**uMN013-2011**

# AIR QUALITY STUDY FOR THE BASIC ENVIRONMENTAL ASSESSMENT FOR THE PROPOSED BIOMASS CO-FIRING FACILITY AT THE ARNOT POWER STATION

## Draft-final


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**EXECUTIVE SUMMARY**

Eskom's coal-fired Arnot Power Station which is located ~37 km south east of Middelburg, and close to Rietkuil in Mpumalanga, has a base load generation capacity of 2 352 MW, generated in 6 units, each with a nominal capacity of between 350 and 400 MW. It is proposed that a small portion of the coal is displaced with biomass (wood pellets) as a co-firing fuel source. The main purpose of this project is to reduce the carbon footprint of Eskom (decreasing the carbon emissions), starting with this pilot biomass co-firing project.

Savannah Environmental is conducting the required basic environmental assessment and appointed uMoya-NILU to conduct the air quality specialist study. Amongst others, the scope of work included in the air quality specialist study is to provide :

- A description of the receiving environment with regard to ambient air quality;
- A description of the legal framework with respect to air quality;
- A development of an emissions inventory;
- An assessment of the impacts of the proposed project on ambient air quality by estimating the ambient concentrations of key pollutants for construction, operations including coal and coal/wood biomass mix, and decommissioning; by comparison of predicted ambient concentrations with South African Ambient Air Quality Standards.

The main findings of the air quality specialist study are:

For construction and decommissioning of the infrastructure for the biomass receipt, storage, milling and mixing, the impacts on ambient air quality concern particulate matter only. The impacts are expected to be of a nuisance nature only, and will be limited to less than 1 km from the source and may impact on Rietkuil. The impacts have a low significance.

For $PM_{10}$ for coal only the predicted ambient concentrations resulting from Arnot Power Station are compliant with the current and future national ambient standards. Similarly predicted concentrations are compliant for the coal and wood biomass mix. The introduction of wood biomass results in a marginal reduction in predicted ambient $PM_{10}$ concentrations, but it is unlikely that the reduction can be measured. Particulate emissions from Arnot Power Station contribute to the current ambient $PM_{10}$ concentrations of the eastern highveld. With the introduction of biomass the contribution of Arnot Power Station to ambient $PM_{10}$ concentrations is reduced somewhat. However the modelled cumulative concentrations comply with the national ambient standards. The impacts associated with $PM_{10}$ are considered to have a low significance.

For Arnot Power Station with biomass co-firing option the predicted annual average concentration of $SO_2$ for complies with the national ambient standard for coal and for the coal and wood biomass mix. The cumulative concentrations, i.e. including background ambient $SO_2$ concentrations, also comply with the annual standard. The predicted 24-hour maximum concentrations exceed the limit value of the national ambient standard up to ~3 km to the north and northeast of the plant, ~8 km to the east and east-southeast of the site, and ~2 km to the south of the site. Exceedances also occur in relatively small areas, ~8 km east-southeast from the site and ~9 km south-southwest from the Arnot Power Station for both fuel scenarios. The predicted number of exceedances do not exceed the permitted tolerance. Similarly the predicted 1-hour maximum concentrations exceed the limit value in the national standard, but over a considerably larger area of up to 20 km around Arnot Power Station for both fuel scenarios. Again the predicted number of exceedances does not exceed the permitted tolerance. The predicted 24-hour and 1-hour $SO_2$ concentrations for Arnot Power Station for biomass co-firing therefore comply with the national standards. The introduction of wood biomass results in a marginal reduction in predicted ambient $SO_2$ concentrations from the coal only scenario, but it is unlikely that the small reduction can be measured. However the modelled cumulative concentrations also comply with the national ambient standards. Despite this the significance of the impacts associated with $SO_2$ for the biomass co-firing option are considered to be medium due to its contribution to regional scale impacts. Since the predicted concentrations of $SO_2$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is expected to have a positive impact on air quality.

For Arnot Power Station the predicted annual average $NO_x$ concentration complies with the national ambient standard for $NO_2$ coal and for the coal and the biomass co-firing option. The cumulative concentrations also comply with the annual standard. The predicted 1-hour maximum concentrations for the biomass co-firing option exceed the limit value of the national standard, over an area of up to 20 km around Arnot Power Station for both fuel scenarios. However the predicted number of exceedances does not exceed the permitted tolerance. In other words, the predicted 1-hour $NO_2$ concentrations for the biomass co-firing comply with the national standards. The introduction of wood biomass results in a marginal reduction in predicted ambient $NO_2$ concentrations, but it is unlikely that the reduction can be measured. $NO_2$ emissions from Arnot Power Station currently contribute to the ambient $NO_x$ concentrations on the eastern highveld. However, the modelled cumulative $NO_x$ concentrations also comply with the national ambient standards. Despite this the significance of the impacts associated with $NO_x$ for the biomass co-firing option is considered to be medium due to its contribution to regional scale impacts. Since the predicted concentrations of $NO_x$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is expected to have a positive impact on air quality.

Indirect impacts associated with the $SO_2$ and $NO_x$ emissions relate to acidification, and those associated with CO and $CO_2$ relate to global warming. The magnitude of indirect impacts associated with the two operational scenarios relates to the relative contribution to acidification and global warming. While quantification of the relative contribution of Arnot Power Station to $CO_2$ emissions is difficult, the contribution is considered to be relatively small in the national and global context, and somewhat less for the co-fired option. The significance of the indirect impacts is therefore anticipated to be low for both scenarios. The carbon content of wood at an average of 47.5% is less than that of Arnot coal at 58.48%. $CO_2$ emissions are directly proportional to the carbon content of the fuel burnt. This implies that if coal was replaced by an equivalent quantity of wood, then there would be a decrease in $CO_2$ emissions. However, due to its lower calorific value, a larger quantity of wood is required to offset the replacement of a smaller quantity of coal. This will ultimately result in emissions of $CO_2$ increasing with the replacement of coal by wood. The $CO_2$ emissions are expected to increase by 0.08% and 0.12% for 10% biomass substitution in one unit only and 5% wood biomass substitution in each of 3 units, respectively. This is an equivalent increase of 31 ton/day of $CO_2$ for a 10% substitution of coal by biomass for one unit and 48 ton/day for a 5% substitution of coal with biomass in three units. The biomass co-firing option in one unit will however reduce Arnot Power Station's reliance on fossil fuel (coal) by 10% as biomass is a renewable source of energy.

The carbon content of wood is less than that of coal. Despite this, the $CO_2$ emission is expected to increase by 0.08% and 0.12% for 10% for one unit and 5% for three units wood biomass substitution, respectively. This is an equivalent increase of 31 ton/day of $CO_2$ for a 10% substitution in one unit and 48 ton/day for a 5% substitution of biomass in each of three units. The increase is counter intuitive and results as more wood is required than coal to generate an equivalent amount of heat due to its lower calorific value.

Particulate emissions at the Arnot Power Station are well controlled using bag filters, and some control measures are in place to control diffuse sources at the power station. With the imminent publication of the Air Quality Management Plan (AQMP) for the HPA, despite the fuel mix, Arnot Power Station will need to evaluate all aspects of its operation in order to comply with Goal 2 of the AQMP which reads '*By 2020, industrial emissions are equitably reduced to achieve compliance with air quality standards and dust fallout limit values*'. Objectives of this goal include, amongst others:

1) Quantification of emissions from all sources
2) Reduction of gaseous and particulate emissions
3) Minimisation of fugitive emissions
4) Reduction in emissions from dust-generating activities
5) Reduction in Greenhouse gas emissions
6) Reduction in the incidences of spontaneous combustion in coal storage piles and discard dumps
7) Optimum operation of appropriate abatement technology, and
8) Exceedances of ambient air quality standards and dust fallout limit values as a result of plant emissions are assessed.

The details of emission abatement for stack and diffuse sources during operations will need to be agreed on with the licensing authority and will be captured in Arnot Power Station's Atmospheric Emission Licence (AEL). Examples to control/mitigate dust emissions during construction and decommissioning are include:

- Tarring unpaved roads to accommodate the additional traffic bringing in biomass for the co-firing option.
- Stabilise open areas with dust palliative, gravel or similar
- Cover the load on trucks
- Load and unload in areas protected from wind
- Wet or cover stockpiles of construction material

In conclusion, this study shows that the substitution of 10% of coal with wood biomass in one unit at Arnot Power Station has a potentially positive impact on ambient air quality as it reduces the emissions of particulates, $SO_2$ and $NO_x$ and as a result marginally reduces the ambient concentrations of $PM_{10}$, $SO_2$ and $NO_x$. It is however unlikely that these small differences are measurable. Ambient concentrations of these pollutants are predicted to comply with all ambient air quality standards when coal and when coal and wood biomass mix is used. The significance of the impact substituting 10% wood biomass for coal in one unit at Arnot Power Station is low for $PM_{10}$, and medium for $SO_2$ and $NO_x$ due to their contribution to regional scale acidification. The $CO_2$ emission is expected to increase by 0.08% for 10% wood biomass substitution in one unit. This is an equivalent increase of 31 ton/day of $CO_2$.

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# 1. INTRODUCTION AND BACKGROUND INFORMATION

## 1.1 Background to study

Eskom Holdings SOC (Ltd) is a South African utility that generates, transmits and distributes electricity. The coal-fired Arnot Power station, which is located ~37 km south east of Middelburg, and close to Rietkuil in Mpumalanga (Figure 1.1), has a base load generation capacity of 2 352 MW, generated in 6 units, each with a nominal capacity of between 350 and 400 MW. It is proposed at the Arnot Power Station that a small portion of the coal is displaced with biomass (wood pellets) as a co-firing fuel source. The main purpose of this project is to reduce the carbon footprint of Eskom (decreasing the carbon emission from fossil fuel sources), starting with this pilot biomass co-firing project.

The combustion of wood pellet biomass and coal for electricity generation as proposed at Arnot is a Listed Activity in terms of the National Environmental Management: Air Quality Act (Act No. 39 of 2004, the AQA) (Republic of South Africa, 2009, Category 1: Combustion Installations). The Arnot Power Station currently holds a valid Registration Certificate for electricity production in terms of the Atmospheric Pollution Prevention Act (APPA, Act No. 45 of 1965). This certificate is valid until 1 April 2014 in terms of the transitional arrangements in the AQA. The current Registration Certificate will therefore need to be amended to include biomass as a fuel source. The amendment and converting the Registration Certificate to an Atmospheric Emission Licence (AEL) are likely to be considered as a single process by the licensing authority. Issuing of the AEL is contingent on the issuing of Environmental Authorisation (EA) for the environmental impact assessment processes for the project.

Savannah Environmental (Pty) Ltd has been appointed as an independent consultant by Eskom Holdings SOC Limited to conduct the Basic Assessment for the proposed project. Savannah have, in turn, appointed uMoya-NILU Consulting (Pty) Ltd, to conduct the required air quality specialist study.

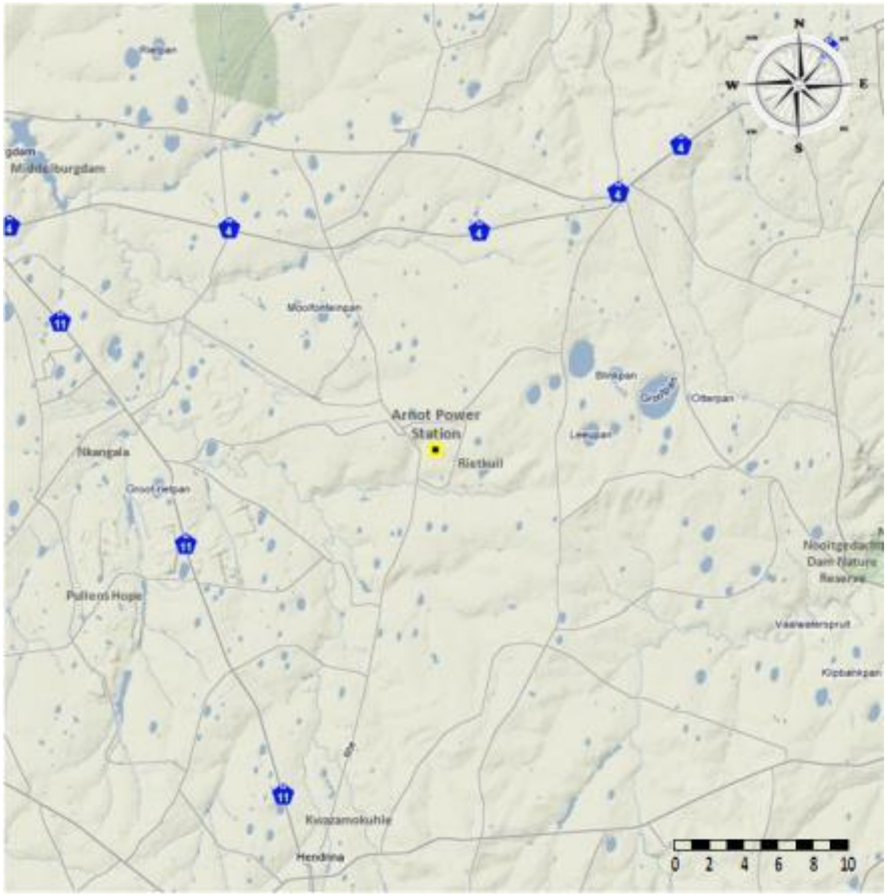


***Figure 1.1: Location of the Arnot Power Station in Mpumalanga***

This specialist air quality report includes a description of the data used, the methodology, current air quality status, regulatory requirements, results of the dispersion modelling and the assessment of the impacts, and recommendations for emission abatement.

## 1.2 Summary description of preferred sites and project description

### *1.2.1 General overview of biomass*

The biomass composition depends on the type of biomass, plant species and part of the plant used, and a host of associated characteristics to where and how the plant is grown. For this project reference is made to the use of wood pellets, made from woody sawdust residue and tree parts (off cuts, bark, etc.). Biomass fuels are commonly contaminated with soil and other material during the collection of raw material, handling and storage. This results in the fuel specification varying, even for the same species of biomass.

### *1.2.2 Design*

Two milling strategies are proposed for evaluation, one being the co-milling of biomass and coal within the existing coal mills, and the other being separate milling approach where biomass and coal are milled separately. With the separate milling strategy, the milled biomass is injected into the existing coal pulverized fuel lines or via separate burners. In comparison between the two milling strategies the infrastructure required is larger for the separate milling option; hence this is discussed in further detail. Engineering will consider both options for the basic design however one will be selected for implementation based on both technical and environmental evaluations. The proposed method of delivery will be through covered side-tipper road trucks. It is expected that a maximum of 35 trucks will be used per day, each with a weight of approximately 30 tons.

### *1.2.3 Separate milling*

The separate milling design will consider the replacement of up to 10% of coal with biomass and will be implemented on only one unit – unit 4 of the Arnot Power Station.

Road trucks will enter via the existing coal truck entrance and will cross over the existing coal weigh bridge. The existing gravel road will be used to access the new offloading area. It is proposed that the existing road, within station boundaries, be upgraded for a distance of approximately 300 m (surface area of 8 m wide and a maximum area of 2 400 $m^2$) leading up to the off-loading facility to a tarred road and then extended into a loop system around the off loading facility. The loop road will be 4 m wide and an estimated length of 500 m (surface area of 4 m wide road is a maximum area of 2 000 $m^2$). The location of the new proposed off-loading facility is also within the station boundaries. A road truck offloading area (footprint – 600 $m^2$) is proposed at the open area at the northern side of the existing coal stockyard and the western side of coal staith 4 that feeds coal to units 4, 5 and 6.

As emergency storage a covered off-loading building is included and will have a plan view footprint of 1 870 $m^2$. The emergency off-loading building will be used in cases of unexpected break downs with the day bins still being stocked up with biomass wood pellets. In this event, trucks driving towards the station at that time will either be required to dump the wood pellets in the temporary off-loading building, or they will be requested to return to their destination of origin.

The new offloading area (600 $m^2$) will incorporate all the following structures and equipment required to support a fully functional reception facility: a roofed area where the tarpaulin covers can be removed from the trucks. A fully enclosed shed with a concrete floor and an elevated offloading ramp for side-tipper trucks with dust extraction and dust suppression systems. A micro water spray system (mixture of water and air) may also be included to assist with dust control. The water usage will be minimal and will be obtained from Arnot Power station water supply.

Biomass will be transported from the off-loading facility on a conveyor, approximately 34 m long, to the screening plant. The conveyor will be enclosed to protect the biomass against environmental impacts e.g. wind and water.

The screening building will contain vibrating screens for the separation of oversized and foreign materials as well as a metal separation system and may include an automated sampling facility. The metal separation system will comprise of a mechanical magnet separation mechanism, and no chemical treatment will be involved. The metal will not be treated by Eskom but will most probably be returned to the fuel supplier. It is essential to remove all metal contamination from the feed stock to eliminate the fire risk and damage in the milling plant caused by metal impact and sparking. The expected footprint of the sampling building will be 100 $m^2$ and comprise of mainly steel structures.

The biomass from the sampling plant will feed onto an enclosed conveyor system (estimated length of 100 m) to a bucket elevator. The bucket elevator will feed a coated metal transfer bin (footprint of approximately 144 $m^2$) with an approximate capacity of 12 hours.

The discharge from the transfer bin will be conveyed to a day bin (also 12 hours capacity) located above a new milling plant (footprint of approximately 144 $m^2$) by means of inclined aero-conveyors (estimated length of 315 m). It is proposed that the day bin will be around the location of unit 4 fabric filter plant or adjacent to the boiler house.

The day bin's outlet will be linked to hammer mills in the milling plant. The feed into each mill will be by means of a variable speed screw feeder linked to the mill. Discharge from the mills will be by means of variable speed screw feeders into a pneumatic conveying pipeline arrangement.

#### *1.2.4 Co-milling*

The percentage of biomass for co-milling will be 5% per unit for three units. Coal and biomass will be co-milled in the existing coal mills. With the design of Arnot Power Station one set of inclined coal conveyor feeds three units.

The biomass transporting vehicles will use the same access as per the separate milling approach; hence the same road upgrades will be required. The offloading building will be a covered shed with a concrete slab. A front loader will be used to load the biomass onto a loading hopper which will be equipped with a variable screw discharge feeder. This feeder will be linked to the head end of the existing coal understaith reclaim conveyor. Biomass will be blended onto the existing coal understaith reclaim conveyor. The existing coal infrastructure will be used to move the blend of biomass and coal to the coal bunkers and feed the existing coal mills. This system feeds three units; hence control of biomass pellet supply to only one unit is not possible. The biomass and coal will be milled and fired into the boiler via the existing systems at the plant.

### 1.3 General information

In terms of input elements, the quantities of sulphur and nitrogen are lower in biomass compared to coal. 10% of biomass by mass in one unit is approximately 20 ton/hr, to keep the same energy input as compared to coal only; the resulting coal quantity is approximately 184.5 ton/hr. The maximum number of additional vehicles for biomass delivery at this stage is expected to be 35 trucks/day operating all through the week, should the biomass system not be available for any reason the plant will be operated on 100% load of coal. The operating philosophy still needs to be confirmed, possible lower biomass ratios over weekends may apply. For present and future purposes, Arnot Power Station expects approximately 300 trucks/day carrying coal at a load of 30 tons/truck.

### 1.4 Description of environmental issues

The description of environmental issues will relate solely to air quality impacts associated with the construction (and decommissioning) and operation of the biomass co-firing development at Arnot Power Station.

#### *1.4.1 Construction and decommissioning*

Direct impacts during construction and decommissioning will result primarily from exposure to dust. Dust emissions during construction result mainly from earth moving activities (scraping, compacting, excavation, grading), movement of construction vehicles and back-fill operations. Dust emissions during decommissioning result from the demolition of structures, earth moving activities (scraping, compacting, excavation, grading), movement of construction vehicles and back-fill operations. During windy conditions, this dust could potentially have negative impacts beyond the construction site. Contractors and site agents may be required to adopt dust control measures to reduce dust emissions to an acceptable level while carrying out construction works.

#### *1.4.2 Operation*

The combustion of coal, oil or wood results in emissions of a number of pollutants into the atmosphere. These include particulate matter, gases (including sulfur dioxide ($SO_2$), nitrogen oxides ($NO + NO_2 = NO_x$) and carbon monoxide (CO)), organics (volatile organic compounds, polycyclic organic matter (PAH, PCDD etc) and trace elements (mercury, arsenic, etc). The resultant pollutants are a function of fuel composition, combustion temperature, oxygen mixing and sufficient time for complete combustion. Green house gases (GHG) emitted during coal combustion include carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxides ($N_2O$). Dust is generated during the various stages of fuel handling and preparation. These include delivery by truck or conveyor, stacking and reclaiming and milling. Dust may also result from loading, transport and storage of ash. Direct impacts associated with the operational phase will therefore result primarily from exposure to the pollutants contained in the exit plume from the stacks and from the various diffuse sources of dust. Indirect impacts relate to GHG emissions.

## 2. SCOPE OF THE SPECIALIST STUDY

The air quality specialist study comprises the following scope of work:

- » Provide a description of the receiving environment with regard to ambient air quality, including meteorology, baseline air pollutant concentrations and sensitive receptors;
- » Describe the legal framework with respect to air quality;
- » Consider geographic alternatives for the biomass infrastructure where applicable;
- » Identify all project specific air pollutants, including Greenhouse Gases from the proposed development by activity and source, including milling, transport, stockpiles and combustion and develop an emission inventory.
- » Work with Eskom's engineering design team to evaluate the possible mitigation measures that are being considered.

- Assess the impacts of the proposed project on ambient air quality by estimating the ambient concentrations of key pollutants described in the emission inventory. The assessment will consider the impacts associated with:
  - Construction – qualitative;
  - Operations – using dispersion modelling for:
    - Normal operations using coal for Arnot only and against the existing air pollution loading;
    - Normal operations displacing a percentage of coal with biomass for Arnot only and against the existing air pollution loading.
  - Decommissioning – qualitative;
  - Greenhouse gas emissions – qualitative.
- Dispersion modelling will be conducted using the US-EPA approved CALPUFF dispersion model.
- The assessment of the significance of the impacts will be done by comparison of predicted ambient concentrations with South African Ambient Air Quality Standards (Republic of South Africa, 2009).
- Compilation of a specialist assessment report.

# 3. METHODOLOGY

The methodology used to achieve the objectives of the project is described here:

## 3.1 Description of the receiving environment

### *3.1.1 Meteorology and current air quality status*

The Arnot Power Station is situated on the eastern edge of the Mpumalanga Highveld, approximately ~37 km south east of Middelburg, and close to Rietkuil. A weather station is in operation at the Arnot Power Station, but insufficient data is available for a descriptive analysis of the current meteorology. The South African Weather Service and Eskom run a few weather stations, but these are located at a distance away from the Arnot Power Station. Wind data from the Witbank weather station and climate data from the Loskop Dam weather station is used to describe the meteorology in the study area.

There are no ambient monitoring stations in the vicinity of the Arnot Power Station. Without actual data the baseline air quality description for the eastern parts of the HPA contained in the AQMP (Republic of South Africa, 2011a) is used as the basis for describing the current status of air quality in the study area.

