1.21	17.35	3.00	0.99	0.78	2.55	2.70	28.57
Receptor 55 (Buffer Zone)	703.217	7121.682	1.21	28.22	4.32	0.92	0.66	5.64	2.75	43.72
Receptor 56 (Emaforumini)	703.631	7121.689	1.21	31.57	4.97	0.87	0.48	6.18	2.90	48.18

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – Annual $PM_{2.5}$ (20 µg/m³)							
Receptor 57 (Vezibuhle)	704.038	7121.679	1.22	38.70	7.22	0.85	0.36	5.10	3.15	56.60
Receptor 58	704.451	7121.669	1.22	48.28	9.69	0.87	0.32	2.12	3.47	65.97
Receptor 59	704.862	7121.677	1.23	39.45	7.62	0.88	0.32	2.36	4.21	56.07
Receptor 60	703.208	7121.284	1.22	23.04	3.38	0.89	0.57	3.39	3.01	35.50
Receptor 61 (Oyco)	703.617	7121.267	1.22	29.70	4.49	0.85	0.48	3.95	3.34	44.03
Receptor 62	704.024	7121.271	1.22	28.07	4.47	0.83	0.35	2.90	3.55	41.39
Receptor 63	703.621	7120.873	1.24	26.05	3.93	0.86	0.44	1.75	4.08	38.35
Eskom Chicken Farm AQMS	694.498	7125.216	1.74	1.93	0.17	3.41	0.33	0.10	1.65	9.32
Eskom Elandsfontein AQMS	741.853	7094.089	1.10	0.74	0.05	0.27	0.09	0.02	0.40	2.66
Eskom Kendal AQMS	698.242	7112.343	3.04	1.61	0.10	1.19	0.29	0.08	2.69	8.99
Eskom Kriel Village AQMS	724.814	7094.533	2.14	3.45	0.30	0.67	0.30	0.06	1.51	8.42
Eskom Masakhane AQMS	731.596	7125.309	1.38	51.40	7.32	0.63	0.16	6.01	0.67	67.57
Eskom Phola AQMS	703.970	7123.219	1.21	86.44	19.01	1.60	0.36	6.49	2.82	117.94
SAWS eMalahleni AQMS	719.076	7136.018	0.89	56.21	8.29	1.21	0.26	0.46	0.78	68.09
Maximum			23.22	600.05	115.59	15.79	7.00	18.74	32.94	720.25

Table A-10: Model predicted 24-hour dustfall rates in mg/m²/day at discrete receptors and at the point of maximum for the five emission source categories

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour dustfall (600 mg/m²/day for residential and 1200 mg/m²/day for non-residential)							
Receptor 01	704.929	7125.782	9.31			3.18		29.00	24.40	42.80
Receptor 02	705.339	7125.782	9.33			1.87		22.90	30.70	45.40
Receptor 03	703.270	7125.411	9.46			0.87		16.00	16.90	31.70
Receptor 04	704.503	7125.394	9.52			2.71		20.60	21.10	40.60
Receptor 05	704.920	7125.381	9.52			2.89		21.00	22.30	37.40
Receptor 06	705.334	7125.383	9.56			1.91		36.10	25.30	51.00
Receptor 07	703.260	7124.996	9.82			0.89		17.30	17.50	33.40
Receptor 08	703.683	7124.984	9.86			1.00		21.50	19.10	39.20
Receptor 09	704.087	7124.982	9.81			1.03		21.60	19.10	41.40
Receptor 10	704.496	7124.974	9.86			3.16		24.10	21.30	47.20
Receptor 11	704.913	7124.969	9.83			2.46		27.20	23.70	42.10
Receptor 12	702.839	7124.589	10.30			0.96		22.10	17.80	43.20
Receptor 13	703.249	7124.567	10.20			0.97		21.30	18.60	40.60
Receptor 14	703.674	7124.580	10.30			2.50		29.40	21.20	49.40
Receptor 15	704.086	7124.570	10.30			3.31		73.20	21.90	94.80
Receptor 16	704.492	7124.559	10.30			3.02		112.00	22.30	132.00
Receptor 17	704.910	7124.560	10.20			2.37		101.00	27.60	117.00
Receptor 18	702.836	7124.176	10.50			0.89		20.90	18.70	42.70
Receptor 19	703.250	7124.164	10.50			0.93		18.40	18.70	38.90
Receptor 20	703.661	7124.165	10.60			2.97		48.80	21.60	69.60
Receptor 21	704.077	7124.162	10.70			2.43		171.00	23.00	195.00
Receptor 22	704.489	7124.149	10.60			2.33		140.00	23.40	158.00
Receptor 23	704.900	7124.145	10.50			2.06		106.00	27.60	122.00
Receptor 24	703.244	7123.762	10.70			1.09		20.40	19.00	40.60
Receptor 25 (New Stand)	703.658	7123.748	10.80			2.43		45.20	21.10	62.40
Receptor 26	704.069	7123.739	10.80			2.11		205.00	23.90	222.00
Receptor 27	704.482	7123.734	10.70			1.98		152.00	25.30	171.00