### *3.1.2 Sensitive receptors*

Sensitive receptor points in the area surrounding the Arnot Power Station are selected based on the relative location of human settlements with the intention of protecting the most sensitive individual to exposure to air pollution.

## 3.2 Legal context

The legal context with regard to air quality is described in terms of the following:

» The National Environmental Management Act (No. 107 of 1998);
» The National Environmental Management: Air Quality Act (No. 39 of 2004) and the supporting regulations regarding:
  * Ambient air quality standards (Republic of South Africa, 2009)
  * Listed activities and minimum emission standards (Republic of South Africa, 2010)
  * Dust management (Republic of South Africa, 2011b).

## 3.3 Consider geographic alternatives for the biomass infrastructure

The proposed site layout is assessed with regard to the location of emission sources, the relative location of neighbouring communities (sensitive receptors) and the prevailing wind direction. If required, alternatives locations of the of the infrastructure required for receiving and processing biomass will be assessed and suggested.

## 3.4 Evaluation of possible mitigation measures

Chemical engineers in the project team have worked with Eskom Holdings SOC Limited’s staff to evaluate the possible mitigation measures that are being considered. These have been taken into account in the emissions inventory used for the modelling scenarios.

## 3.5 Air pollution sources and emissions inventory

The following are the current key sources of air pollution identified at the Arnot Power Plant:

* Power generation
* Coal storage piles and ash dumps
* Motor vehicles

The nature of these sources and the types of air pollutants emitted are described here in greater detail in the following sections. Emissions from the conveyors and screening plant are not taken into account in the emissions inventory. These structures and enclosed and emissions from these sources is regarded as negligible.

### *3.5.1 Power generation*

The Arnot Power Station has a generation capacity of 2 352 MW and comprises 6 steam turbine units, each with a nominal capacity of between 350 and 400 MW. The primary fuel used in the boilers to generate steam is coal, while provision is made for the use of heavy fuel oil (HFO) as a backup to coal.

The quantity and nature of emissions from combustion of solid or liquid fuels in boilers differs depending on the fuel composition, fuel consumption, boiler design and operation, and the emission and pollution control devices in use. When fuels burn, they produce various pollutants. Products of combustion of coal include $SO_2$, $NO_x$, CO and PM, acid gases and

VOCs. Metals and their compounds may also be entrained (i.e. carried forward by a stream of gas or vapour of fine liquid droplets). With respect to greenhouse gases (GHGs), of significance is $CO_2$.

$SO_2$ is produced from the combustion of sulphur bound in coal. The stoichiometric ratio of $SO_2$ to sulphur dictates that 2 kg of $SO_2$ are produced from every kg of sulphur combusted. The coal used by the Arnot Power Station has a sulphur content (wt %) of between 0.6 and 0.7 %.

NOx is produced from thermal fixation of atmospheric nitrogen in the combustion flame and from oxidation of nitrogen bound in the coal. The quantity of $NO_x$ produced is directly proportional to the temperature of the flame.

The main species produced from the oxidation of carbon in coal is $CO_2$. However, incomplete combustion will result in the formation of CO, albeit at a much smaller proportion than $CO_2$. Boilers that are well maintained and operated are more likely to provide a high combustion efficiency.

The non-combustible portion of the fuel remains as solid waste. The coarser, heavier waste is called 'bottom ash' and is extracted from the burner, and the lighter, finer portion is 'fly ash' and is usually emitted as particulates through the stack. This results in the formation of PM.

### *3.5.2 Storage piles*

A characteristic of operations that use mineral products such coal is the maintenance of outdoor storage piles. Storage piles are usually left uncovered, partially because of the need for frequent material transfer into or out of storage. Dust emissions occur at several points in the storage cycle, such as coal loading onto the pile, disturbances by strong wind currents, and loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a substantial source of dust. The quantity of dust emissions from coal storage operations varies with the volume of coal passing through the storage cycle. Emissions also depend on 3 parameters of the condition of a particular storage pile, namely, age of the pile, moisture content, and proportion of aggregate fines.

When fresh coal is loaded onto a storage pile, the potential for dust emissions is at a maximum. Fine coal particles are easily disaggregated and released to the atmosphere upon exposure to air currents, either from coal transfer itself or from high winds. As the coal pile weathers, however, potential for dust emissions is greatly reduced. Moisture causes aggregation and cementation of fines to the surfaces of larger particles. Any significant rainfall soaks the interior of the pile, and then the drying process is very slow.

### *3.5.3 Motor vehicles*

A motor vehicle is defined as an on-road vehicle that derives its power for propulsion from the combustion of fossil fuel (Environment Australia, 1999). The type of motor vehicle most commonly used at the Arnot Power Station is trucks or heavy duty vehicles. The partial switch in fuel from coal to biomass will result in an additional 35 trucks/day visiting the site. It is estimated that 300 trucks/day transport coal to the site at present.

The energy to propel trucks comes from burning fuel in an engine. Trucks use diesel as their sole fuel. Pollution from trucks arise from the by-products of the combustion process (emitted via the exhaust system). Some particulate matter is also emitted from brakes and tyre wear. Trucks use internal combustion engines to produce power to propel the vehicle. The main polluting emissions from trucks are PM, $NO_X$, CO and $SO_2$. CO and PM are produced as a result of incomplete combustion, and are continuously being reduced as engine technology improves. NOx results from the oxidation of nitrogen at high temperature and pressure in the combustion chamber. CO is generated when carbon in the fuel is partially oxidised rather than fully oxidised to carbon dioxide. $SO_2$ is derived from the combustion of sulphur in diesel. PM is produced from the incomplete combustion of fuels, additives in fuels and lubricants, and worn material that accumulates in the engine lubricant.

Another type of emission that arises from the use of motor vehicles is dust emissions from roads. As the vehicle's tyres turn, particles on the road are crushed and re-suspended into the atmosphere.

### *3.5.4 Emission estimations*

#### *Power generation*

*Sulphur dioxide:*

Emissions of $SO_2$ from the combustion of coal in the boilers of the Arnot Power Station are estimated by using the mass balance approach, while assuming 90.7% oxidation of sulphur in the coal to $SO_2$. The oxidation efficiency of 90.7% is based on the results of actual tests conducted at the power station. The quantity of $SO_2$ emitted depends on the mass fraction of sulphur in the coal burnt. In general, for every ton of sulphur burnt, 2 tons (2000 kg) of $SO_2$ is produced if the combustion efficiency is 100%. At an efficiency of 90.7%, 1814 kg (2000 kg x 0.907) of $SO_2$ is produced. Coal is analysed at the power station on at least a daily basis for sulphur content. The measured mass fraction of sulphur in coal over a two-year period averaged 0.65%. The following equation is used to estimate $SO_2$ emissions from combustion processes:

$$SO_2 \text{ emission rate (kg/year)} = 1\,814 \times M \times MFS \quad (1)$$

Where,

M = mass rate of coal to the boilers (in ton/year)

MFS = mass fraction of sulphur in fuel

The power station reported a coal consumption rate of 6 525 670 ton/annum, which was equally apportioned to the 6 coal-fired boilers.

*Nitrogen oxide:*

The use of emission factors and fuel consumption is generally used to estimate emissions of $NO_x$ from combustion processes. The choice of emission factors is critical as there are many factors that affect the quantity of $NO_x$ emitted. The choice of an inappropriate emission factor could result in the incorrect estimation of $NO_x$ emissions. With respect to the Arnot, this task has been simplified as site-specific emission factors have been determined. By averaging a series of spot measurements at the power station, the NO emission factor was derived to be 4.87 kg/ton, while the $NO_2$ emission factor was calculated to be 7.47 kg/ton. The following equation is then used to estimate $NO_2$ emissions from the Arnot Power Station:

$NO_2$ emission rate (kg/year) = $EF_{NO2} \times M$

Where,
$EF_{NO2}$ = Emission factor (in kg $NO_2$/ton of coal combusted)
M = Mass rate of coal combusted (in ton/year)

*Particulate matter:*

Various organisations such as the USEPA have developed PM emission factors from combustion processes. However, it is preferable to use site-specific emission factors. The Arnot Power continuously measures PM emissions using opacity meters on its two stacks, which are correlated to provide emission concentration in units of $mg/Nm^3$. The concentration is multiplied by the gas flow rate to arrive at the emission rate. Using the results of continuous measurements at the power station, it was determined that the PM emission factor downstream of the filter bags is 0.33 kg PM emitted/ton of coal combusted.

By applying the following equation, it is possible to estimate PM emissions using the emission factor method:

PM emission rate (kg/year) = $EF_{PM} \times M$

Where,
$EF_{PM}$ = Emission factor (in kg PM/ton of coal combusted)
M = Mass rate of coal combusted (in ton/year)

The estimation of the $PM_{10}$ emission rate is based on the fraction of particles with an aerodynamic diameter of less than 10 microns in the total particulate mass. According to the USEPA (USEPA, 2001), this fraction is approximately 92%. This provides a sound basis for assuming that all PM can be equated to be $PM_{10}$.

*Carbon dioxide:*

The Arnot Power Station has developed a site specific emission factor of 2 058 kg $CO_2$/ton coal. This factor is used for the estimation of $CO_2$ emissions. By applying this emission factor to the following equation, the annual emission rate of $CO_2$ can be determined:

$CO_2$ emission rate (kg/year) = $EF_{CO2} \times M$

Where,

$EF_{CO2}$ = Emission factor (in kg $CO_2$/ton of coal combusted)

M = Mass rate of coal combusted (in ton/year)

***Emissions from coal handling***

*Particulate matter:*

Total dust emissions from coal storage piles result from several distinct source activities within the storage cycle:

1. Loading of coal onto storage piles (batch or continuous drop operations).
2. Equipment traffic in storage area.
3. Wind erosion of pile surfaces and ground areas around piles.

Either adding coal to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation. The quantity of particulate emissions generated by either type of drop operation, per kilogram (kg) (ton) of material transferred, may be estimated, with a rating of A (USEPA rating for the credibility of an emission factor with A being the highest and E the lowest), using the following empirical expression

$$E = k\,(0.0032)\frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (Pound [lb/ton])} \quad (1)$$

Where:

$E$ = emission factor

$k$ = particle size multiplier (dimensionless)

U = mean wind speed (miles per hour [mph])

M = material moisture content (%)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range, as follows:

| Aerodynamic Particle Size Multiplier (k) For Equation 1 | | | | |
|---|---|---|---|---|
| < 30 µm | < 15 µm | < 10 µm | < 5 µm | < 2.5 µm |
| 0.74 | 0.48 | 0.35 | 0.20 | 0.053 |

Particle size multiplier is 0.35 and 0.74 for $PM_{10}$ and total suspended particulate matter respectively, average material moisture content was given as 7.55% and the mean wind speed was taken to be 3.14m/s, which was obtained from Witbank meteorological station, which was identified as an appropriate estimate for wind speed at Arnot Power Station. Using equation 1, the emission factor for $PM_{10}$ was found to be $2.71\times10^{-4}$lb/ton.

The general equation for emissions estimation is:

$$E = A \times EF \times (1 - ER/100) \qquad (2)$$

Where:
E = emissions;
A = activity rate;
EF = emission factor, and
ER =overall emission reduction efficiency, %

**Particulate matter emissions from unpaved roads**

The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Field investigations also have shown that emissions depend on source parameters that characterize the condition of a particular road and the associated vehicle traffic. Characterization of these source parameters allow for "correction" of emission estimates to specific road and traffic conditions present on public and industrial roadways.

Dust emissions from unpaved roads have been found to vary directly with the fraction of silt (particles smaller than 75 µm in diameter) in the road surface materials. The following empirical expression may be used to estimate the quantity in pounds (lb) of size-specific particulate emissions from an unpaved road, per vehicle mile travelled (VMT):

For vehicles travelling on unpaved surfaces at industrial sites, emissions are estimated from the following equation:

$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \qquad (1)$$

Where
$E$ = size-specific emission factor (lb/VMT)
$s$ = surface material silt content (%)
$W$ = mean vehicle weight (tons)

The source characteristics *s* and *W* are referred to as correction parameters for adjusting the emission estimates to local conditions. The metric conversion from lb/VMT to grams (g) per vehicle kilometre travelled (VKT) is as follows:
1 lb/VMT = 0.2819Kg/VKT

The constants k, a and b (equation 1) are based on the stated aerodynamic particle sizes, for $PM_{10}$ and Total suspended particulates (TSP) the constants are indicated in the table below:

| Constant | $PM_{10}$ |
|---|---|
| *k* (lb/VMT) | 1.5 |
| *a* | 0.9 |
| *b* | 0.45 |

| Constant | Total suspended particulates (TSP) |
|---|---|
| *k* (lb/VMT) | 4.9 |
| *a* | 0.7 |
| *b* | 0.45 |

The mean vehicle weight (W) can be estimated by using the number of vehicles that will be making use of the gravel road at the Arnot Power Station. It is expected that a maximum of 35 trucks for biomass deliveries will be used per day, each with a weight of approximately 30 tons. The US EPA42 manual for unpaved roads gives the mean % silt content (s) for different types of industrial roads. The surface material silt content for the gravel road at Arnot Power Station was assumed to be similar to the coal mining plant road mean silt content of 5.1%. Using the equation 1 the emission factor (EF) for PM-10 was found to be 1.957lb/VMT and for total suspended particulate matter 2.139lb/VMT.

The general equation for emissions estimation is:

$$E = A \times EF \times (1 - ER/100) \qquad (2)$$

Where:

E = emissions;

A = activity rate;

EF = emission factor, and

ER =overall emission reduction efficiency, %

The reduction efficiency does not apply therefore equation 2 is reduced to:

$$E = A \times EF$$

***Vehicle exhaust emissions***

Emissions from vehicle exhausts are based on European emission standards (European Union Directive, 1989) and have been defined in a set of European Union directives. They give acceptable limits for exhaust emissions of all new vehicles that are sold in the European Union, covering $NO_x$, hydrocarbons (HC), carbon monoxide (CO) and particulate matter emissions. The limits are set at different levels for different vehicle types and compliance is determined by running a vehicle's engine over a standard test cycle for a set time. Euro standards are defined in g/km or engine power (g/kWh). Emission rates are therefore calculated as a function of distance travelled or engine power. In this study, only particulates and $NO_x$ were considered.

### 3.6 Dispersion model description

A number of models with different features are available for air dispersion studies. The selection of the most appropriate model for an air quality assessment needs to consider the complexity of the problem and factors such as the nature of the development and its sources, the physical and chemical characteristics of the emitted pollutants and the location of the sources.

In this study, the CALPUFF suite of models (http://www.src.com/calpuff/calpuff1.htm) are used together with the Air Pollution Model (TAPM) (Hurley, 2000; Hurley et al., 2001; Hurley et al., 2002). CALPUFF has been adopted by the U.S. Environmental Protection Agency (U.S. EPA) in its Guideline on Air Quality Models (http://www.epa.gov/ttn/scram/dispersion_prefrec.htm) as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. The U.S. EPA Guideline of Air Quality Models also provides for the use of CALPUFF on a case-by-case basis for air quality estimates involving complex meteorological flow conditions, where steady-state straight-line transport assumptions are inappropriate.

CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation and removal. CALPUFF can be applied on scales of tens to hundreds of kilometres. It includes algorithms for sub-grid scale effects (such as terrain impingement), as well as, longer range effects (such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, and visibility effects of particulate matter concentrations). CALPUFF is considered to be an appropriate air dispersion model for the purpose of this assessment as it well suited to simulate dispersion from the complex array of point source and area sources at the Arnot Power Station and it has the ability to simulate dispersion over complex terrain.

The Air Pollution Model (TAPM) (Hurley, 2000; Hurley et al., 2001; Hurley et al., 2002) is used to model meteorological data for the study domain. TAPM uses global gridded synoptic-scale meteorological data with observed surface data to simulate surface and upper air meteorology at given locations in the domain, taking the underlying topography and land cover into account. The global gridded data sets that are used are developed from surface and upper air data that are submitted routinely by all meteorological observing stations to the Global Telecommunication System of the World Meteorological Organisation. TAPM has been used successfully in Australia where it was developed (Hurley, 2000; Hurley et al., 2001; Hurley et al., 2002), and in South Africa (Raghunandan et al., 2007). It is considered to be an ideal tool for modelling applications where meteorological data does not adequately meet requirements for dispersion modelling. TAPM modelled output data is therefore used to augment the site specific surface meteorological data for upper air data for input to CALPUFF.

### *3.6.1 Dispersion model set-up*

**TAPM**

TAPM is set-up in a nested configuration of three domains. The outer domain is 400 km by 400 km, the middle domain is 200 km by 200 km and the inner domain of 50 km by 50 km, corresponding with the CALPUFF domain. Three years (2004 to 2006) of hourly observed meteorological data from the SAWS meteorological station at Belfast, Nelspruit, Ermelo, Elandsfontein and Witbank are input to TAPM to 'nudge' the modelled meteorology towards the observations. The nesting configuration ensures that the effects of the Highveld escarpment on meteorology are captured and that meteorology is well resolved and characterised across the boundaries of the inner domain, i.e. the CALPUFF domain.

**CALPUFF**

The CALPUFF modelling domain of 2 500 $km^2$ is 50 km (west-east) by 50 km (north-south) and is centred on the Arnot Power Station (Figure 3.1). It consists of a uniformly spaced receptor grid with 0.5 km spacing, giving 10 000 grid cells (100 X 100 grid cells). The grid resolution is considered appropriate to resolve any topographical effects on the meteorology. Three years (2004 to 2006) of modelled hourly meteorological data from nine TAPM derived surface and upper air meteorological stations are used as input to CALPUFF (Figure 3.1).

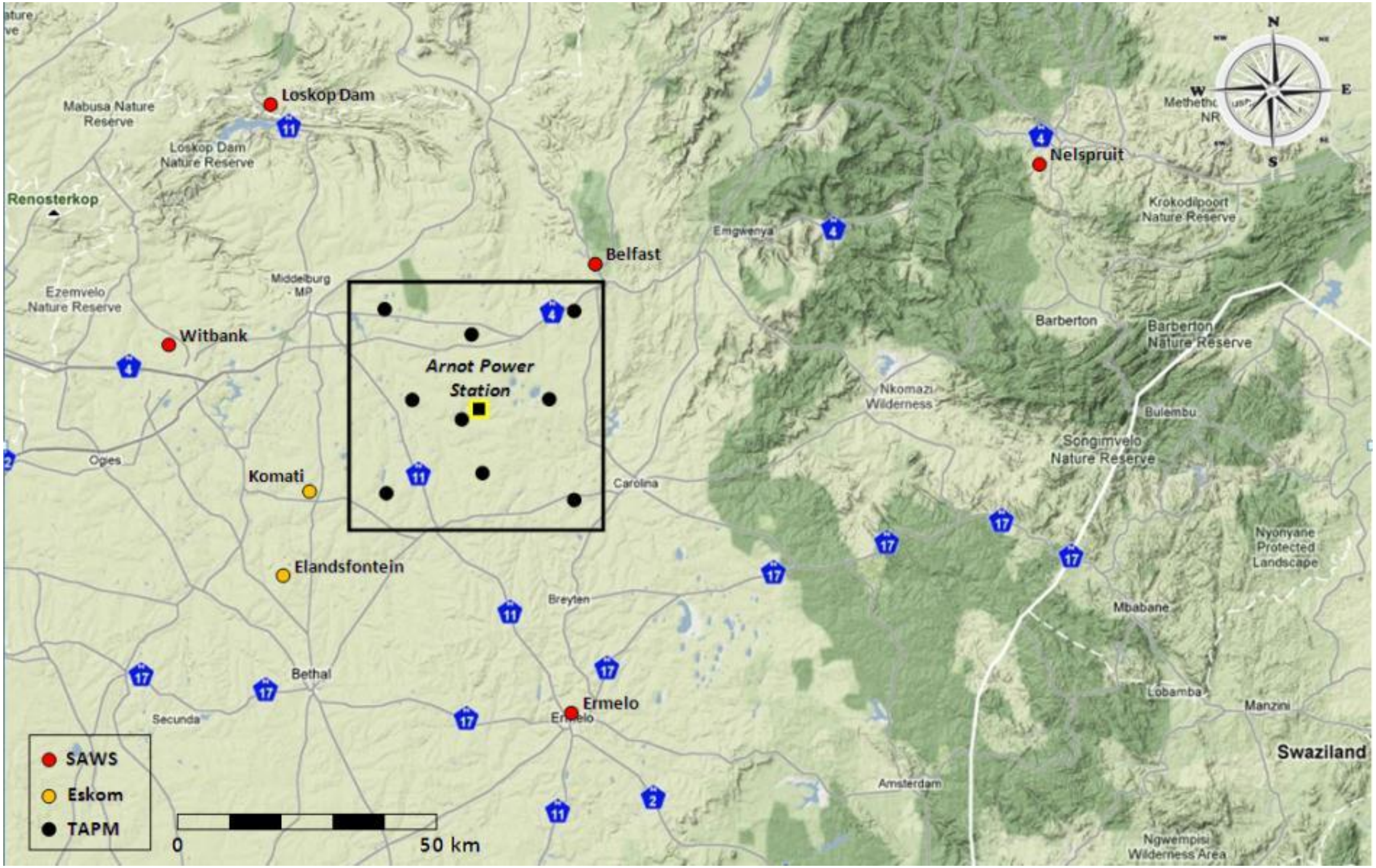


***Figure 1.2: The relative location of the SAWS, Eskom and the TAPM meteorological sites to the Arnot Power Station. The CALPUFF modelling domain is demarcated by the black square***

### *3.6.2 Model scenarios*

In order to assess the impact of the Arnot Power Station on air quality using biomass, it is necessary to assess the resultant changes in air quality against the current situation, i.e. to assess the effect of improved biomass emissions with all other current emissions from the Power Station.

The emission sources for the different scenarios of this assessment are listed in Table 3.1. The emission inventory for these scenarios is detailed in Section 6.

***Table 1: Dispersion modelling scenarios for normal operating conditions***

| | | Process unit point and diffuse sources | | | | |
|---|---|---|---|---|---|---|
| | | Stack 1 | Stack 2 | Roads | Vehicles | Stockpiles |
| Scenario 1 (Baseline) | Coal only + background | ✓ | ✓ | ✓ | ✓ | ✓ |
| Scenario 2 (Co-firing option) | Coal + biomass* + background | ✓ | ✓ | ✓ | ✓ | ✓ |

* Replacement of 10% of coal by mass in one unit

The cumulative effects of emission from the project to the current air quality status are assessed by adding background concentrations of respective pollutants to the modelled (estimated) concentrations resulting from Arnot emissions. In other words, the effect of contributing sources will not be modelled.

The uncertainty associated with the model predictions as a result of assumptions in the emissions data; inaccuracies or inadequacies in the meteorological data and inadequate scientific formulation of the model are quantified. There is no ambient monitoring close to Arnot Power Station so direct comparison of model output with monitored data is not possible. Model performance is therefore assessed quantitatively.

### 3.7 Assessment of air quality impacts

The assessment will consider the impacts associated with:

» Construction – qualitative;
» Operations – using dispersion modelling for:
  * Normal operations using coal for Arnot only and against the existing air pollution loading;
  * Normal operations displacing 10% of coal (by mass) with wood for Arnot only and against the existing air pollution loading.
» Decommissioning – qualitative;
» Greenhouse gas emissions – qualitative.

The assessment of the potential impacts associated with the scenarios presented above is based on the comparison of predicted ambient concentrations of relevant pollutants with the

South African ambient air quality standards to assess the level of compliance and the significance of the potential impact. The predicted annual average, 24-hour maximum and 1-hour maximum concentrations of $NO_x$, $SO_2$ and $PM_{10}$ are presented as isopleth maps on a base map of the area for each scenario. The frequency of exceedance of the ambient 24-hour air quality standards are also presented spatially. Populated areas, or sensitive receptors, are considered in the designation of significance.

The additive effects of emissions from the project will be assessed by adding background concentrations of respective pollutants to the modelled (estimated) concentrations resulting from Arnot Power Station in isolation. In other words, the effect of contributing sources will not be modelled.

This assessment is conducted in terms of the significance of direct, indirect and additive air quality impacts from the proposed modifications. The assessment considers the nature, extent, duration, probability and severity of air quality impacts, which leads to the determination of the significance of the impacts.

The nature of impacts examines what causes the effect, what is affected and how it is affected. The extent of impacts involves determining whether the impacts are local or regional and scoring the impacts accordingly from 1 to 5. The duration of impacts considers the lifetime of the impacts, allocating scores from 1 to 5 for very short (0 - 1 years), short (2 – 5 years), medium-term (5 – 15 years), long-term (> 15 years) and permanent. . The magnitude of impacts are rated on a scale of 0 to 10, examines the magnitude of the impacts as no effect (0), minor effect, low effect, moderate effect, high effect and very high effect (10). The probability of occurrence examines the likelihood of the impact actually occurring. Probability is also estimated on a scale of 1 to 5, where 1 is very improbable, 2 is improbable, 3 is probable, 4 is highly probable, and 5 is definite.

The significance of impacts is derived from an assessment of all of the above and is categorised as low, medium or high.

### 3.8 Assumptions

The following assumptions and limitations are associated with this study:

- » The assessment is based only on emissions from the Arnot Power Station and on-site vehicle exhaust emissions. The additive impact is assessed by adding background concentrations (to account for "nearby" and "other" background sources); and not by modelling contributing sources;
- » The impact assessment is based on worst-case meteorological conditions. It is therefore likely that predicted ambient concentrations are higher than would actually be expected;
- » The US EPA (1985) Good Engineering Practice for Stack Height to Minimise the Effects of Building Downwash recommends stack height ≥ H + 1.5L where H is the building height measured from ground to the highest point and L is the lesser of building height

or building width. These requirements are met at the Arnot Power Station and the effects of building downwash on plume dispersion are not modelled in this assessment.

# 4. DESCRIPTION OF THE RECEIVING ENVIRONMENT

## 4.1 Climatic conditions

The closest South African Weather Service stations to the Arnot Power Station where climatically representative data is available include Witbank (~62 km to the west-northwest), Loskop Dam (~74 km to the north-northwest) and Belfast (~37 km to the northeast). Eskom monitoring stations are located at Komati (~38 km to the southwest), from the Eskom network (Figure 3.1). Those at Belfast and the Komati Power Station are closest to the Arnot Power Station. They are however located on the eastern and southern side of the Drakensburg escarpment, respectively, and therefore do not represent the Highveld climate regime. The Witbank and Loskop Dam weather stations despite being further away are located in the same climate regime and are representative of the area under study. Wind data is available at Witbank, but no record of other climate statistics is available at this station. A fairly long record of climate data is available at Loskop Dam, with the exception of wind data. A weather station is in operation at the Arnot Power Station, but insufficient data is available for a descriptive analysis of the study area.

### *4.1.1 Temperature and rainfall*

The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The most commonly used climate classification scheme was originally developed by Wladimir Köppen.

The Arnot Power Station lies on the eastern edge of the Mpumalanga Highveld in temperate latitudes at approximately 25$^0$56’38” S and 29$^0$47’24” E, and approximately 1 680 m above sea level. As a result, it experiences a temperate climate with summer rainfall and dry winters according to the Köppen Climate Classification system. Temperature and rainfall over the northeastern parts of the Mpumalanga Highveld are best illustrated by the long term measurements at the South African Weather Service station at the Loskop Dam (Figure 4.1).

Winters are mild and dry with average maximum temperatures dropping below 25 °C in May, June, July, and August but cold at night in June and July when temperatures drop below 7 °C. Average summer maximums exceed 27 °C from September to March, with extremes reaching more than 30 °C particularly from December to January.

The area experienced an annual average rainfall of 643 mm with rain occurring almost exclusively in the summer months from October to March, with more than 60% of the rain occurring from November to February (Figure 4.1). Rainfall seldom occurs in winter between April and September.

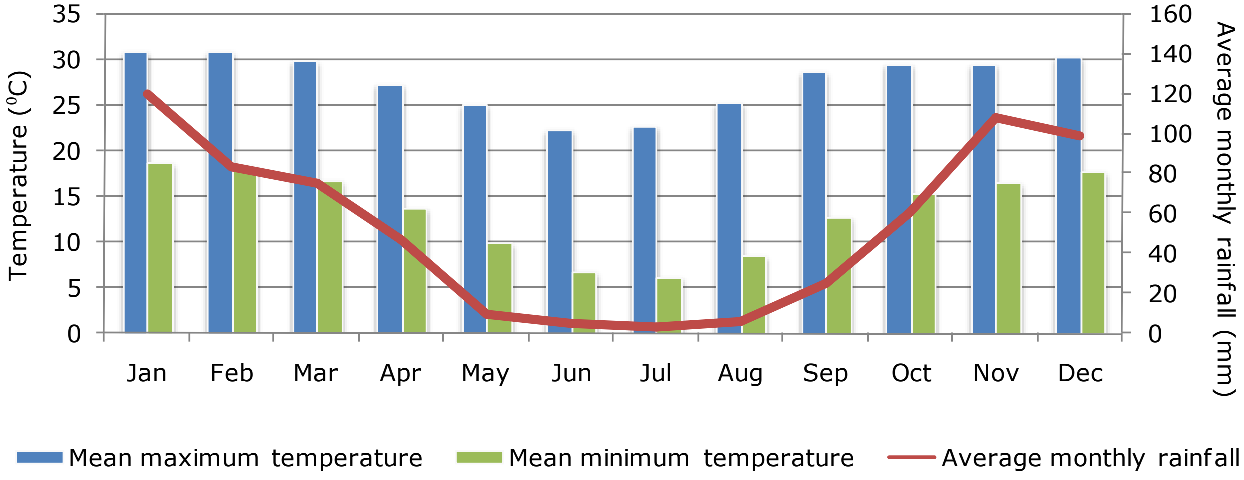


***Figure 4.1: Average monthly maximum and minimum temperature, and average monthly rainfall at Belfast from 1961 to 1990***

#### *4.1.2 Wind*

The Mpumalanga Highveld is relatively flat with little influence by topography on the wind flow. The wind pattern over the northeastern parts of the Mpumalanga Highveld is therefore best represented by the wind measurements at Witbank (Figure 4.2).

The windrose in Figure 4.2 illustrates the frequency of hourly wind from the 16 cardinal wind directions, with wind indicated from the direction it blows, i.e. easterly winds blow from the east. It also illustrates the frequency of average hourly wind speed in six wind speed classes. Generally the winds are light and seldom exceed 5.4 m/s. The prevalence of light winds measured at Witbank is similar to that described for the larger area with more than 90% of all wind recorded being less than 5 m/s (Figure 4.2). The average annual wind speed is 3.1 m/s and the station experienced calm conditions for approximately 12.5% of the observation period. The prevailing winds in Witbank are predominantly westerly, northerly easterly and east-south easterly, associated with the relative location and strength of the Indian Ocean anticyclone and the low pressure trough over the southern African interior. The annual frequency of occurrence of westerly and northerly winds is more than 7% and 10% respectively, and the combined frequency of easterly and east-southeasterly winds exceed 20%. The wind speeds from these sectors are generally light to moderate with strong south to south-westerly winds in excess of 8.5 m/s occurring at times.

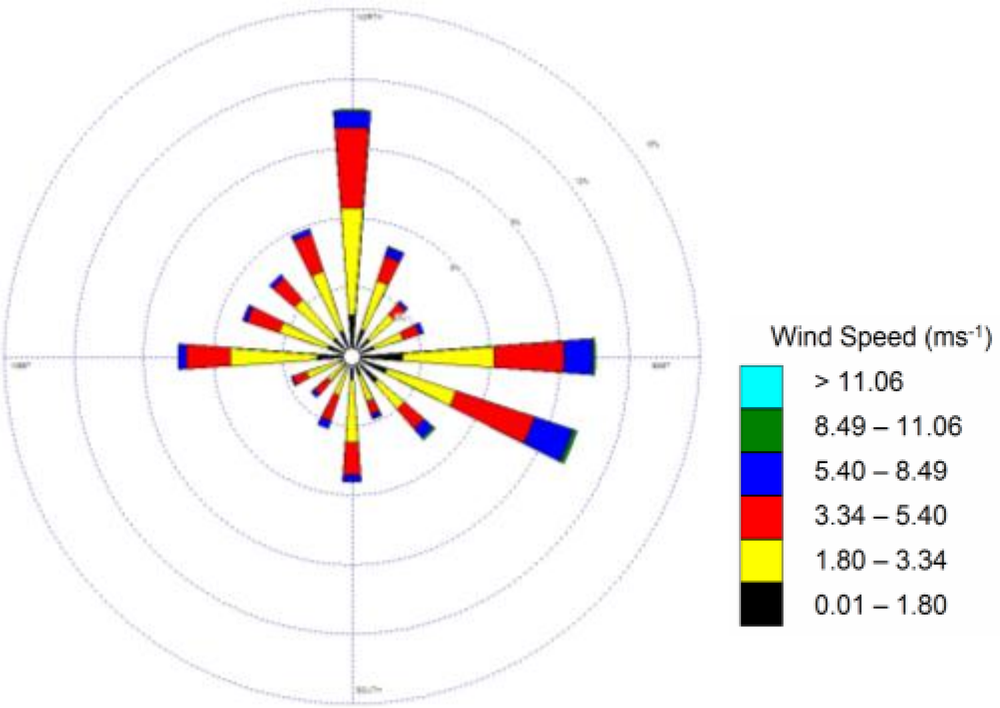


***Figure 4.2: Annual windrose for Witbank***

### 4.2 Current status of ambient air quality

The Arnot Power Station is located in the Steve Tshwete *air quality hot spot* identified in the Air Quality Management Plan for the HPA (Republic of South Africa, 2011a). In other words, it is an area where measured or modelled ambient air quality standards are exceeded. The hotspot extends across the Local Municipality from its border with Emalahleni to Arnot in the east. Exceedances of ambient air quality standards do not occur throughout the hotspot, but in three nodes. Exceedances of the $SO_2$ standard occur in the Arnot node. In the Middelburg node the modelled and monitored $PM_{10}$ concentrations; as well as modelled $SO_2$ concentrations exceed the ambient standard, but this is not relevant to this assessment as it is located beyond the northwest extent of the study area. The Komati-Hendrina node is located further south in the Local Municipality and is also not relevant to this assessment, however, modelled and monitored ambient $SO_2$ and $PM_{10}$ standards are exceeded.

The Arnot Power Station itself is an industrial source of air pollutants. It is surrounded by agricultural land with a number of mining activities and heavy industry some distance away. The mining activities occur at Mafube (~16 km to the north), Pullens Hope (~20 km to the west -southwest), and to the south of Rietkuil. Ferro-metal industries are located in Middelburg, ~35 km to the northwest, but this area is out of the modelling domain. Motor vehicle traffic on the N4 and surrounding roads will also have some influence on ambient air quality, but the effect is typically limited to areas immediately adjacent to the respective roadways. Low-income residential areas where coal is used for cooking and heating alos influence ambient air quality. Concentrations of particulates and $SO_2$ can be high in these areas, but due to the low release height and other factors dispersion is poor and the scale of the effect is relatively limited. The Hendrina Power Station is located ~20 km west-southwest of the Arnot Power Station and is an important source of $NO_2$, $SO_2$ and particulates ($PM_{10}$).

The dispersion modelling conducted for the AQMP for the HPA (Republic of South Africa, 2011a) considered industrial sources, domestic fuel burning and emissions from traffic. In the Steve Tshwete *air quality hotspot* the modelling shows that the areas of non-compliance with ambient air quality standards include the Middelburg and Arnot nodes. This suggests that ambient air quality in the vicinity of the Arnot Power Station is relatively poor.

***Sensitive receptors***

Sensitive receptors are defined as residential areas where individuals may be exposed to air pollutants when going about their daily activities i.e. commercial and residential. Most of the area around the site is used for mining and agricultural activities with small holdings.

The closest and most sensitive residential area in the vicinity of the Arnot Power Station is the residential township of Rietkuil, which is located immediately adjacent to the power station property. The western side of the Rietkuil boundary is located ~400 m away from the boiler stack on the southern end of the power station and 600 m away from the coal stockpiles on the northern end.

The other sensitive receptors which have been identified in the modelling domain are much further away from the Arnot Power Station. These include the residential townships of Hendrina (~24 km, south-southwest), Pullens Hope (~20 km, west-southwest) and Kwazamokuhle (~22 km, south-southwest). Areas of ecological importance include the Middelburgdam (~27 km, northwest) and the Nooitgedacht Dam Nature Reserve (~24 km east-southeast). The two dams are located on the extreme edge of the modelling domain.

# 5 POLICIES, LEGISLATION AND STANDARDS

## 5.1 Atmospheric Emission Licence (AEL)

The Atmospheric Pollution Prevention Act (Act No. 45 of 1965) (APPA) was repealed on 31 March 2010 when the National Environmental Management: Air Quality Act (Act No. 39 of 2004, the NEM:AQA) came into full effect. Two important regulations that support the NEM:AQA are Listed Activities and their respective Minimum Emission Standards in terms of Section 21 of the AQA (Republic of South Africa, 2010) to regulate air emissions from defined activities and the National Ambient Air Quality Standards (Republic of South Africa, 2009).

The Arnot Power Station is located in the Highveld Priority Area (HPA), declared by the Minister of Environmental Affairs and Tourism on 23 November 2007. As such an air quality management plan (AQMP) has been developed for the HPA with the primary motivation to achieve and maintain compliance with the ambient air quality standards across the HPA (Republic of South Africa, 2011a). The AQMP provides the framework for implementing departments and industry to include AQM in business planning to ensure effective implementation and monitoring. Specific goals have been developed for Listed Activities and for mining. The Arnot Power Station will be required to manage its current and future activities to meet the goals and objectives AQMP for the HPA.

## 5.2 National Environmental Management Act (Act No. 107 of 1998)

Section 28 of the NEMA addresses the duty of care and remediation of environmental damage. Sub-section 1 and 3 apply to the Arnot Power Station and air quality management. These are:

Sub-section 1: Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.

Sub-section 3: The measures required in terms of the above may include the following measures:

- i) Investigate, assess and evaluate the impact on the environment;
- ii) Inform and educate employees about the environmental risks of their work and the manner in which their tasks must be performed in order to avoid causing significant pollution or degradation of the environment;
- iii) Cease, modify or control any act, activity or process causing the pollution or degradation;
- iv) Contain or prevent the movement of pollutants or the cause of degradation;
- v) Eliminate any source of the pollution or degradation;
- vi) Remedy the effects of the pollution or degradation.

Considering the requirements of Section 28 of the NEMA, the current study by uMoya-NILU is to evaluate the potential current and future impact of the Arnot Power Station on ambient air quality relative to the existing background state and the effectiveness of the proposed dust abatement.

## 5.3 The National Environmental Management: Air Quality Act (Act No. 39 of 2004)

### *5.3.1 Atmospheric Emission Licence (AEL)*

The Atmospheric Pollution Prevention Act (APPA) was repealed on 31 March 2010. With this, the Atmospheric Emission Licensing (AEL) function was delegated to District and Metropolitan Municipalities. The AEL function includes the review and conversion of existing APPA Registration Certificates to AEL's and the issuing of AEL's for new Listed Activities. In Mpumalanga Province the AEL function has not yet been delegated to the Nkangala District Municipality. The responsibility resides with the provincial Department of Economics, Development, Environment and Tourism (D:EDE&T). The designated Air Quality Officer (AQO) is Mr Fikile Theledi; Address: Private Bag X11219, Nelspruit, 1200; Telephone number: 013 759 4000; email address: mtheledi@nel.mpu.gov.za.

### 5.4 Minimum emission standards

The combustion of fuels for steam raising or electricity generation is classified as a Listed Activity. Minimum emissions standards and compliance time frames for solid fuel combustion installations using coal and biomass for existing and new plants have been set accordingly for particulate matter, $SO_2$ and $NO_x$ (Republic of South Africa, 2010) and are listed in Table 5.1. The minimum emission standards for existing plants apply to the Arnot Power Station from 2015. However, by 2020 all existing plants will be required to implement emission reduction plans to meet the minimum emission standards for new plants.

***Table 5.1: Minimum emission standards for combustion installations (Republic of South Africa (2010)***

| Common name | Plant status | Coal | Biomass |
|---|---|---|---|
| | | mg/Nm$^3$ under standard conditions of 273 K and 101.3 kPa | |
| Particulate matter | New | 50 | 50 |
| | Existing | 100 | 100 |
| Sulphur dioxide ($SO_2$) | New | 500 | 500 |
| | Existing | 3 500 | 3 500 |
| Oxides of nitrogen ($NO_x$ expressed and $NO_2$) | New | 750 | 750 |
| | Existing | 1 100 | 1 100 |

### 5.5 Ambient air quality standards and guidelines

The effects of air pollutants on human health occur in a number of ways with short-term, or acute effects, and chronic, or long-term, effects. Different groups of people are affected differently, depending on their level of sensitivity, with the elderly and young children being more susceptible. Factors that link the concentration of an air pollutant to an observed health effect are the level and the duration of the exposure to that particular air pollutant.

Criteria pollutants occur ubiquitously in urban and industrial environments. Their effects on human health and the environment are well documented (e.g. WHO, 1999; 2000; 2005). South Africa has established national ambient air quality standards for the criteria pollutants, i.e. carbon monoxide (CO), $NO_2$, $SO_2$, $PM_{10}$, ozone ($O_3$), lead (Pb) and benzene ($C_6H_6$). (Republic of South Africa, 2009).

The national ambient air quality standard consists of a limit value and a permitted frequency of exceedance. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant. The permitted frequency of exceedance represents the tolerated exceedance of the limit value and accounts for high concentrations as a result of process upsets and meteorological variation. Compliance with the ambient standard therefore implies that ambient concentrations are below the limit value and the frequency of exceedance does not exceed the permitted tolerance. Being a health-based standard, ambient concentrations below the standard imply that air quality is acceptable and poses little or no risk to human health, while exposure to ambient concentrations above the standard imply that there is a risk to human health, particularly for sensitive individuals.

The criteria pollutants that result from emissions from the Arnot Power Station are $SO_2$, $NO_2$ and $PM_{10}$. These pollutants are described below.

### *5.5.1 Sulphur dioxide ($SO_2$)*

**Sources**

Dominant sources of $SO_2$ include fossil fuel combustion from industry and power plants. $SO_2$ is emitted when coal is burnt for energy. The combustion of oil also results in high $SO_2$ emissions. Domestic coal or kerosene burning can thus also result in the release of $SO_2$. Motor vehicles also emit $SO_2$, in particular diesel vehicles due to the higher sulphur content of diesel fuel. Mining processes where smelting of mineral ores occurs can also result in the production of $SO_2$ as metals usually exist as sulphides within the ore.

$SO_2$ emissions from coke oven batteries originate from oven charging and coking as a result of the sulphur in the coal. The emission is via the charge holes and the levelling port, and during coking through door cracks and lid leaks and the coke oven stack. $SO_2$ emissions are also associated with coke oven gas treatment.

**Health and environmental effects**

On inhalation, most $SO_2$ only penetrates as far as the nose and throat, with minimal amounts reaching the lungs, unless the person is breathing heavily, breathing only through the mouth, or if the concentration of $SO_2$ is high (CCINFO, 1998). The acute response to $SO_2$ is rapid, within 10 minutes in people suffering from asthma (WHO, 2005). Effects such as a reduction in lung function, an increase in airway resistance, wheezing and shortness of breath, are enhanced by exercise that increases the volume of air inspired, as it allows $SO_2$ to penetrate further into the respiratory tract (WHO, 1999).

$SO_2$ reacts with cell moisture in the respiratory system to form sulphuric acid. This can lead to impaired cell function and effects such as coughing, broncho-constriction, exacerbation of asthma and reduced lung function. $SO_2$ has the potential to form sulphurous acid or slowly form sulphuric acid in the atmosphere via oxidation by the hydroxyl radical. The sulphuric acid may then dissolve in water droplets and fall as precipitation. This may decrease the pH of rain water, altering any balance within ecosystems and can be damaging to man-made structures. $SO_2$ causes visible injury to plants that is characterised by chlorosis of the leaf tissue (white areas of dying tissue), resulting is a reduction in growth and yield. The WHO (2000) propose an annual ambient guideline for $SO_2$ of 30 $\mu g/m^3$ for the protection of agricultural crops and 20 $\mu g/m^3$ for the protection of forests.

**Ambient standards**

***Table 5.2: Ambient standard for $SO_2$ (Republic of South Africa, 2009)***

| Exposure period | Averaging period | Limit value (µg/m$^3$) | Number of permissible exceedances per annum |
|---|---|---|---|
| Hourly | 1 hour | 350 | 88 |
| Daily | 24 hour | 125 | 4 |
| Annual | 1 year | 50 | 0 |

### *5.5.2 Nitrogen dioxide ($NO_2$)*

**Sources**

Nitrogen dioxide ($NO_2$) and nitric oxide (NO) are formed simultaneously in combustion processes and other high temperature operations such as metallurgical furnaces, blast furnaces, plasma furnaces, and kilns. $NO_x$ is a term commonly used to refer to the combination of NO and $NO_2$. $NO_x$ can also be released from nitric acid plants and other types of industrial processes involving the generation and/or use of nitric acid. $NO_x$ also forms naturally by de-nitrification by anaerobic bacteria in soils and plants. Lightning is a source of $NO_x$ during the discharge and the rapid cooling of air after the electric discharge.

$NO_x$ emissions from coke oven batteries originate from oven charging and coking as a result of the nitrogen in the coal. The emission is via the charge holes and the levelling port, and during coking through door cracks and lid leaks and the coke oven stack. $NO_x$ emissions are also associated with coke oven gas treatment.