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour dustfall (600 mg/m^2/day for residential and 1200 mg/m^2/day for non-residential)							
Receptor 28	704.898	7123.715	10.60			1.67		131.00	30.90	155.00
Receptor 29	705.305	7123.730	10.40			1.56		58.40	34.10	80.50
Receptor 30	703.237	7123.345	10.80			0.94		19.40	20.70	41.00
Receptor 31 (Dark City)	703.649	7123.334	10.90			1.84		53.60	20.80	70.70
Receptor 32	704.063	7123.336	10.90			1.57		192.00	24.70	208.00
Receptor 33	704.470	7123.330	10.80			1.40		164.00	26.70	182.00
Receptor 34	704.891	7123.323	10.80			1.16		156.00	41.20	199.00
Receptor 35	705.301	7123.308	10.40			1.35		89.50	44.10	125.00
Receptor 36 (Siyabonga)	703.232	7122.933	11.00			0.96		37.10	23.60	52.00
Receptor 37	703.640	7122.921	11.00			1.30		55.50	22.80	72.90
Receptor 38 (Phola SP)	704.049	7122.908	10.90			1.30		123.00	25.80	139.00
Receptor 39	704.470	7122.914	10.70			1.07		146.00	28.10	165.00
Receptor 40	704.880	7122.907	10.60			1.06		154.00	41.60	187.00
Receptor 41	705.299	7122.902	10.30			1.26		93.50	56.10	135.00
Receptor 42	703.226	7122.528	11.20			0.90		56.80	26.20	67.60
Receptor 43 (Tycoon)	703.637	7122.516	11.10			0.86		83.00	25.00	94.80
Receptor 44	704.051	7122.501	10.80			0.85		76.70	24.30	88.20
Receptor 45	704.465	7122.495	10.60			0.81		116.00	28.10	134.00
Receptor 46	704.874	7122.489	10.40			1.00		82.00	42.40	107.00
Receptor 47	705.289	7122.485	10.10			1.14		71.60	52.10	114.00
Receptor 48	702.809	7122.110	11.70			0.86		38.60	28.10	58.90
Receptor 49	703.216	7122.090	11.50			0.85		44.30	27.90	67.40
Receptor 50	703.627	7122.087	11.30			0.82		121.00	27.30	144.00
Receptor 51	704.044	7122.087	10.90			0.80		101.00	25.30	115.00
Receptor 52	704.456	7122.083	10.60			0.78		107.00	26.80	124.00
Receptor 53	704.873	7122.082	10.30			0.95		78.10	41.00	110.00
Receptor 54	702.798	7121.700	12.10			0.85		65.20	31.20	78.20
Receptor 55 (Buffer Zone)	703.217	7121.682	11.80			0.82		125.00	28.60	140.00
Receptor 56 (Emaforumini)	703.631	7121.689	11.50			0.79		145.00	30.70	161.00

Discrete Receptors	UTMx	UTMy	Power Generation	Residential Fuel Burning	Waste Burning	Biomass Burning	Vehicles - Paved Roads	Vehicles - Unpaved Roads	Mining	All Sources
			NAAQS – 24-hour dustfall (600 mg/m^2/day for residential and 1200 mg/m^2/day for non-residential)							
Receptor 57 (Vezibuhle)	704.038	7121.679	11.10			0.77		106.00	30.60	122.00
Receptor 58	704.451	7121.669	10.60			0.77		75.30	30.50	90.60
Receptor 59	704.862	7121.677	10.20			0.76		71.50	36.90	99.80
Receptor 60	703.208	7121.284	12.20			0.82		80.60	29.20	98.80
Receptor 61 (Oyco)	703.617	7121.267	11.80			0.80		94.70	37.50	113.00
Receptor 62	704.024	7121.271	11.20			0.78		78.60	33.10	95.60
Receptor 63	703.621	7120.873	12.00			0.80		53.30	32.10	71.00
Eskom Chicken Farm AQMS	694.498	7125.216	12.10			3.40		4.78	23.60	28.60
Eskom Elandsfontein AQMS	741.853	7094.089	8.98			0.48		1.43	7.74	13.20
Eskom Kendal AQMS	698.242	7112.343	17.50			1.11		5.25	20.50	29.00
Eskom Kriel Village AQMS	724.814	7094.533	26.20			0.81		3.03	18.20	26.90
Eskom Masakhane AQMS	731.596	7125.309	8.00			0.65		111.00	22.10	117.00
Eskom Phola AQMS	703.970	7123.219	10.90			1.51		187.00	24.80	203.00
SAWS eMalahleni AQMS	719.076	7136.018	8.05			1.53		11.30	10.60	16.90
Maximum			210.00			20.00		358.00	254.00	358.00

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