**Health and environmental effects**

The route of exposure to $NO_2$ is inhalation and the seriousness of the effects depend more on the concentration than the length of exposure. The site of deposition for $NO_2$ is the distal lung where $NO_2$ reacts with moisture in the fluids of the respiratory tract to form nitrous and nitric acids (WHO, 1997). About 80 to 90% of inhaled nitrogen dioxide is absorbed through the lungs (CCINFO, 1998). Nitrogen dioxide (present in the blood as the nitrite ion) oxidises unsaturated membrane lipids and proteins, which then results in the loss of control of cell permeability. Nitrogen dioxide caused decrements in lung function, particularly increased airway resistance. People with chronic respiratory problems and people who work or exercise outside will be more at risk to $NO_2$ exposure (EAE, 2006). People with a vitamin C deficiency may be more at risk, as vitamin C inhibits the oxidation reactions of $NO_2$ in the body (WHO, 1997).

$NO_x$ also reacts with water in the atmosphere and can contribute to the formation of acid rain.. $NO_x$ can reduce plant growth at high concentrations, but can stimulate growth at low concentrations. The WHO (2000) recommends a critical level for $NO_x$ in the ambient environment of 30 µg/m$^3$ as an annual mean. The critical level is the concentration of a pollutant in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials may occur. $NO_x$ is a key ingredient in atmospheric photochemistry and the formation of secondary pollutants such as ozone and smog.

**Ambient standards**

***Table 5.3: Ambient standard for $NO_2$ (Republic of South Africa, 2009)***

| Exposure period | Averaging period | Limit value ($\mu g/m^3$) | Number of permissible exceedances per annum |
|---|---|---|---|
| Hourly | 1 hour | 200 | 88 |
| Annual | Calendar year | 40 | 0 |

### *5.5.3 Particulates*

**Sources**

Particulate matter is a broad term used to describe the fine particles found in the atmosphere, including soil dust, dirt, soot, smoke, pollen, ash, aerosols and liquid droplets. The most distinguishing characteristic of PM is the particle size and the chemical composition. Particle size has the greatest influence on the behaviour of PM in the atmosphere with smaller particles tending to have longer residence times than larger ones. PM is categorised, according to particle size, into TSP, $PM_{10}$ and $PM_{2.5}$.

**Total suspended particulates (TSP)** consist of all sizes of particles suspended within the air smaller than 100 micrometres (µm). TSP is useful for understanding nuisance effects of PM, e.g. settling on houses, deposition on and discolouration of buildings, and reduction in visibility.

**$PM_{10}$** describes all particulate matter in the atmosphere with a diameter equal to or less than 10 µm. Sometimes referred to simply as coarse particles, they are generally emitted from motor vehicles (primarily those using diesel engines), factory and utility smokestacks, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood. Natural sources include sea spray, windblown dust and volcanoes. Coarse particles tend to have relatively short residence times in the atmosphere? as they settle out rapidly and $PM_{10}$ is generally found relatively close to the source except in strong winds.

**$PM_{2.5}$** describes all particulate matter in the atmosphere with a diameter equal or less than 2.5 µm. They are often called fine particles, and are mostly related to combustion (motor vehicles, smelting, incinerators), rather than mechanical processes as is the case with $PM_{10}$. $PM_{2.5}$ may be suspended in the atmosphere for long periods and can be transported over large distances. Fine particles can form in the atmosphere in three ways: when particles form from the gas phase, when gas molecules aggregate or cluster together without the aid of an existing surface to form a new particle, or from reactions of gases to form vapours that nucleate to form particles.

PM emissions occur at all stages of coke production. PM results from the coal handling processes, in all of the battery operations, i.e. charging, levelling, coking, pushing and quenching. PM also results for coke storage and handling.

**Health and environmental effects**

Particulate matter may contain both organic and inorganic pollutants. The extent to which particulates are considered harmful depends on their chemical composition and size, e.g. particulates emitted from diesel vehicle exhausts mainly contain unburned fuel oil and hydrocarbons that are known to be carcinogenic. Very fine particulates pose the greatest health risk as they can penetrate deep into the lung, as opposed to larger particles that may be filtered out through the airways' natural mechanisms.

In normal nasal breathing, particles larger than 10 µm are typically removed from the air stream as it passes through the nose and upper respiratory airways, and particles between 3 µm and 10 µm are be deposited on the mucociliary escalator in the upper airways. Only particles in the range of 1 µm to 2 µm penetrate deeper where deposition in the alveoli of the lung can occur (WHO, 2003). Coarse particles ($PM_{10}$ to $PM_{2.5}$) can accumulate in the respiratory system and aggravate health problems such as asthma. $PM_{2.5}$, which can penetrate deeply into the lungs, are more likely to contribute to the health effects (e.g. premature mortality and hospital admissions) than coarse particles (WHO, 2003).

People with existing health conditions such as cardiovascular disease and asthmatics, as well as the elderly and children, are more at risk to the inhalation of particulates than normal healthy people (Pope, 2000; Zanobetti et al., 2000). The 24-hour and annual ambient standard for $PM_{10}$ is indicated in Table 5.4.

***Table 5.4: Ambient standards for $PM_{10}$ (Republic of South Africa, 2009). The values in brackets come into effect on 1 January 2015.***

| Exposure period | Averaging period | Limit value (µg/m$^3$) | Number of permissible exceedances per annum |
|---|---|---|---|
| Daily | 24-hour | 120 (75) | 4 |
| Annual | Calendar year | 50 (40) | 0 |

On 5 August 2011 the Minister of Water and Environmental Affairs published air quality standards for $PM_{2.5}$ for comment (Republic of South Africa, 2011c), with phased stages of implementation (Table 5.5).

***Table 5.5: Draft national ambient air quality standards for $PM_{2.5}$ (Republic of South Africa, 2011c)***

| Averaging period | Concentration (($\mu g/m^3$) | Frequency of exceedance | Compliance date |
|---|---|---|---|
| 24 hours | 65 | 0 | Immediate to 31 Dec 2015 |
| 24 hours | 40 | 0 | 1 Jan 2016 – 31 Dec 2029 |
| 24 hours | 25 | 0 | 1 Jan 2030 |
| 1 year | 25 | 0 | Immediate to 31 Dec 2015 |
| 1 year | 20 | 0 | 1 Jan 2016 – 31 Dec 2029 |
| 1 year | 15 | 0 | 1 Jan 2030 |

A four-band scale is used to evaluate dust deposition (Republic of South Africa, 2009) (Table 5.6), with target, action and alert thresholds in Table 5.7. This is currently a guideline that is likely to be regulated in the foreseeable future.

***Table 5.6: Bands of dust deposition evaluation rates (Republic of South Africa, 2009)***

| Band number | Band description label | Dust-fall rate (*D*) (mg $m^{-2}$ $day^{-1}$, 30-day average) | Comment |
|---|---|---|---|
| 1 | Residential | $D < 600$ | Permissible for residential and light commercial. |
| 2 | Industrial | $D \leq 1\ 200$ | Permissible for heavy commercial and industrial. |
| 3 | Action | $1\ 200 < D \leq 2\ 400$ | Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year. |
| 4 | Alert | $D > 2\ 400$ | Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority. |

***Table 5.7: Target, action and alert thresholds for ambient dust deposition (Republic of South Africa, 2009)***

| **Level** | **Dust-fall rate (*D*) (mg $m^{-2}$ $day^{-1}$, 30-day average)** | **Averaging period** | **Permitted frequency of exceedances** |
|---|---|---|---|
| Target | 300 | Annual | |
| Action residential | 600 | 30 days | Three within any year, no two sequential months. |
| Action industrial | 1 200 | 30 days | Three within any year, not sequential months. |
| Alert threshold | 2 400 | 30 days | None. First exceedance requires remediation and compulsory report to authorities. |

The publication of the Draft National Dust Control Regulation (Republic of South Africa, 2011b) on 27 May 2011 for public comment formalises the SANS recommendations. This regulation states that no person may conduct any activity in such a way as to give rise to dust in such qualities and concentrations that:

a) The dust, or dust fall, has a detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage, or has contributed to the degradation of ambient air quality beyond the premises where it originates; or
b) The dust remains visible in the ambient air beyond the premises where it originates; or
c) The dust fall at the boundary and beyond the boundary of the premises where it originates exceeds:
    i) 600 $mg/m^2/day$ averaged over 30 days in residential or light commercial areas measured using reference method ASTM D1739; or
    ii) 1200 $mg/m^2/day$ averaged over 30 days in areas other than residential and light commercial areas measured using reference method ASTM D1739.

### 5.6 The AQMP for the HPA

The overall objective of the AQMP for the HPA is that ambient air quality complies with all national ambient air quality standards (Republic of South Africa, 2011a). Seven goals in the AQMP address different aspects in achieving the overall objective. Goal 2 which reads 'By 2020, industrial emissions are equitably reduced to achieve compliance with air quality standards and dust fallout limit values' applies to the Arnot Power Station.

All objectives under this goal apply to the Arnot Power Station. These include:
1) Emissions are quantified from all sources
2) Gaseous and particulate emissions are reduced
3) Fugitive emissions are minimised
4) Emissions from dust-generating activities are reduced
5) Greenhouse gas emissions are reduced
6) Incidences of spontaneous combustion in coal storage piles and discard dumps are reduced
7) Abatement technology is appropriate and operational
8) Industrial AQM decision making is robust and well-informed, with necessary information available
9) Clean technologies and processes are implemented
10) Adequate resources are available for AQM in industry
11) Ambient air quality standard and dust fallout limit value exceedances as a result of industrial emissions are assessed
12) A line of communication exists between industry and communities

### 5.7 Geographical alternatives

Alternatives for siting the biomass milling plant on the Arnot Power Plant site are relatively limited as a result of the need for proximity to existing infrastructure and the need to integrate this plant into the existing milling and fuel feed processes. Ideally the plant should be located on the eastern side of the power plant where it would be as far as possible from the nearest sensitive receptor area (Rietkuil) as possible. This will ensure that nuisance impacts associated with dust will be reduced. The proposed location on the western side of the plant has operational advantages. The tall trees between the plant and Rietkuil will serve to continue to reduce dust impacts at Rietkuil from coal storage and handling at Arnot. However, the dust control measures on the milling plant and the biomass storage and handling processes will need to be rigorous to ensure the dust fall at Rietkuil is not increased. See the mitigation section.

# 6 EMISSIONS INVENTORY

## 6.1 Power generation – stack emissions

The results of emission estimations for key pollutants are presented in Table 6.1. The following are the three scenarios considered:

1. Scenario 1: The current scenario which is the current operational status of the power station (100% coal). This represents the baseline scenario which was modelled.
2. Scenario 2: The replacement of 10% coal by mass with wood of equivalent heating value in boiler 4, and the coal mass consequently a bit more than 90% of the original mass, so that the heat input remains the same. This represents one of the likely future scenarios which was modelled.
3. Scenario 3: The replacement of 5% coal by mass with wood of equivalent heating value on three boilers units (boilers 1, 2 and 3). This also represents a likely future scenario, but was not modelled.

***Table 6.1: Emission rates of key pollutants from the Arnot Power Station***

| Scenario | Boiler No. | $SO_2$ Emission Rate (kg/month) | $NO_2$ Emission Rate (kg/month) | PM Emission Rate - Controlled (kg/month) | $CO_2$ Emission Rate (kg/month) |
|---|---|---|---|---|---|
| Scenario 1: Current | 1 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 2 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 3 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 4 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 5 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 6 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | **Total** | **6,536,309** | **4,061,142** | **179,456** | **1,140,980,771** |
| Scenario 2: Replace 10% coal mass in 1 boiler | 1 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 2 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 3 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 4 | 1,005,175 | 624,536 | 27,597 | 175,463,826 |
| | 4 | 9,043 | 33,424 | 81 | 15,627,620 |
| | 5 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 6 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | **Total** | **6,461,142** | **4,042,244** | **177,224.76** | **1,141,908,756** |
| Scenario 3: Replace 5% coal mass in each of 3 boilers | 1 | 1,047,280 | 650,696 | 28,753 | 182,813,644 |
| | 1 | 4,521 | 16,712 | 40 | 7,813,810 |
| | 2 | 1,047,280 | 650,696 | 28,753 | 182,813,644 |
| | 2 | 4,521 | 16,712 | 40 | 7,813,810 |
| | 3 | 1,047,280 | 650,696 | 28,753 | 182,813,644 |
| | 3 | 4,521 | 16,712 | 40 | 7,813,810 |
| | 4 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 5 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | 6 | 1,089,385 | 676,857 | 29,909 | 190,163,462 |
| | **Total** | **6,423,559** | **4,032,796** | **176,109.18** | **1,142,372,748** |

Biomass in the form of wood is a considerably cleaner fuel than coal with the result that the replacement of coal with wood will result in a reduction in emissions if coal is replaced with equal quantities of wood.

The sulphur content of wood (0.03 to 0.08%) is significantly less than that of coal (0.65%). $SO_2$ emission rates are directly proportional to the content of sulphur bound in the fuel. The baseline emission rate of $SO_2$ is estimated to be 6,536,309 kg/month (214.9 ton/day). The $SO_2$ emission rates will decrease by 1.2% and 1.7% for scenarios 2 and 3, respectively. This represents a reduction rate of 2.4 ton/day for scenario 1 and 3.7 ton/day for scenario 2.

The baseline emission rate for $NO_2$ is estimated to be 4,061,142 kg/month (133.5 ton/day). The $NO_2$ emission rates will decrease by 0.5% and 0.7% for scenarios 2 and 3, respectively.

This will result in a $NO_2$ reduction rate of 0.7 ton/day for scenario 1 and 1.0 ton/day for scenario 2.

The ash content of wood (0.5 to 3.5%) is also significantly less than that of coal (25%). PM emission rates are directly proportional to the content of ash in the fuel. The baseline PM emission rate downstream of the filter bags is estimated to be 179,456 kg/month (5.9 ton/day). The PM emission rates will decrease by 1.2% and 1.8% for scenarios 2 and 3, respectively. This will result in a PM reduction rate of 0.07 ton/day for scenario 1 and 0.1 ton/day for scenario 2.

$CO_2$ emission rates are directly proportional to the carbon content in the fuel. The carbon content of wood (45 to 50%) is less than that for coal (58.48%). The baseline emission rate of $CO_2$ using coal is estimated to be 1,140,980,771 kg/month (37,511 ton/day). However, due to its lower calorific value, more wood is required than coal in mass terms to generate an equivalent amount of heat. Any benefits that might be gained from the lower carbon content in terms of $CO_2$ emissions are therefore off-set by the requirement of more wood. In contrast to the other pollutants, the $CO_2$ emission rates are therefore expected to increase by 0.08% and 0.12% for scenarios 2 and 3, respectively (Table 6.1). The $CO_2$ emission rates will increase by 31 ton/day for a biomass substitution of 10% in one unit only and by 48 ton/day for a biomass substitution of 5% in each of three units . The reason for the increase is twofold:

- The variance between the carbon contents of coal and wood is not large.
- The quantity of coal earmarked for replacement by wood for the two future scenarios is not large.

In summary, the replacement of coal with wood in the quantities described above will result in a marginal reduction of $SO_2$, $NO_2$ and PM emissions and a marginal increase in $CO_2$ emissions.

## 6.2 *Emissions from coal handling*

The emissions for $PM_{10}$ were estimated for the baseline to be 1.3 ton/yr and the total suspended particulate matter emissions were estimated to be 2.7 ton/yr.

| **Particulate matter ($PM_{10}$)**<br>E = A × EF(s) | **Stock pile** |
|---|---|
| Quantity of coal transferred daily (ton/day) | 28 512 |
| EFs (Emission factor) (lb/ton) | 0.000271 |
| Emission Rate (lb/day) | 7.734980 |
| Emission Rate (kg/yr) | 1280.61 |
| Emission Rate (ton/yr) | 1.28061 |
| Emission Rate (ton/day) | 0.00351 |

| **TSP particulate matter**<br>E = A × EF(s) | **Stockpile** |
|---|---|
| Quantity of coal transferred daily (ton/day) | 28 512 |
| EFs (Emission factor) (lb/ton) | 0.000574 |
| Emission Rate (lb/day) | 16.353958 |
| Emission Rate (kg/yr) | 2707.58 |
| Emission Rate (ton/yr) | 2.708 |
| Emission Rate (ton/day) | 0.00742 |

### 6.3 Emissions from unpaved roads

The activity rate was taken as the total distance travelled by the trucks per day on the gravel road. Using Google maps the length of the gravel road was estimated to be about 800m. The total distance travelled by the 35 trucks on the gravel road was calculated to be 28 Km/day. The emissions for PM-10 were estimated to be 5.64 ton/yr and for total suspended particulate matter 22 ton/yr.

| **Particulate matter (PM10)**<br>E = A × EF(s) | **Gravel Road** |
|---|---|
| Distance Vehicle Travelled (KM/day) | 28 |
| EFs (Emission factor) (kg/VKT) | 0.552 |
| Emission Rate (kg/day) | 15.45 |
| Emission Rate (kg/yr) | 5639 |
| Emission Rate (ton/yr) | 5.64 |
| Emission Rate (ton/day) | 0.015 |

| **TSP particulate matter**<br>E = A × EF(s) | **Gravel Road** |
|---|---|
| Distance Vehicle Travelled (KM/day) | 28 |
| EFs (Emission factor) (kg/VKT) | 2.139 |
| Emission Rate (kg/day) | 59.89 |
| Emission Rate (kg/yr) | 21858 |
| Emission Rate (ton/yr) | 22 |
| Emission Rate (ton/day) | 0.060 |

### 6.4 Emissions from vehicle exhaust

The activity rate was taken as the total distance travelled by the trucks per day on the gravel road. The total distance travelled by the 35 trucks on the gravel road was calculated to be 28 km/day. The emissions for PM-10 were estimated to be 0.95 ton/yr and 95.3 ton/yr for $NO_x$.

| $PM_{10}$ | $NO_x$ |
|---|---|
| **0.95** | **95.3** |

## 7 PREDICTED AMBIENT AIR QUALITY IMPACTS

The impacts on air quality as a result of construction activities and decommissioning of the Arnot Plant, and the two defined operational scenarios are described in this section.

### 7.1 Construction

Construction work will entail building of new infrastructure and heavy construction work with concrete, steel, piping, etc to accommodate the co-firing option and separate milling. Dust emissions during construction result mainly from earth moving activities (scraping, compacting, excavation, grading), movement of construction vehicles and back-fill operations. Dust emissions during decommissioning result from the demolition of structures, earth moving activities (scraping, compacting, excavation, grading), movement of construction vehicles and back-fill operations. All aspects of the construction inherently generate dust, but the movement of construction vehicles on paved and unpaved surfaces at the construction site are generally the largest source of dust. Construction vehicles will be in operation for the duration of the construction and decommissioning. Dust is also easily entrained from exposed areas by the wind.

The impact of dust is more of a nuisance nature and does not typically pose a health risk due to its typically coarse size. The impact of dust from the construction and decommissioning activities on air quality is expected to be relatively short lived, i.e. limited to the duration of the construction or decommissioning. The impacts are also expected to be localised and limited to the area adjacent to the activity.

### 7.2 Operations

The impact on air quality associated with the baseline and co-firing option operational scenarios is assessed for the key air pollutants associated with power generation, i.e. $PM_{10}$, $NO_x$ and $SO_2$ and $CO_2$ as a Greenhouse Gas. Predicted ambient concentrations of these pollutants resulting from the co-firing option operational scenario are evaluated against the baseline (100% coal fired) to assess the nature of the change induced by the substitution of coal with biomass. The assessment takes account of existing ambient concentrations measured in Middleburg by the DEA. The background concentrations that have been applied to assess the cumulative effect of the project are 25 $\mu g/m^3$ for $PM_{10}$ as an hourly average, 13.3 $\mu g/m^3$ for $SO_2$ and 15.3 $\mu g/m^3$ for $NO_2$.

The impacts associated with the operational phases are assessed by the comparison of predicted ambient concentrations with the National Ambient Air Quality Standards. These are health based standards, i.e. ambient concentrations below the standards imply that air quality is acceptable while exposure to ambient concentrations above the standard imply that there is a risk to human health, particularly for sensitive individuals. The ambient standards for a given pollutant consist of a limit value and a permitted frequency of exceedance.

The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant. The permitted frequency of exceedance represents the tolerated exceedance of the limit value. Compliance with the standard therefore implies that ambient concentrations are below the limit value and the frequency of exceedance does not exceed the permitted tolerance.

## 7.3 Model Results

### *7.3.1 Particulates (PM)*

Total particulate emissions, also referred to as TSP consist of all sizes of particles suspended within the air smaller than 100 µm. This includes all particulate matter in the atmosphere with a diameter equal to or less than 10 µm ($PM_{10}$). There are no ambient air quality standards for total particulates, but for $PM_{10}$ and $PM_{2.5}$ only. In this assessment only $PM_{10}$ is assessed. It assumed that the total particulates emitted from the Arnot Power Station are $PM_{10}$. This approach is conservative since not all emitted particles are less than 10 µm. This should be recognised when comparison of the modelled concentrations is made against national ambient air quality standards for $PM_{10}$ (Table 5.4).

#### *Annual average*

Predicted annual average $PM_{10}$ concentrations for the baseline scenario (Scenario 1) (Figure 7.1) and the co-firing option scenario (Scenario 2) at the Arnot Power Station are well below the current and 2015 national annual ambient $PM_{10}$ standard of 50 µg/m$^3$ and 40 µg/m$^3$ respectively. No exceedances of the limit values are predicted for both scenarios within the site or in residential areas around the site.

For the cumulative situation, the highest predicted annual $PM_{10}$ concentration for the baseline operational scenario is 25.2 µg/m$^3$. The co-firing option scenario results in slightly lower emissions. This brings about a very slight decrease in the predicted annual maximum concentration. Both maxima occur ~3 km to the east-northeast of the Arnot Power Station.

Figure 7.2 shows the difference between maximum modelled ambient concentration for the cumulative situation between the co-firing and baseline emission scenarios. Ambient concentrations decrease marginally throughout most of the study area when wood is co-fired, but the greatest decrease of 0.015% occurs over an area that extends from the north to the southeast around the site. A slight improvement in baseline annual ambient particulate concentrations is predicted for biomass co-firing, but not measurably so.

#### *24-hour maximum concentrations*

Predicted maximum 24-hour ambient $PM_{10}$ concentrations for both the baseline scenario (Figure 7.3) as well as the biomass co-firing option scenario at the Arnot Power Station are well below the current and 2015 national annual ambient $PM_{10}$ standard of 120 μg/m$^3$ and 75 μg/m$^3$ respectively. No exceedances of the limit values are predicted within the site or in residential areas around the site for both scenarios.

For the cumulative situation, the highest predicted annual $PM_{10}$ concentration for the baseline scenario is 30.4 μg/m$^3$. The co-firing option scenario results in slightly lower particulate emissions. This brings about a slight decrease in the predicted 24-hour maximum concentration to 30.3 μg/m$^3$. Both maxima occur ~2 km to the east-northeast of the Arnot Power Station.

Figure 7.4 shows the difference between maximum modelled ambient concentration between the co-firing and baseline emission scenario for the cumulative situation. Ambient concentrations decrease by up to 0.2% throughout most of the study area, but the greatest decrease of 0.3% occurs over a small area, ~3 km to the northeast of the Arnot Power Station. A slight improvement in baseline 24-hour maximum particulate concentrations is predicted for biomass co-firing, but not measurably so.

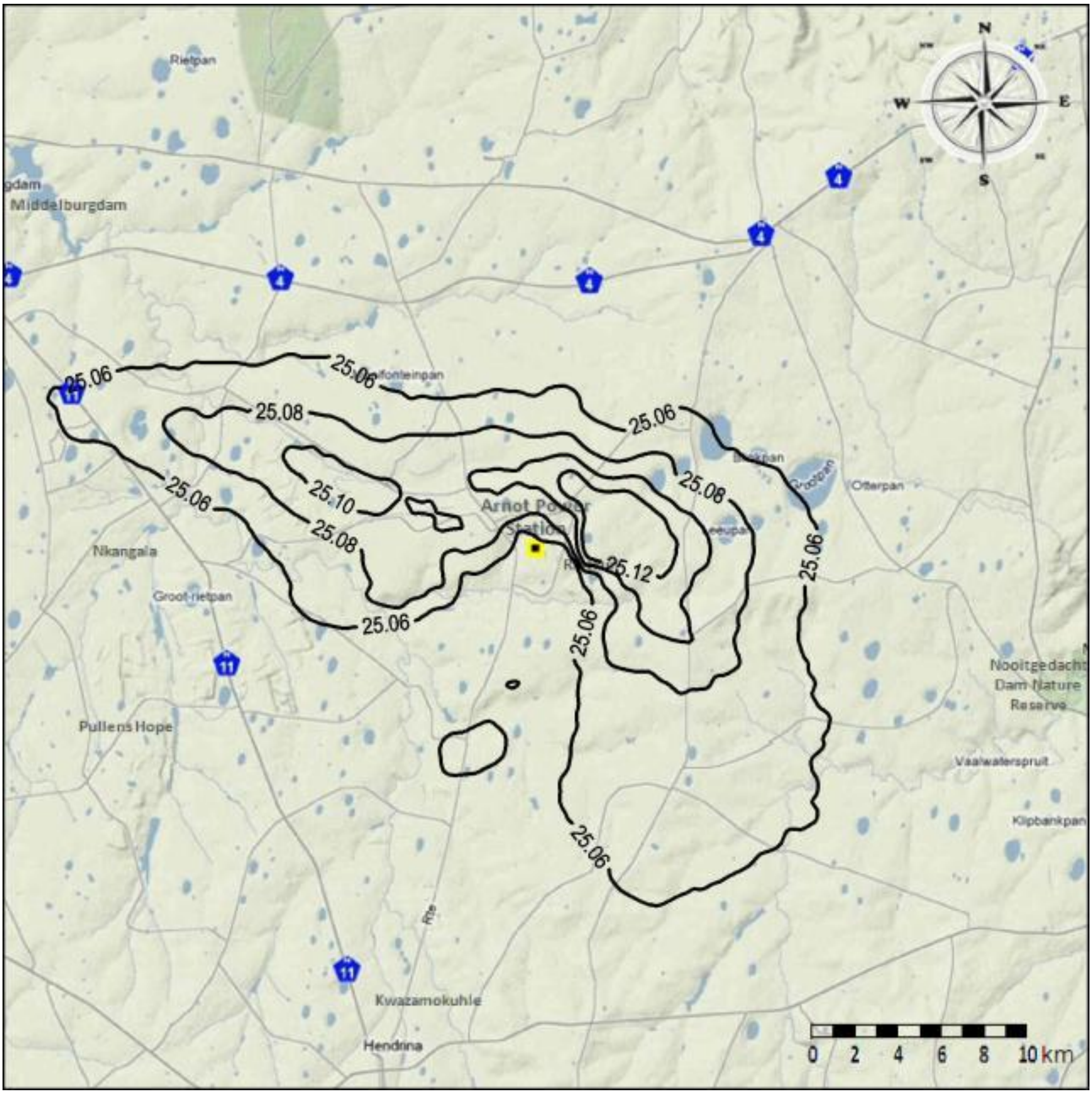


***Figure 7.1: Predicted annual average $PM_{10}$ concentrations ($\mu g/m^3$) for the baseline scenario at the Arnot Power Station***

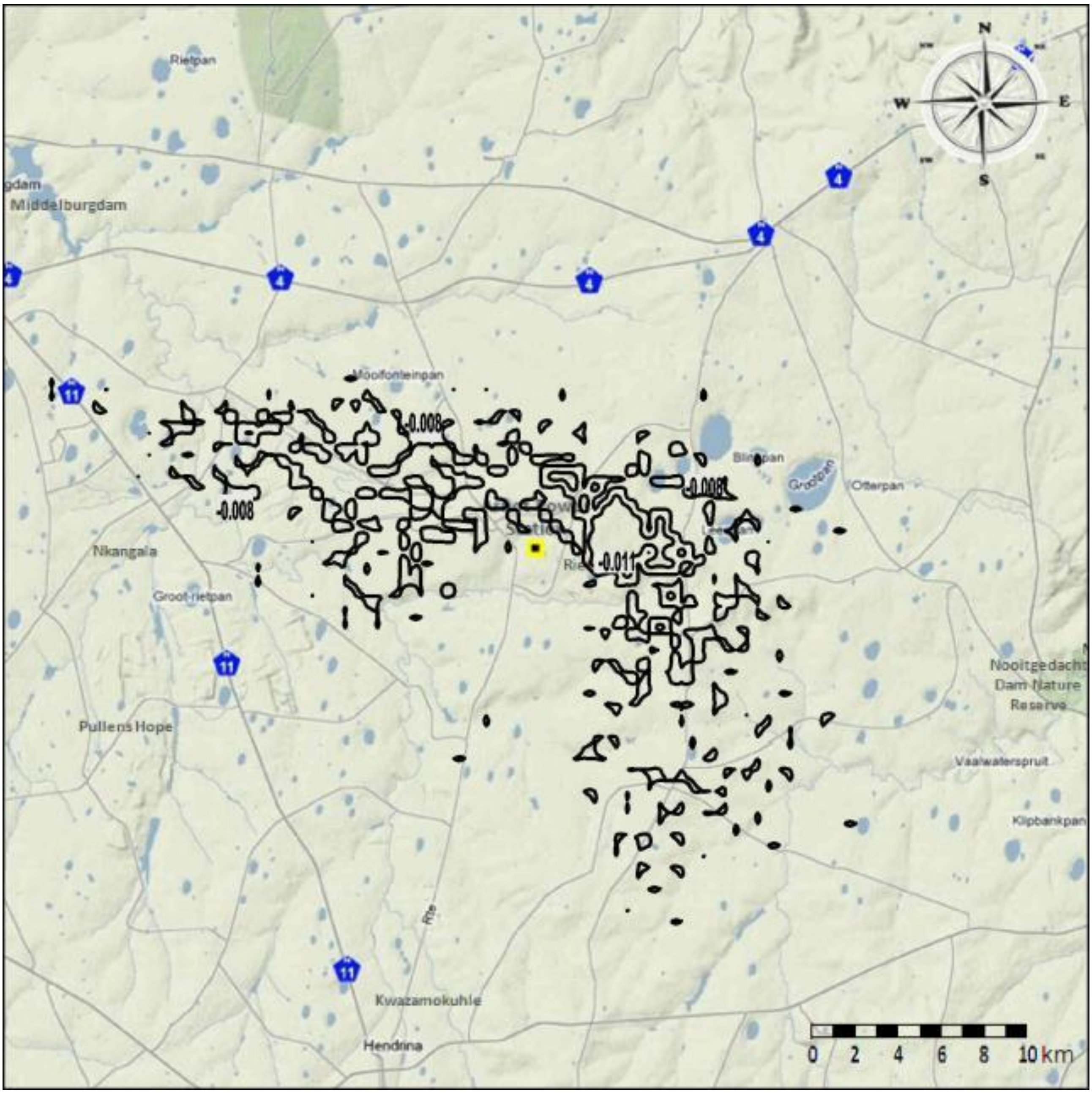


***Figure 7.2: Percentage difference in predicted annual average $PM_{10}$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass) at the Arnot Power Station.***

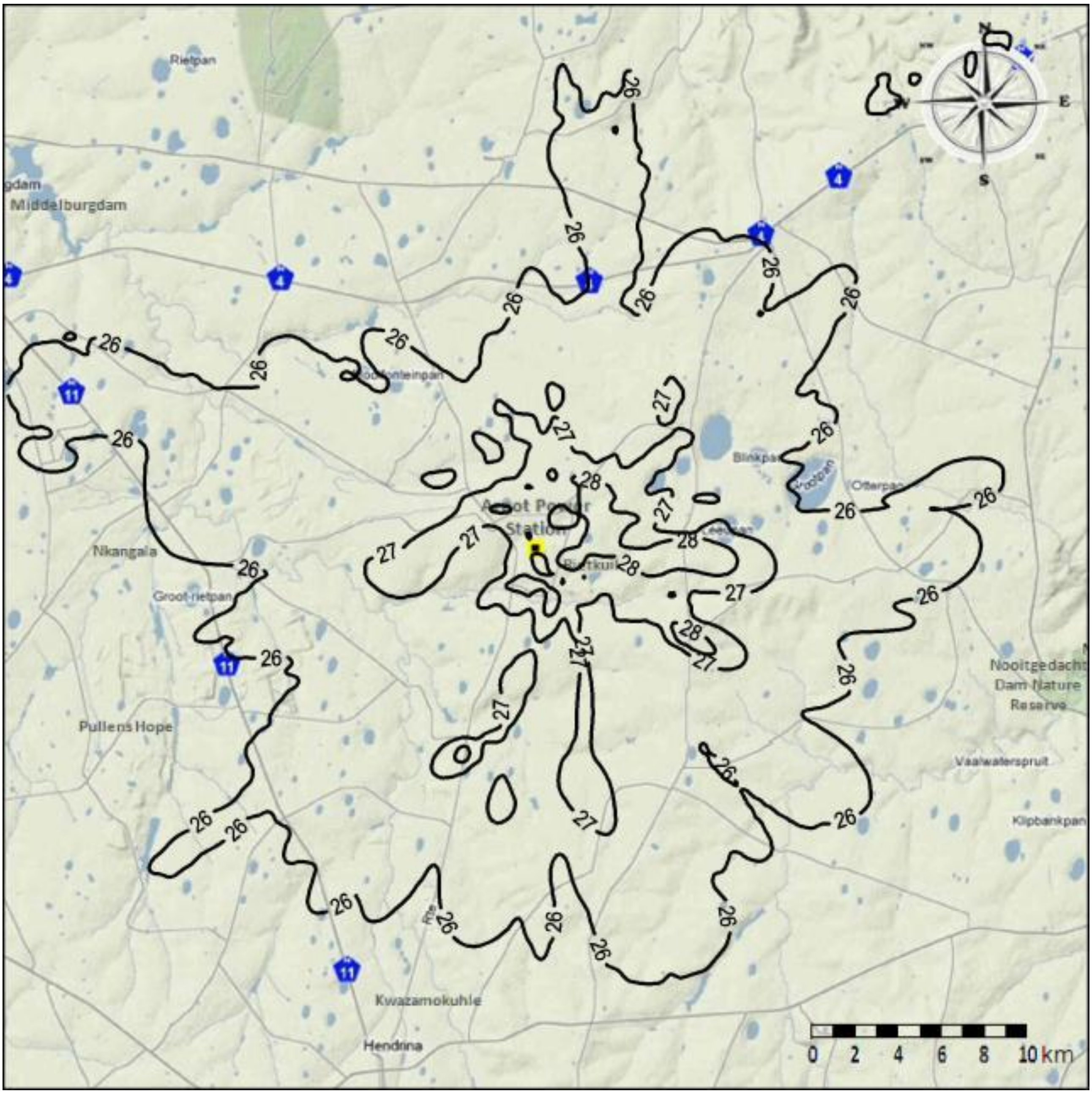


***Figure 7.3: Predicted 24-hour $PM_{10}$ concentrations ($\mu g/m^3$) for the baseline scenario at the Arnot Power Station***

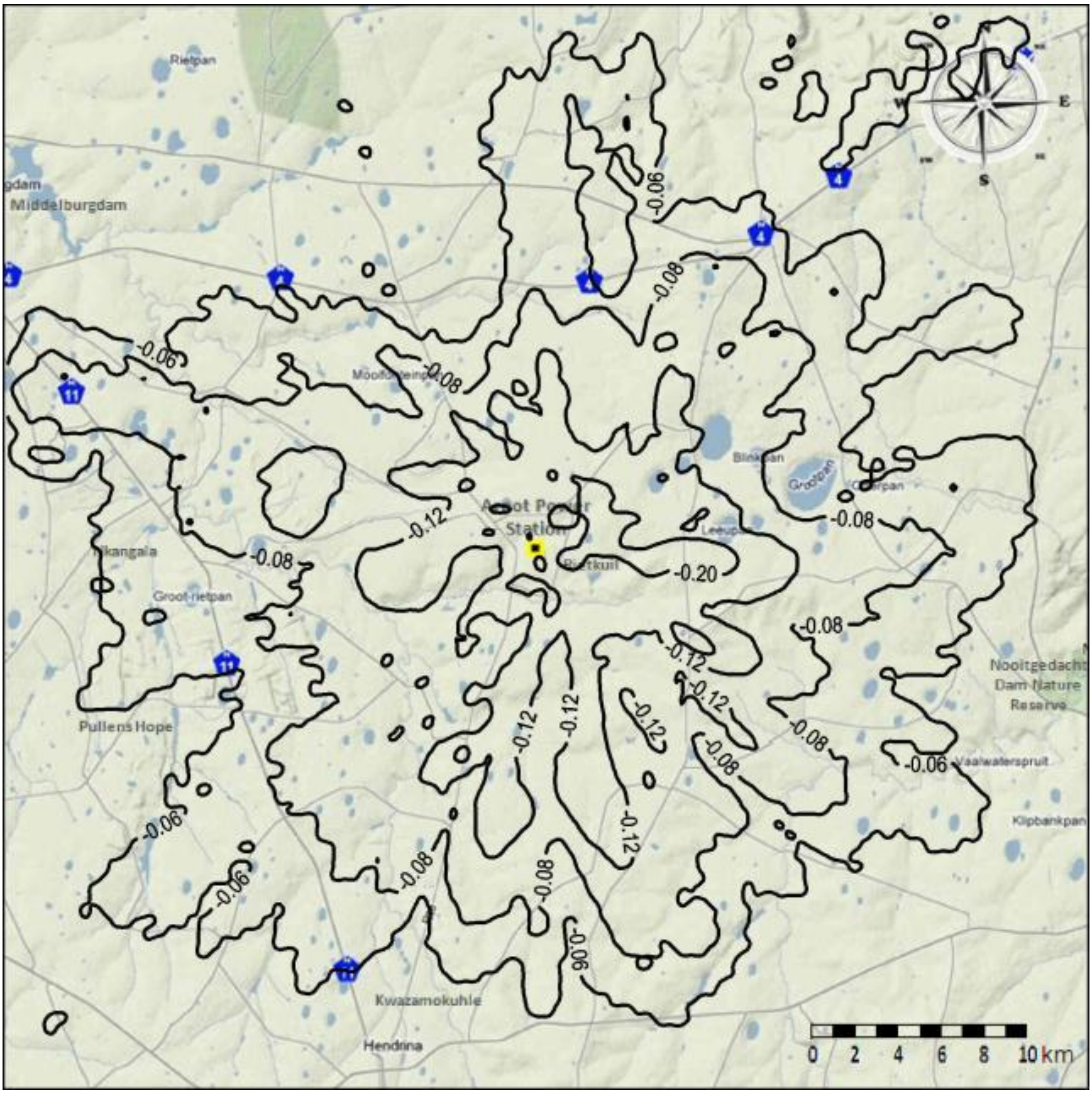


***Figure 7.4: Percentage difference in predicted 24-hour $PM_{10}$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass) at the Arnot Power Station***

**Dust deposition**

The South African target, action and alert thresholds for ambient dust deposition are presented in Tables 5.6 and 5.7.

***30-day average***

Predicted 30-day dust deposition rates for the baseline scenario and the co-firing option scenario at the Arnot Power Station are well below the South African action residential limit for all scenarios and no exceedances of the dust limit is predicted within the Arnot Power Station site or in residential areas around the site.

The highest predicted dust deposition for the baseline scenario is 0.077 μg/m$^3$. The co-firing option scenario results in slightly lower emissions. This brings about a slight decrease in the predicted 24-hour maximum concentration to 0.76 μg/m$^3$. Both maxima occur ~12 km to the west-northwest of the Arnot Power Station.

Deposition rates decrease by 1.85-1.87% throughout the study area. This demonstrates that the predicted dust deposition rates will decrease slightly over the current baseline concentrations for biomass co-firing, but it is unlikely that the difference will be measureable.

### *7.3.2 Oxides of nitrogen ($NO_x$)*

Predicted $NO_x$ concentrations are compared with the ambient $NO_2$ standard. Since not all NO converts to $NO_2$, this approach is conservative and should be recognised when comparison is made against national ambient air quality standards (Table 5.3).

***Annual average***

Predicted annual average $NO_x$ concentrations for the baseline scenario (Figure 7.5) and the co-firing option scenario at the Arnot Power Station are well below the national ambient $NO_2$ standard of 40 μg/m$^3$. No exceedances of the standard are predicted within the site or in residential areas around the site for both scenarios.

For the cumulative situation, the highest predicted annual $NO_x$ concentration for the baseline scenario is 19.7 μg/m$^3$. The co-firing option scenario results in slightly lower emissions. This brings about a slight decrease in the predicted annual maximum concentration of 19.6 μg/m$^3$. Both maxima occur ~2 km to the east-northeast of the Arnot Power Station.

Figure 7.6 shows the difference between maximum modelled ambient concentration between the co-firing and baseline emission scenario. Ambient concentrations decrease marginally throughout most of the study area, and the greatest decrease of 0.15% occurs over a small area to the east-northeast of the site. This demonstrates that the predicted $NO_x$ concentrations will decrease slightly over the current baseline concentrations for biomass co-firing, but it is unlikely that the difference will be measureable.

***1-hour maximum concentrations***

The predicted maximum 1-hour ambient $NO_x$ concentrations for the baseline (Figure 7.7) and co-firing option scenario indicate that the 1-hour limit value of 200 µg/m$^3$ is exceeded over the Arnot Power Station site, and over an extensive area surrounding the plant. Residential areas where exceedances occur include Rietkuil and parts of Pullens Hope.

For the cumulative situation, the highest predicted annual $NO_x$ concentration for the baseline scenario is 1 366 µg/m$^3$. The co-firing option scenario results in slightly lower emissions which, in turn, brings about a slight decrease in the predicted annual maximum concentration to 1 356 µg/m$^3$. Both maxima occur ~2 km to the north-northeast of the Arnot Power Station.

The national ambient standard permits 88 exceedances of the 1-hour limit value per annum, implying 264 permitted exceedances in the three-year modelling period. A maximum of 53, 54 and 39 exceedances are predicted in the three years modelled, with a maximum of 146 exceedances predicted in the three-year modelling period (Figure 7.8). Therefore the predicted 1-hour $NO_x$ concentrations comply with the national ambient $NO_2$ standard in the ambient environment, in individual years and for the 3-year modelling period. The highest number of exceedances are always predicted to occur ~2.5 km to the east of the Arnot Power Station. No exceedances of the permitted tolerance are predicted at Arnot Power Station or in residential areas around the site.

Figure 7.9 shows the difference between maximum modelled ambient concentration between the co-firing and the baseline scenario. Ambient concentrations decrease by 0.46-0.68% throughout most of the study area. The greatest decrease of 0.69% occurs over a small area, ~3 km to the north-northeast of the site. This demonstrates that the predicted $NO_x$ concentrations will decrease from the current baseline concentrations.

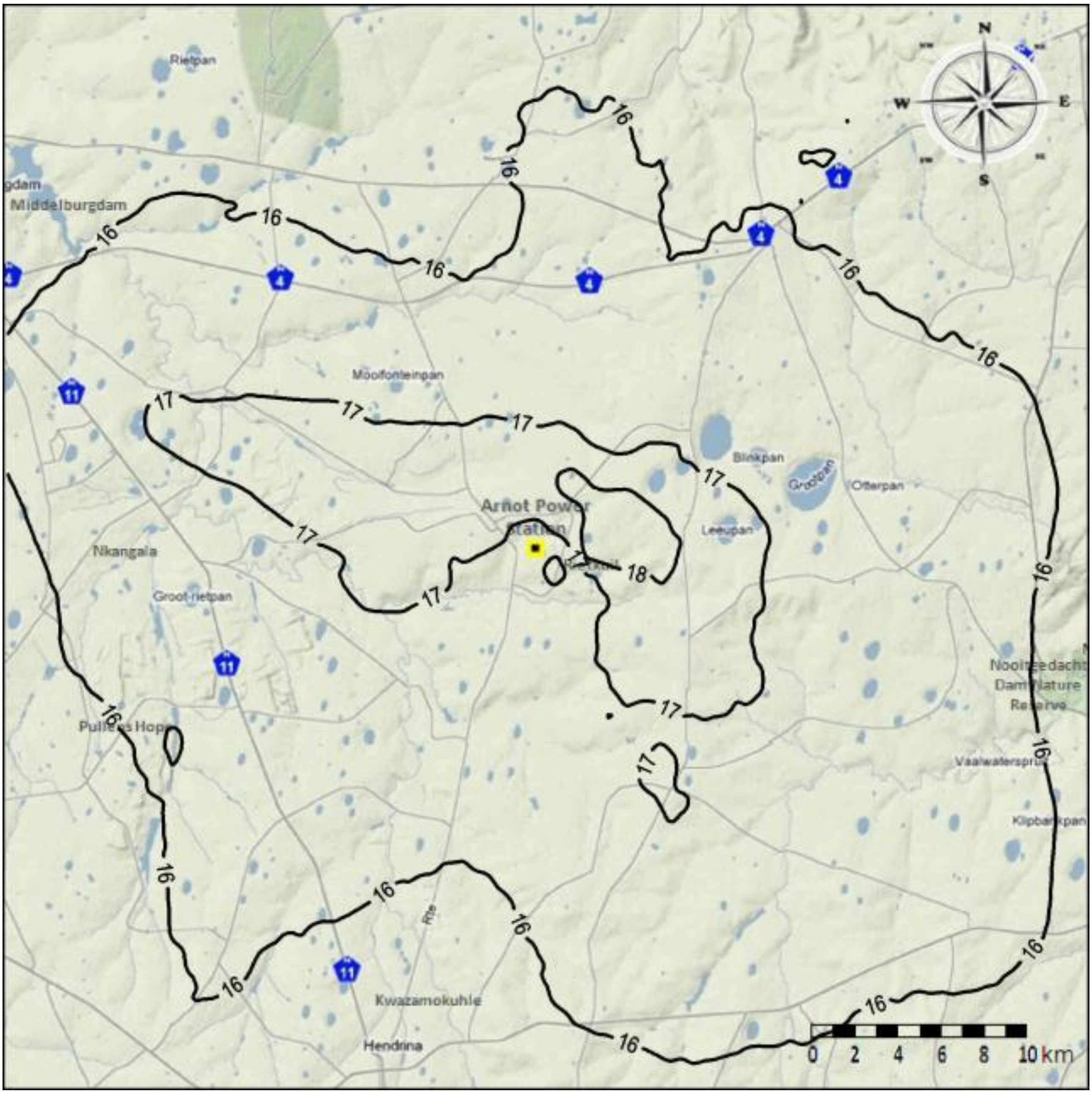


***Figure 7.5: Predicted annual average $NO_x$ concentrations ($\mu g/m^3$) for the baseline scenario at the Arnot Power Station***

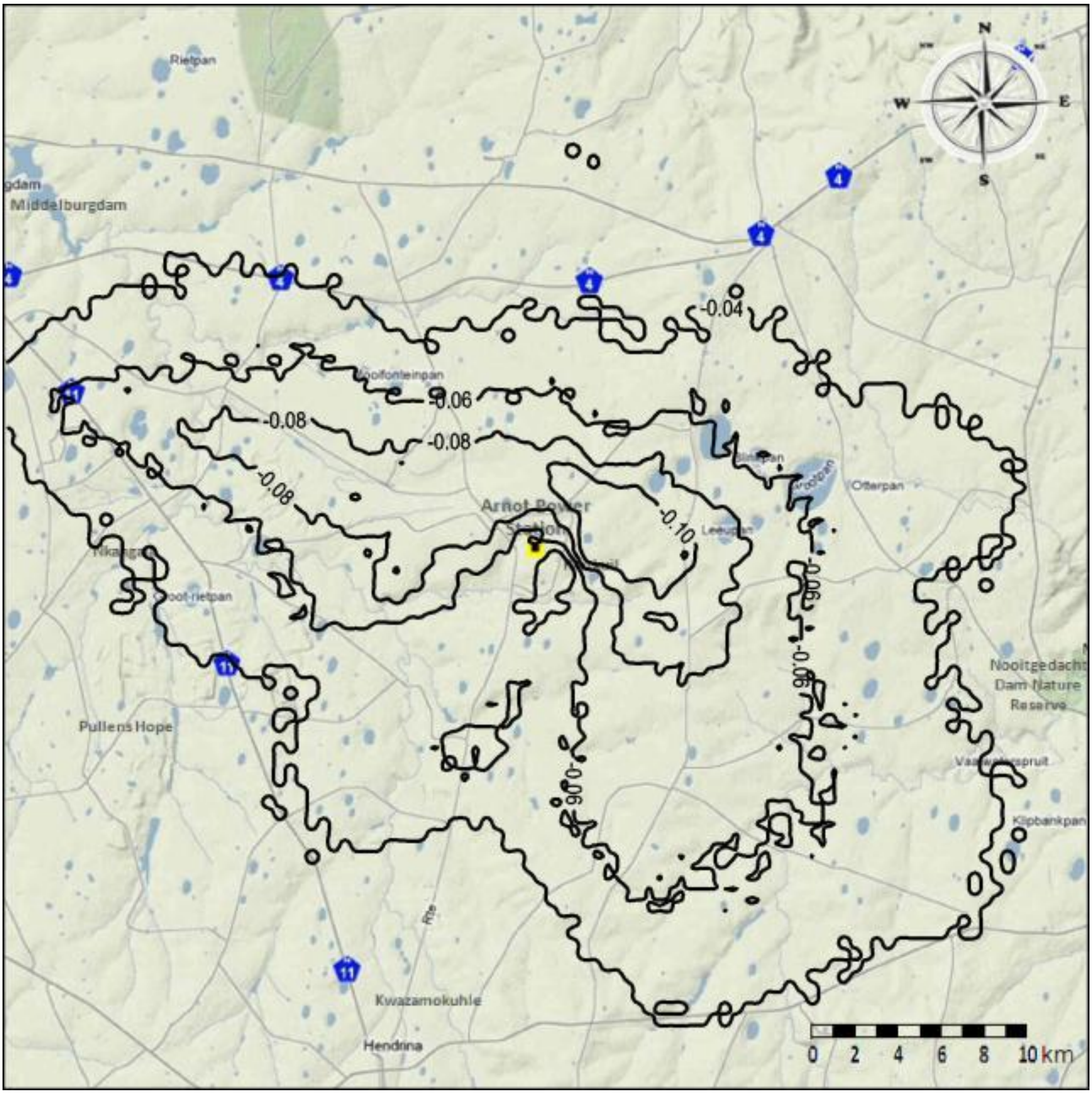


***Figure 7.6:* Percentage difference in predicted annual average $NO_x$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass with wood) at the Arnot Power Station**

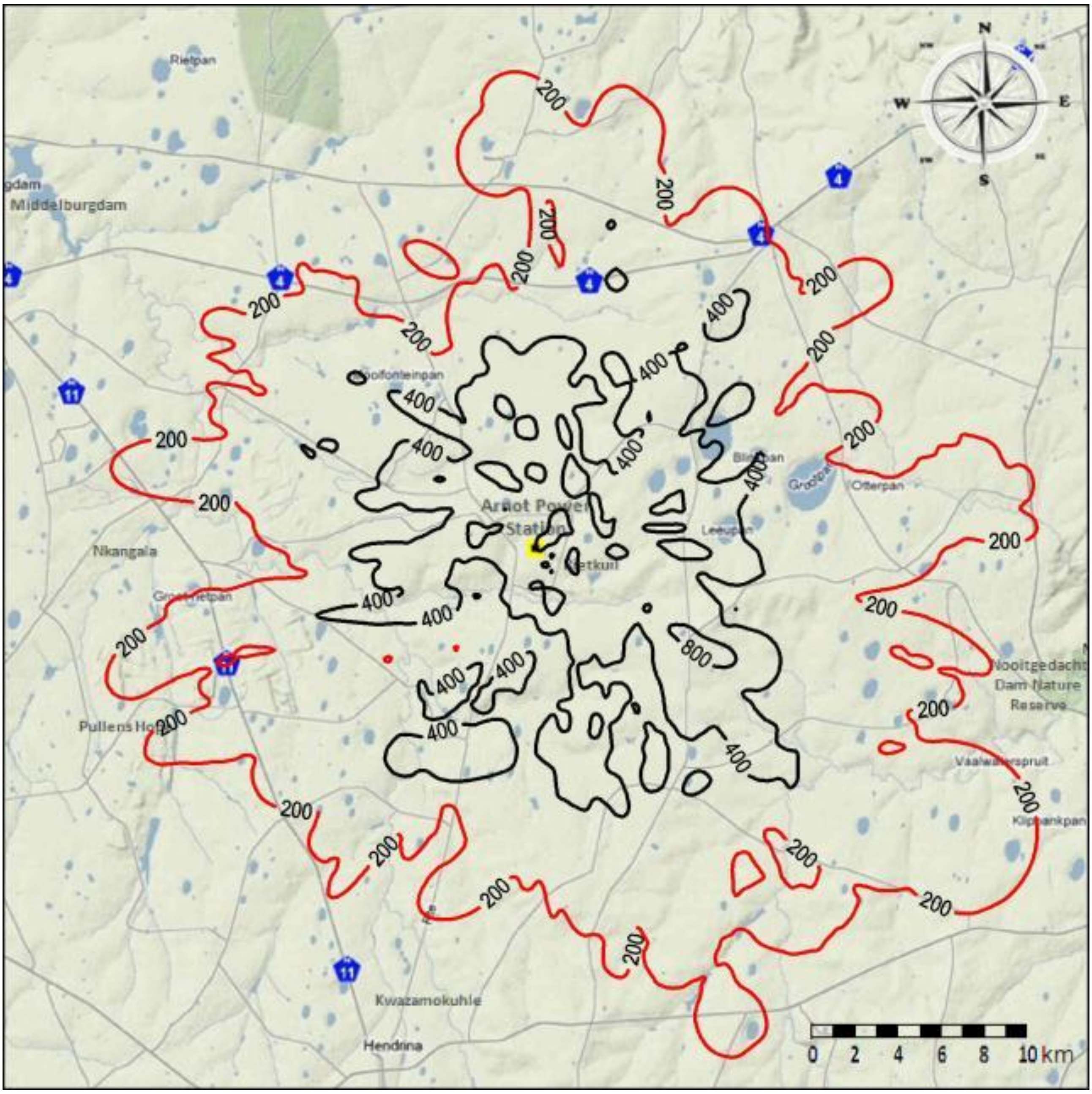


***Figure 7.7: Predicted maximum 1-hour $NO_x$ concentrations (µg/m$^3$) for the baseline scenario at the Arnot Power Station. Red indicates the current ambient standard***

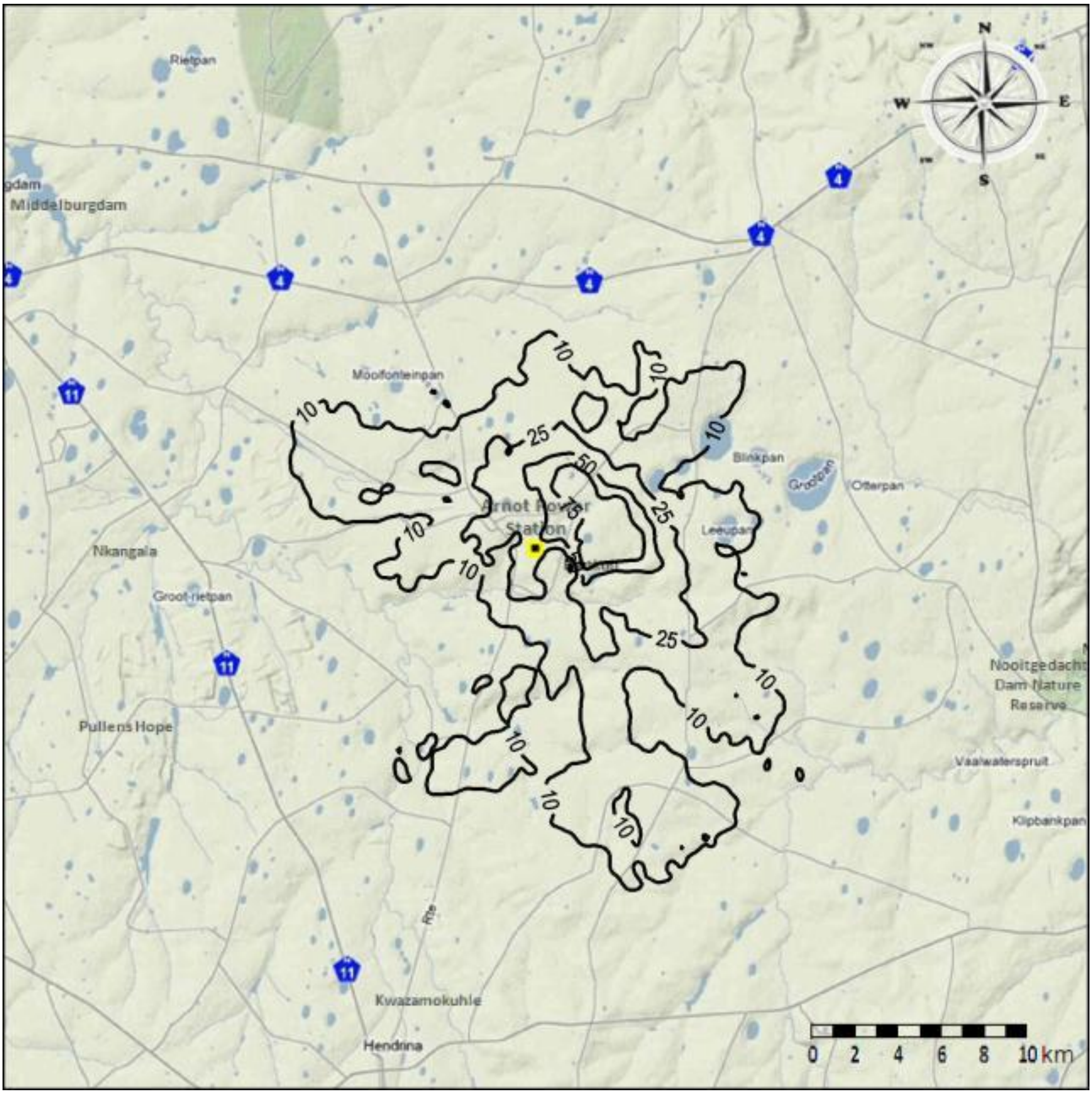


***Figure 7.8: Predicted frequency of exceedance of the ambient 1-hour $NO_2$ standard for the baseline scenario at the Arnot Power Station***

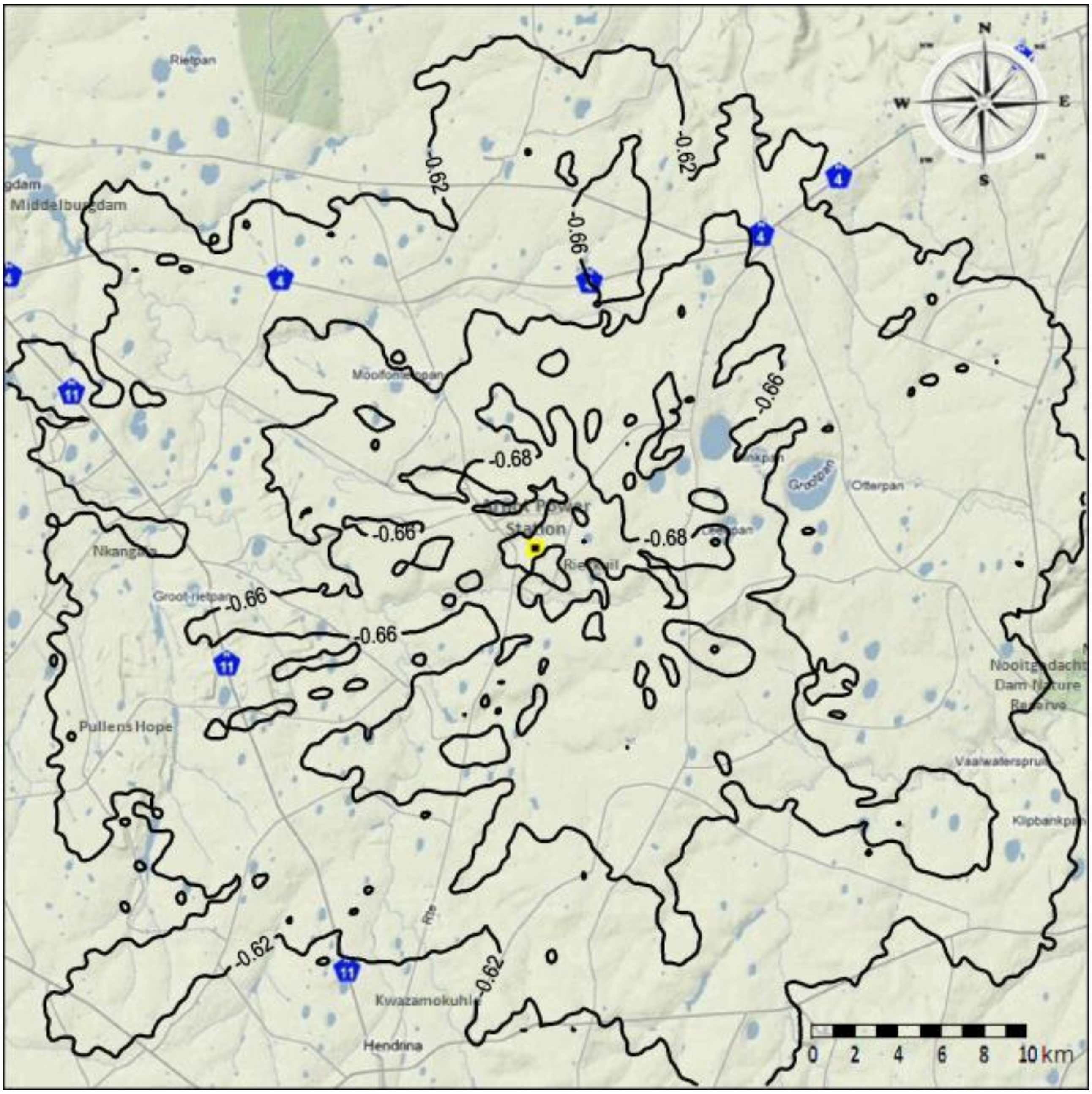


***Figure 7.9: Percentage difference in the predicted 1-hour $NO_x$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass) at the Arnot Power Station***

### *7.3.3. Sulphur dioxide ($SO_2$)*

Predicted ambient $SO_2$ concentrations resulting from the baseline and co-firing option emission sources at the Arnot Power Station are compared with the national ambient annual, 24-hour and 1-hour $SO_2$ standards (Table 5.2).

#### *Annual average*

Predicted annual average $SO_2$ concentrations for the baseline scenario (Figure 7.10) and the co-firing option scenario at the Arnot Power Station are well below the national ambient $SO_2$ standard of 50 μg/$m^3$. No exceedances of the standard are predicted within the site or in residential areas around the site for both scenarios.

For the cumulative situation, the highest predicted annual $SO_2$ concentration for the baseline scenario is 20.4 μg/$m^3$. The co-firing option results in slightly lower emissions which brings about a slight decrease in the predicted annual maximum concentration to 20.2 μg/$m^3$. Both maxima occur ~2 km to the east-northeast of the Arnot Power Station.

Figure 7.11 shows the difference between maximum modelled ambient concentration between the co-firing and baseline emission scenario. Ambient concentrations decrease by 0.1-0.4% throughout most of the study area, but the greatest decrease of 0.5-0.6% occurs over a small area to the east-northeast of the site. This demonstrates that the predicted ambient air quality will be slightly better than current baseline concentrations.

#### *24-hour maximum concentrations*

For the cumulative situation, the predicted maximum 24-hour ambient $SO_2$ concentrations for the baseline (Figure 7.12) and co-firing option scenario indicate that the 24-hour limit value of 125 μg/$m^3$ is exceeded over a few areas around the plant. Exceedances occur up to ~3 km to the north and northeast of the plant, ~8 km to the east and east-southeast of the site, and ~2 km to the south of the site. Exceedances also occur in relatively small areas, ~8 km east-southeast from the site and ~9 km south-southwest from the site. Rietkuil is the only residential area where exceedances are likely to occur. The highest predicted annual $SO_2$ concentration for the baseline scenario is 208 μg/$m^3$. The co-firing option scenario results in slightly lower emissions. This brings about a slight decrease in the predicted annual maximum concentration to 205 μg/$m^3$. Both maxima occur ~2 km to the northeast of the Arnot Power Station.

The national ambient standard permits 4 exceedances of the 24-hour limit value per annum, implying 12 permitted exceedances in the three-year modelling period. A maximum of 2, 1 and 2 exceedances are predicted in 2004, 2005 and 2006 respectively; and a maximum of 5 exceedances are predicted in the three-year modelling period (Figure 7.13). Therefore the predicted 24-hour $SO_2$ concentrations comply with the national ambient $SO_2$ standard in the ambient environment, in individual years and for the 3-year modelling period. The highest number of exceedances are always predicted to occur ~1.5 km to the east-northeast of the

Arnot Power Station. No exceedances of the permitted tolerance are predicted at the Arnot Power Station or in residential areas around the site.

Figure 7.14 shows the difference between maximum modelled ambient concentration between the co-firing and baseline emission scenario. Ambient concentrations decrease by 0.9-1.5% throughout most of the study area, but the greatest decrease of 1.6% occurs over a small area, ~2 km to the northeast of the site. This demonstrates that the predicted ambient air quality will be slightly better than current baseline concentrations.

***1-hour maximum concentrations***

The predicted maximum 1-hour ambient $SO_2$ concentrations for the current (Figure 7.15) and co-firing option scenario indicate that the 1-hour limit value of 350 µg/m$^3$ is exceeded over an extensive area around the plant. Residential areas where exceedances occur include Rietkuil and parts of Pullens Hope.

For the cumulative situation, the highest predicted 1-hour $SO_2$ concentration for the baseline scenario is 2187 µg/m$^3$. The co-firing option scenario results in slightly lower emissions. This brings about a slight decrease in the predicted annual maximum concentration to 2150 µg/m$^3$. Both maxima occur ~2 km to the north-northeast of the Arnot Power Station.

The national ambient standard permits 88 exceedances of the 1-hour limit value per annum, implying 264 permitted exceedances in the three-year modelling period. A maximum of 42, 48 and 27 exceedances are predicted in 2004, 2005 and 2006 respectively; and a maximum of 117 exceedances are predicted in the three-year modelling period (Figure 7.16). Therefore the predicted 1-hour $SO_x$ concentrations comply with the national ambient standard in the ambient environment, in individual years and for the 3-year modelling period. The highest number of exceedances are always predicted to occur ~2 km to the east-northeast of the Arnot Power Station. No exceedances of the permitted tolerance are predicted at the Arnot Power Station or in residential areas around the site.

Figure 7.17 shows the difference between maximum modelled ambient concentration between the co-firing and baseline emission scenario. Ambient concentrations decrease by 1.5-1.6% throughout most of the study area, but the greatest decrease of 1.7% occurs over a relatively large area, generally within a 10 km radius around the plant. This demonstrates that the predicted ambient air quality will be slightly better than current baseline concentrations.

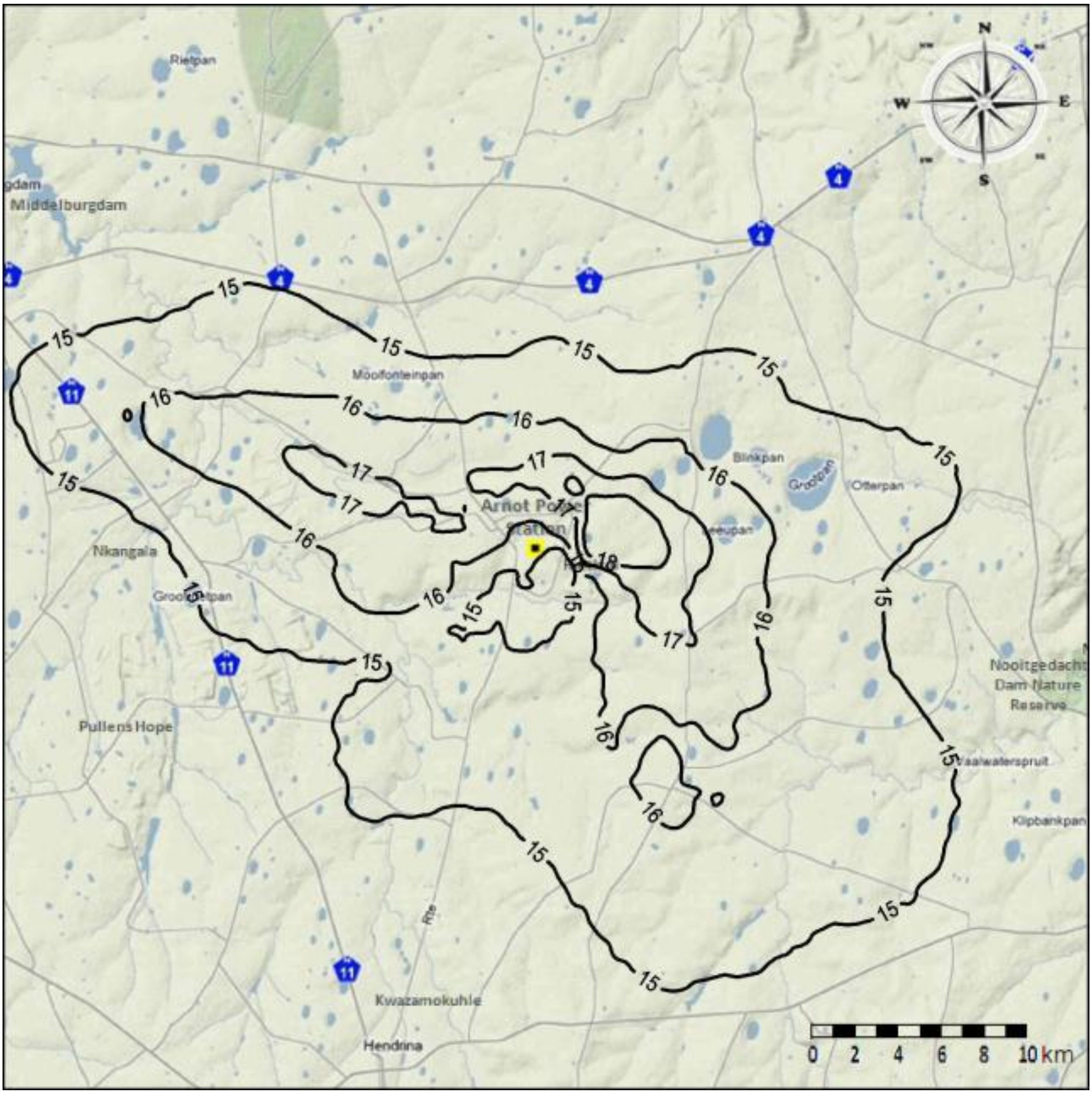


***Figure 7.10: Predicted annual average $SO_2$ concentrations (µg/m$^3$) for the baseline scenario at the Arnot Power Station***

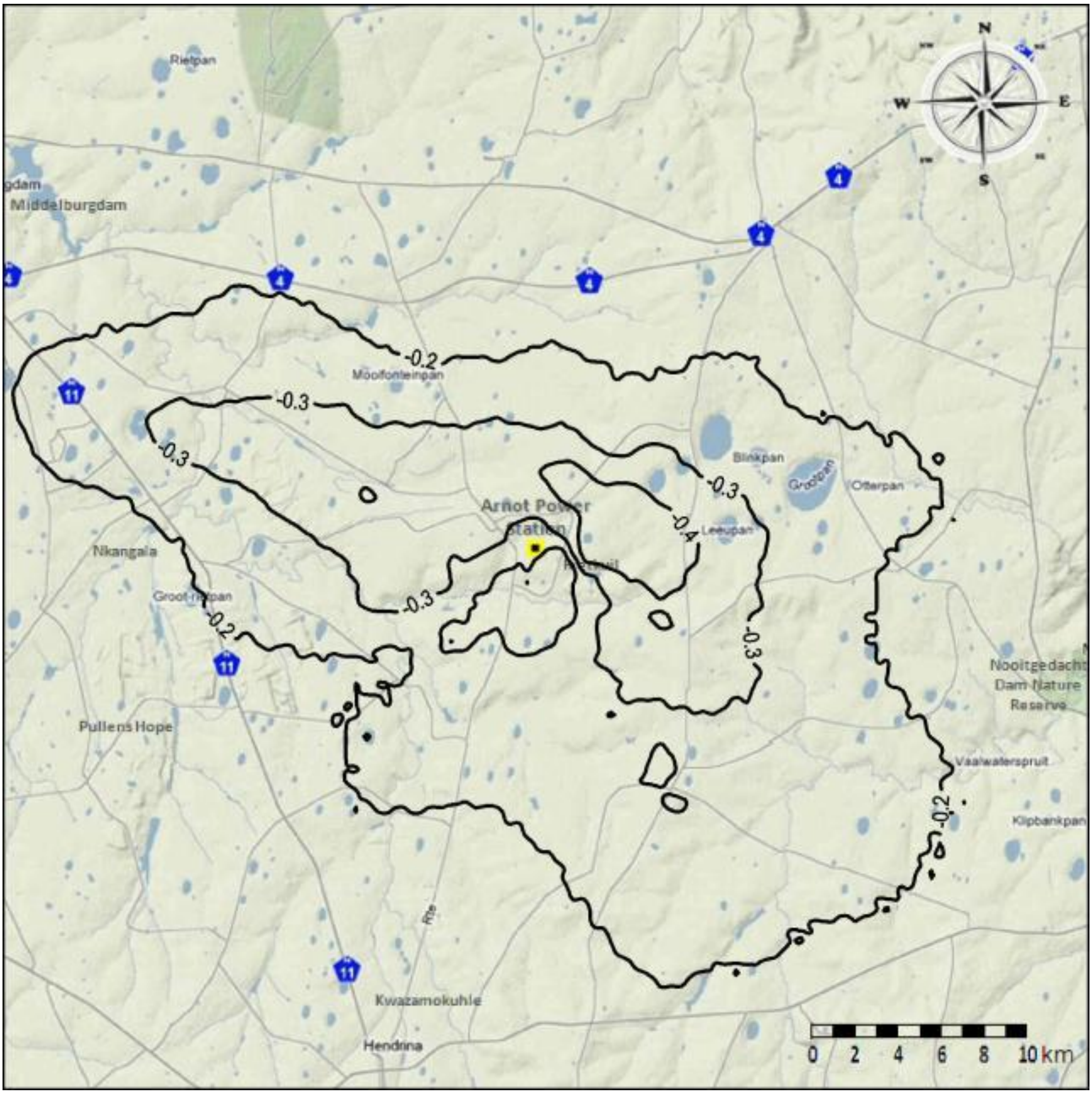


***Figure 7.11: Percentage difference in predicted annual average $SO_2$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass) at the Arnot Power Station***

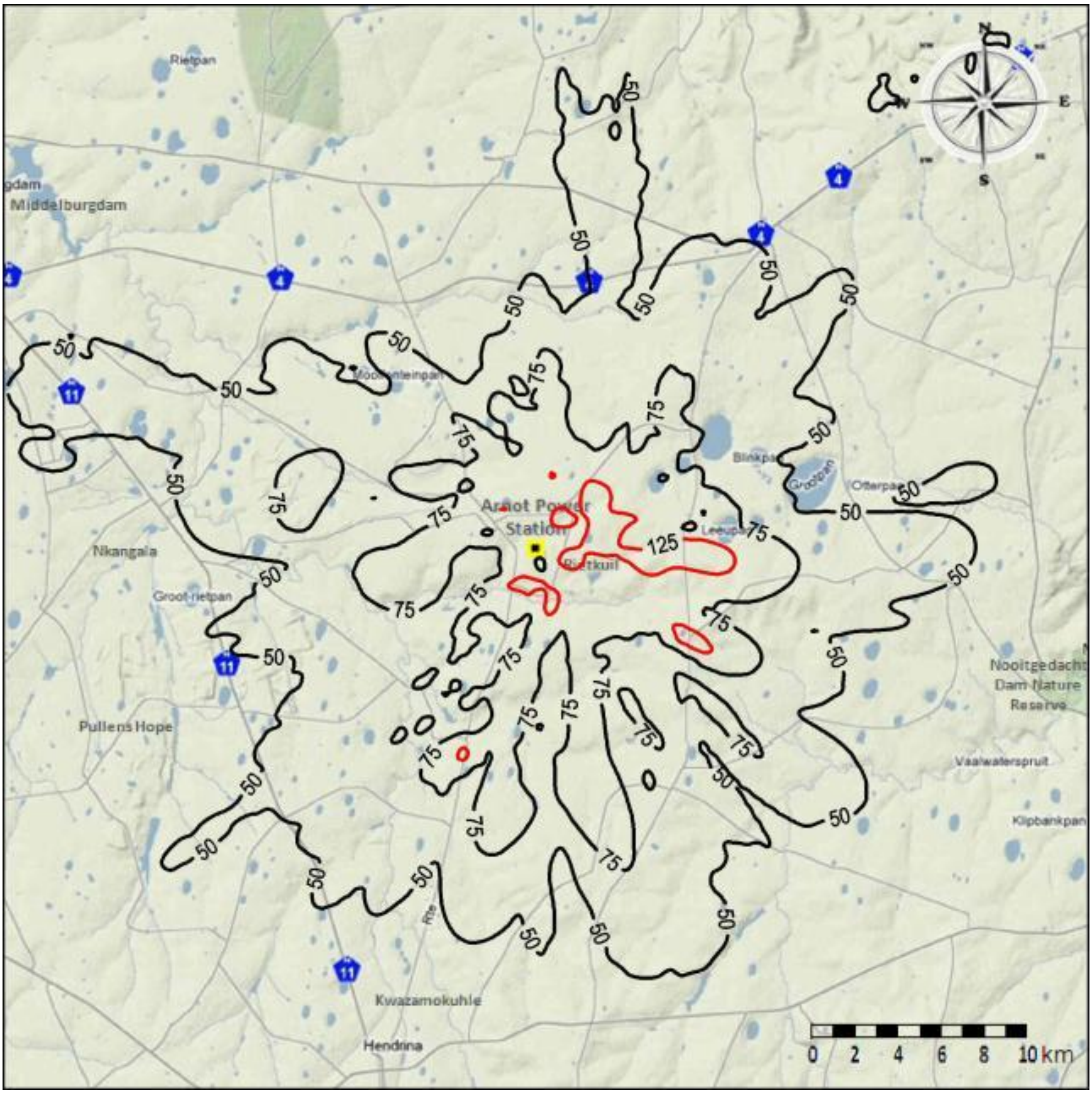


***Figure 7.12: Predicted 24-hour $SO_2$ concentrations ($\mu g/m^3$) for the baseline scenario at the Arnot Power Station. Red indicates the current ambient standard***

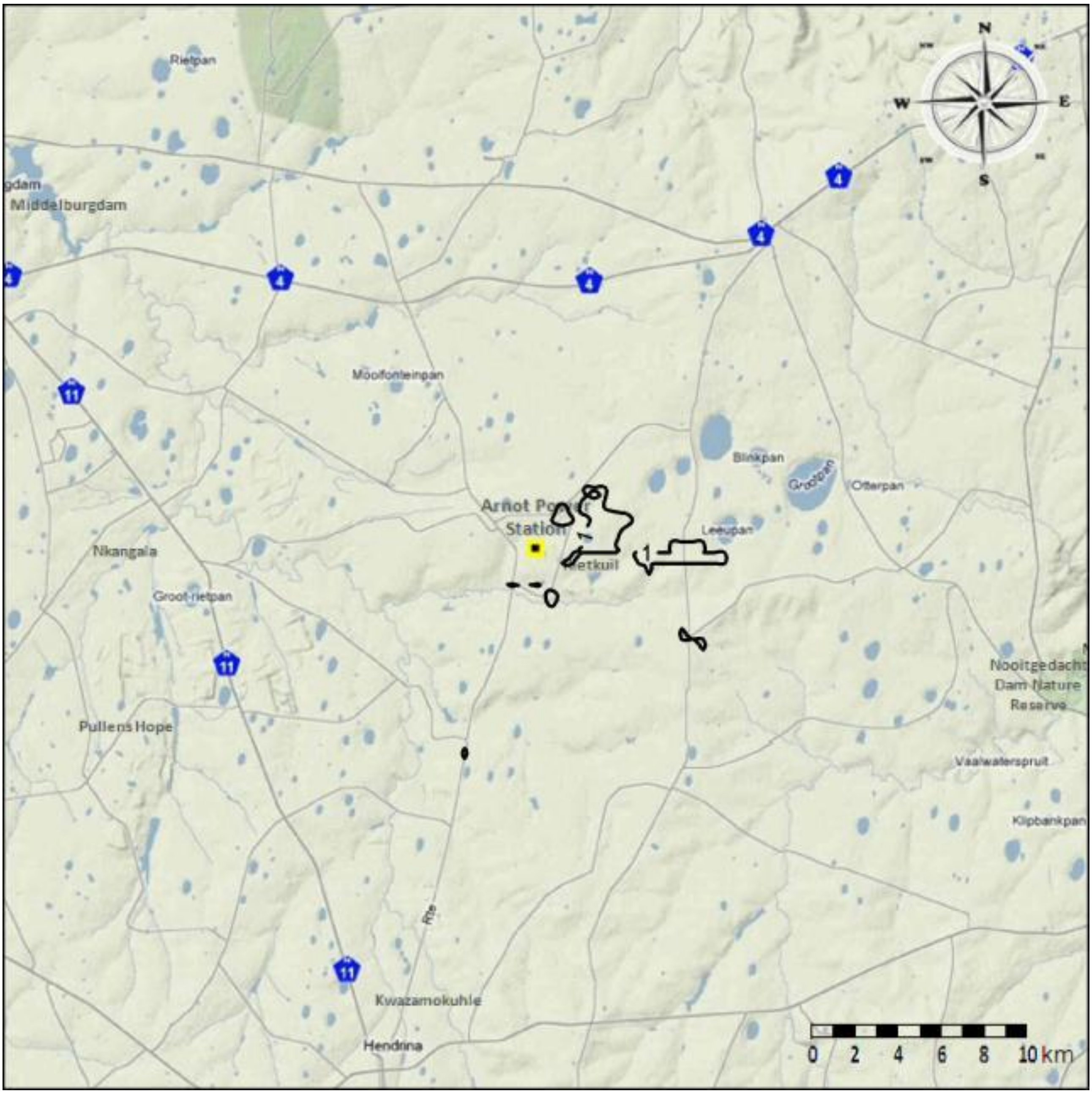


***Figure 7.13: Predicted frequency of exceedance of the maximum 24-hour $SO_2$ concentrations for the baseline scenario at the Arnot Power Station***

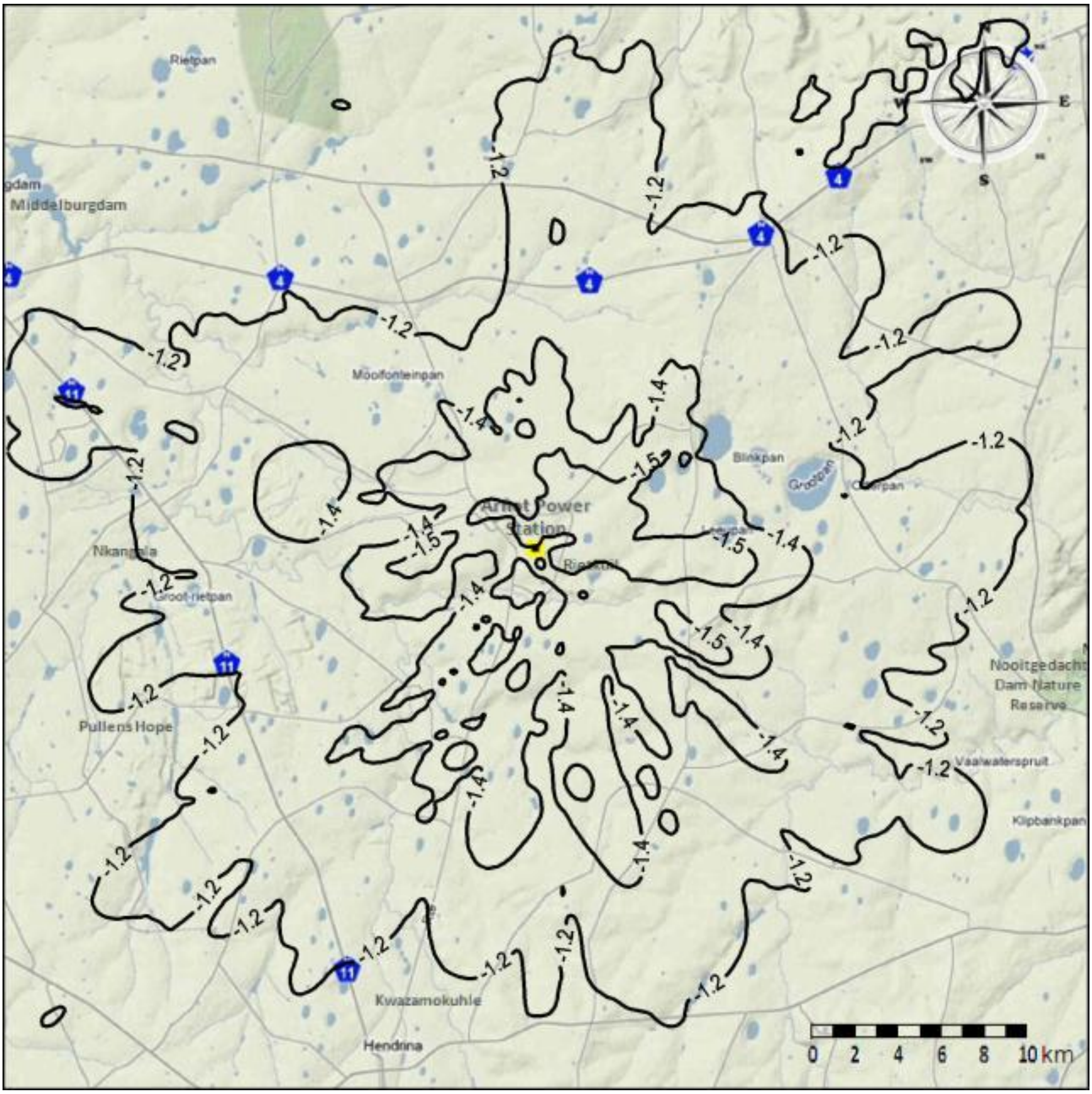


***Figure 7.14: Percentage difference in the predicted 24-hour $SO_2$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass) at the Arnot Power Station***

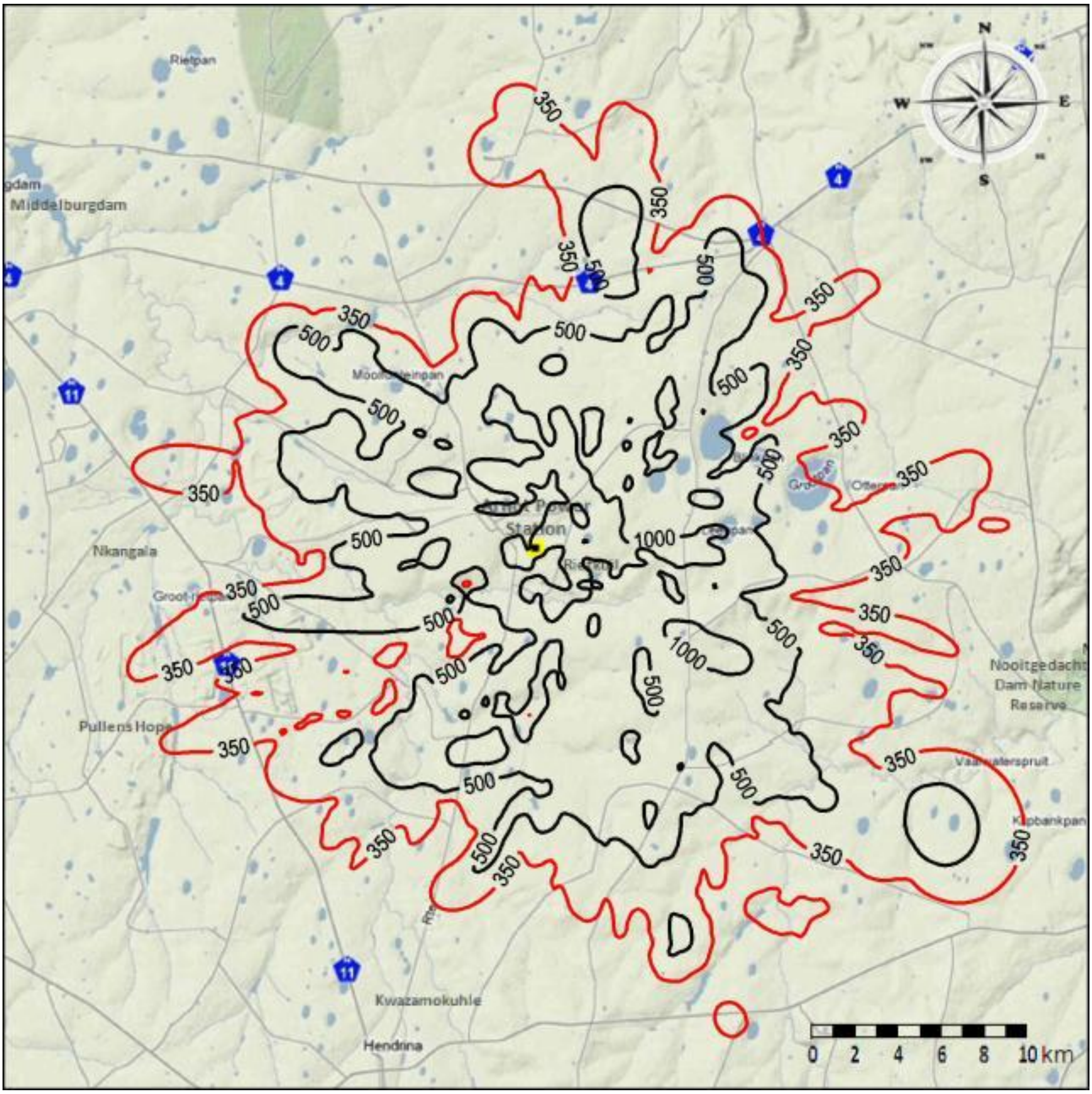


***Figure 7.15: Predicted 1-hour $SO_2$ concentrations ($\mu g/m^3$) for the baseline scenario at the Arnot Power Station. Red indicates the current ambient standard***

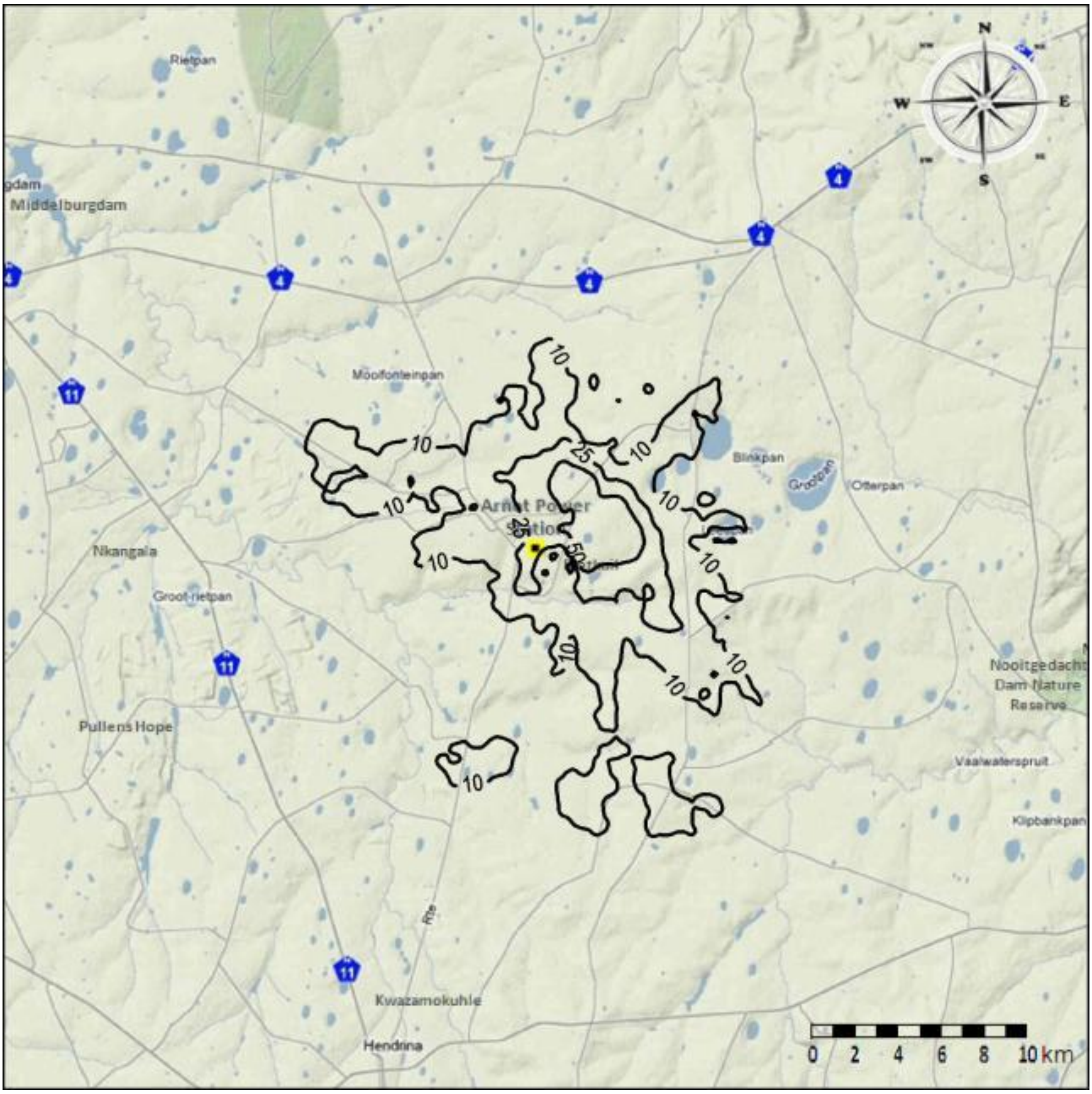


***Figure 7.16: Predicted frequency of exceedance of the maximum 1-hour $SO_2$ concentrations for the baseline scenario at the Arnot Power Station***

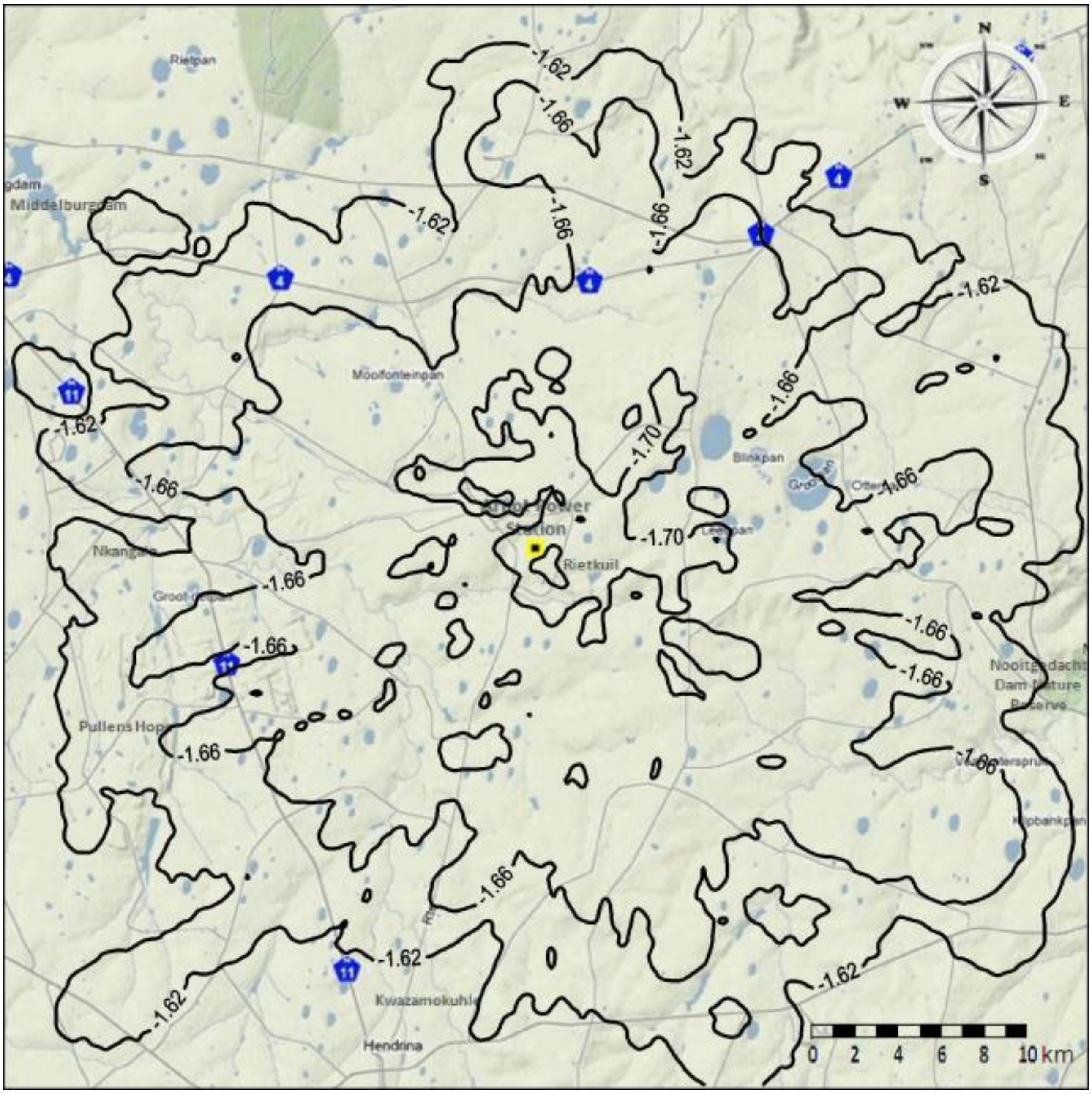


***Figure 7.17: Percentage difference in the predicted 1-hour $SO_2$ concentrations between the baseline and co-firing option scenario (replacement of 10% coal by mass for one unit) at the Arnot Power Station***

### *7.4 Greenhouse gases*

The relative difference in $CO_2$ emissions between the coal only and the coal and wood biomass mix is assessed by evaluating the carbon content of both fuels as the $CO_2$ emission rates are directly proportional to the carbon content in the fuel.

The carbon content of wood (45 to 50%) is less than that for coal (58.48%). The baseline emission rate of $CO_2$ is estimated to be 1,140,980,771 kg/month (37,511 ton/day) as a result of a total coal consumption of 6 525 670 tons per annum. However, in contrast to the other pollutants, the $CO_2$ emission rates are expected to increase by 0.08% for 10% biomass substitution in one unit only and by 0.12% for 5% biomass substitution in each of three units. The $CO_2$ emission rates will increase by 31 ton/day and 48 ton/day for the two substitution rates respectively. The reason for the increase is twofold:

- The variance between the carbon contents of coal and wood is not large.
- The quantity of coal earmarked for replacement by wood for the two future scenarios is not large.

The biomass co-firing option in one unit will however reduce Arnot Power Station's reliance on fossil fuel (coal) by 10% as biomass is a renewable source of energy.

## 8. IMPACT ASSESSMENT

Impacts can generally be categorised as direct, indirect or cumulative. *Direct impacts* are impacts that are caused directly by the project/activity in isolation of other sources and generally occur at the same time and place of the activity. Indirect impacts are indirect or induced changes that may occur as a result of the activity. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or which occur at a different place as a result of the activity. *Cumulative impacts* are impacts that result from the incremental impact of the proposed activity on a common resource when added to the impacts of other past, present or reasonably foreseeable future activities.

For this study, direct impacts will result from the inhalation of $NO_2$, $SO_2$ and particulates ($PM_{10}$) emitted during the operational life of the Arnot Power Station. Direct impacts will also result from exposure to dust generated from the coal stockpiles; and from the construction of structures for the co-firing option and decommissioning activities. Indirect impacts resulting from emissions of $SO_2$ and $NO_x$ from coal-fired power plants include their contribution to acifidification in both dry and wet (acid rain) deposition. Further indirect effects are associated emissions of CO and $CO_2$. $CO_2$ is a GHG, adding to the global concentrations. CO is not considered a GHG, but is a strong precursor in the formation of ozone in the troposphere. The global warming potential of tropospheric ozone is equivalent to between 918-1022 tons of $CO_2$.

The Arnot Power Station is surrounded by agricultural land with a number of mining activities; and heavy industry some distance away. With respect to cumulative impacts, mining and agricultural activities, tailings dams and domestic fuel burning in the area are identified as existing sources of dust. There will thus be a cumulative impact with dust generated during construction of structures for the co-firing option and decommissioning of the Arnot Power Station.

The Arnot Power Station is located in an area where there are no notable sources of particulates, $NO_x$ and $SO_2$ in the immediate vicinity of the site (within a 5 km radius), and a source of dust and $PM_{10}$ at the nearby ash dump. Ferro-metal industries are located in Middelburg, ~35 km to the northwest domain. The Mafube Colliery is located ~15 km to the north-northwest. Motor vehicle traffic on the N4 and surrounding roads will have some influence on ambient air quality as will domestic fuel burning. The Hendrina Power Station is located ~20 km west-southwest of the Arnot Power Station and is an important source of $NO_2$, $SO_2$ and $PM_{10}$ at that locality. It is therefore expected that there will be compounding of effects and hence cumulative impacts during operation of the Arnot Power Station using coal and biomass co-firing. Background concentrations have therefore been added to model predictions for the baseline and biomass co-firing scenarios to assess the relative impacts of biomass co-firing .

***Extent of Impacts***

The extent of impacts are assessed in accordance with the following scoring criteria:
0 – No effect
1 - Limited to the site and its immediate surroundings
2 - Local/municipal extending only as far as the local community or urban area
3 - Provincial/regional
4 - National i.e. South Africa
5 - Across international borders

| PHASE | EXTENT OF IMPACTS | | | IMPACT OF BIOMASS CO-FIRING |
|---|---|---|---|---|
| | **DIRECT** | **INDIRECT** | **CUMULATIVE** | |
| Construction and decommissioning | 1 | 0 | 1 | **NEGATIVE** |
| Operation – baseline | 2 | 5 | 2 | - |
| Operation – co-firing option | 2 | 5 | 2 | **POSITIVE** |

Construction and decommissioning activities will result in the emission of low quantities of terrestrial and construction dust, not expected to pose a health. Furthermore, dust emissions will not travel over vast distances, but will most likely settle within 100 m to 1 km of the Arnot Power Station. A temporary nuisance impact may be experienced in parts of Rietkuil, only 500 m away. The extent of direct and cumulative dust impacts are also considered to be limited to the site and its immediate surroundings and of a nuisance nature only.

For the operational scenarios, the extent of direct impacts resulting from $SO_2$, $NO_x$ and $PM_{10}$ are limited to the local/municipal area extending only as far as the local community or urban area. For the cumulative effect, from the concentration plots in Section 7, it is clear that the short term 1-hour limit values for $NO_x$ and $SO_2$ and 24-hour limit value for $SO_2$ are exceeded over an extensive area around the Arnot Power Station. However, no exceedances of the permitted tolerance for the number of exceedances are predicted at the Arnot Power Station or anywhere in areas around the site. Therefore the predicted concentrations comply with the national ambient standard in the ambient environment. The predicted concentrations of $NO_x$, $SO_2$ and $PM_{10}$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is therefore expected to have a positive impact on air quality.

The extent of indirect impacts associated with the two operational scenarios relate to acidification and global warming. These are regional and global scale issues respectively.

***Duration of Impacts***

The duration of impacts are assessed in accordance with the following scoring criteria:
0 – None (impact will not occur)
1 - Immediate (less than 1 year)
2 - Short term (1-5 years)
3 - Medium term (6-15 years)
4 - Long term (the impact will cease after the operational life span of the project)
5 - Permanent (no mitigation measures of natural process will reduce the impact after construction)

| PHASE | DURATION OF IMPACTS | | | IMPACT OF BIOMASS CO-FIRING |
|---|---|---|---|---|
| | DIRECT | | CUMULATIVE | |
| Construction and decommissioning | 1 | **NEGATIVE** | 1 | **NEGATIVE** |
| Operation – baseline | 4 | | 4 | - |
| Operation – co-firing option | 4 | **POSITIVE** | 4 | **POSITIVE** |

Construction and decommissioning impacts will last for a short period as these activities occur for the duration of these activities only. Direct and cumulative impacts from construction and decommissioning are therefore expected to have an immediate duration.

Impacts from operation will however last for the full period of operation of the Arnot Power Station. The duration of direct, indirect and cumulative impacts from operation are therefore expected to be long-term. The predicted concentrations of $NO_x$, $SO_2$ and $PM_{10}$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is therefore expected to have a positive impact on air quality.

***Magnitude of Impacts***

The magnitude of impacts may be assessed in accordance with the following scoring criteria:
0 - None (where the aspect will have no impact on the environment)
2 - Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
4 - Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),

6 - Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
8 - High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
10 - Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

| **PHASE** | **MAGNITUDE OF IMPACTS** | | | **IMPACT OF BIOMASS CO-FIRING** |
|---|---|---|---|---|
| | **DIRECT** | **INDIRECT** | **CUMULATIVE** | |
| Construction and decommissioning | 4 | 0 | 6 | **NEGATIVE** |
| Operation – baseline | 4 | 4 | 6 | - |
| Operation – co-firing option | 4 | 4 | 6 | **POSITIVE** |

The magnitude of impacts provides an indication of how serious the impacts are. From an air quality perspective, this relates to the potential health impacts to humans through exposure to ambient concentrations that exceed the standard set for the protection of human health.

No direct health impacts are expected from dust generated during construction activities to accommodate the co-firing option and decommissioning of the Arnot Power Station. There may be temporary nuisance impact through dust deposition in Rietkuil during these periods. As a result, the magnitude of these impacts is considered to be low. Cumulative impacts may result from the dust combining with that from other sources such as the mining and agricultural activities, tailings dams and domestic fuel burning in the area. The cumulative impact of dust emissions is therefore considered to be moderate.

The predicted ambient concentrations of $SO_2$, $NO_x$ and $PM_{10}$ resulting from these pollutants being emitted during the two operational scenarios of the Arnot Power Station are well below health-based air quality standards for direct and cumulative situations. The overall magnitude of direct impacts during operation is therefore considered to be low for both. For the cumulative impacts, emissions from Arnot Power Station increase the existing ambient concentrations of all pollutants in the immediate vicinity and the surround areas. The overall magnitude of cumulative impacts during operation is therefore considered to be moderate for both operational scenarios. The predicted concentrations of $NO_x$, $SO_2$ and $PM_{10}$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is therefore expected to have a positive impact on air quality.

The magnitude of indirect impacts associated with the two operational scenarios relates to the relative contribution to acidification and global warming. Quantification of the relative contribution of Arnot Power Station is difficult, but it is considered to be relatively small in the national and global context, and somewhat less for the co-fired option. The magnitude of the indirect impacts is anticipated to be low for both scenarios.

***Probability of Impacts***

The probability of impacts are assessed in accordance with the following scoring criteria:
0 - None (impact will not occur)
1 - Improbable (the possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures)
2 - Low probability (there is a possibility that the impact will occur)
3 - Medium probability (the impact may occur)
4 - High probability (it is most likely that the impact will occur)
5 - Definite / do not know (the impact will occur regardless of the implementation of any prevention or corrective actions or it the specialist does not know what the probability will be based on too little published information)

| **PHASE** | **PROBABILITY OF IMPACTS** | | | **IMPACT OF BIOMASS CO-FIRING** |
|---|---|---|---|---|
| | **DIRECT** | **INDIRECT** | **CUMULATIVE** | |
| Construction and decommissioning | 3 | 0 | 3 | **NEGATIVE** |
| Operation – baseline | 4 | 4 | 4 | - |
| Operation – co-firing option | 4 | 4 | 4 | **POSITIVE** |

The probability of direct impacts are considered to be medium for construction and decommissioning. Dust emissions from construction and decommissioning may reach Rietkuil, which located immediately adjacent to the power station (less than 500 m). There is therefore a medium probability of direct dust nuisance impacts from construction and decommissioning activities. However, there is a high probability of cumulative dust impacts due to the existence of other dust sources in the vicinity of the Arnot Power Station.

The probability of direct and cumulative impacts of from $NO_2$, $SO_2$, $PM_{10}$ and dust, emitted during normal operation of the Arnot Power Station, are also considered to be high for both scenarios. The predictive modelling provides maximum expected ambient concentrations for each pollutant based on a worst-case meteorological scenario. These results show that predicted concentrations comply with the national ambient standard in throughout the study domain. Despite this, some risk to health remains and the probability of direct and cumulative air quality impacts during the operation of the Arnot Power Station is considered to be high. Since the predicted concentrations of $NO_x$, $SO_2$ and $PM_{10}$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is expected to have a positive impact on air quality.

The probability of indirect impacts occurring with the two operational scenarios relates to the relative contribution to acidification and global warming. Quantification of the relative contribution of Arnot Power Station is difficult, but it is considered to be relatively small in the national and global context, and somewhat less for the co-fired option. Despite this, the probability of indirect impacts occurring is high.

***Significance of Impacts***

The significance of impacts is determined through the following equation:

Significance = (Extent + Duration + Magnitude) x Probability
A score of less than 30 implies that impacts are of a low significance, a score of between 30 and 60 implies a medium significance, whereas a score of greater than 60 implies a high significance. For the current (baseline) and proposed modifications to the Arnot Power Station, the significance is:

| PHASE | SIGNIFICANCE OF IMPACTS | | |
|---|---|---|---|
| | DIRECT | INDIRECT | CUMULATIVE |
| Construction and decommissioning | (1+1+4)x3=18 | (0+0+0)x0=0 | (1+1+6)x3=24 |
| Operation – baseline | (2+4+4)x4=40 | (5+4+4)x4=52 | (2+4+6)x4=48 |
| Operation – co-firing option | (2+4+4)x4=40 | (5+4+4)x4=52 | (2+4+6)x4=48 |

From the scoring above, it is predicted that the significance of all impacts during construction and decommissioning phase is low. The significance of these impacts for both operational scenarios is medium.

***Summary of Impacts***

In summarising the impacts (Table 8.1 and 8.2), the highest score in each category described above is selected.

***Table 8.1: Summary of air quality impacts during construction of infrastructure for the co-firing option and decommissioning of the Arnot Power Station***

| ***Nature:*** Cumulative air quality impacts are caused by exposure to dust generated during construction activities and decommissioning of the Arnot Power Station and by other existing sources in the vicinity of the power station. Dust has a nuisance impact and negatively affects quality of life by causing soiling, contamination, structural corrosion and damage to precision equipment, machinery and computers. | | |
|---|---|---|
| | **Without mitigation** | **With mitigation** |
| ***Extent*** | Limited to site and immediate surroundings (1) | Limited to site and immediate surroundings (1) |
| ***Duration*** | Immediate (1) | Immediate (1) |
| ***Magnitude*** | Moderate (6) | Low (4) |
| ***Probability*** | High (3) | Low (2) |
| ***Significance (positive or negative)*** | **Low (24) and negative** | **Low (12) and negative** |
| ***Reversibility*** | Yes | Yes |
| ***Irreplaceable loss of resources?*** | No | No |
| ***Can impacts be mitigated?*** | Yes | N/A |
| ***Mitigation:*** Dust management plan. | | |
| ***Cumulative Impacts:*** Yes | | |
| ***Residual Impacts:*** No | | |

Although the significance of impacts during construction and decommissioning is low, a basic dust management plan is required to ensure the nuisance impacts are mitigated. This can be achieved by addressing dust management in Environmental Management Plan for the Arnot Power Station.

There is only a slight reduction in predicted ambient concentrations of $PM_{10}$, $SO_2$ and $NO_x$ between the coal fired option and biomass co-firing. As it is unlikely that this difference can be measured, the impacts for both options are summarised below.

***Table 8.2: Summary of air quality impacts during operation of the Arnot Power Station – applicable to both the baseline and co-firing option***

| | | |
|---|---|---|
| ***Nature:*** Air quality impacts are caused by the inhalation of $NO_2$, $SO_2$ and particulates ($PM_{10}$), which are contained in emissions from the Arnot Power Station. The inhalation of the $NO_2$, $SO_2$ and $PM_{10}$ at concentrations exceeding health-based air quality standards; and which are greater than the permitted number of exceedances per year, will result in negative health impacts. | | |
| | **Coal only** | **10% biomass substitution in one unit only** |
| ***Extent*** | Local/municipal extending only as far as the local community or urban area (5) | Local/municipal extending only as far as the local community or urban area (5) |
| ***Duration*** | Long-term (4) | Long-term (4) |
| ***Magnitude*** | Moderate (6) | Moderate (4) |
| ***Probability*** | High (4) | High (4) |
| ***Significance (positive or negative)*** | **medium (60) and negative** | **medium (52) and negative** |
| ***Reversibility*** | Yes | Yes |
| ***Irreplaceable loss of resources?*** | No | No |
| ***Can impacts be mitigated?*** | Yes | Yes |
| ***Mitigation:*** Plant engineers and operators are to continue ensure that the abatement technology that is currently installed is always in working order and maintained on a regular basis as per standard operating procedures. | | |
| ***Cumulative Impacts:*** Yes | | |
| ***Residual Impacts:*** No | | |

Current operational emission mitigation at Arnot Power Station is for particulates only, i.e. $SO_2$ and $NO_x$ emissions are not controlled. This situation leads to a medium impact rating for the magnitude of the indirect impacts, associated with regional scale acidification. $SO_2$ and $NO_x$ abatement will result in the rating decreasing to low during the operational phase for both scenarios. See next section.

## 9. MITIGATION

The Arnot Power Station is located in the Highveld Priority Are (HPA). There are a number of emission abatement technologies in place to control particulate emissions in the flue gas and for diffuse sources at the power station. In the context of the AQMP for the HPA, the overall objective is that ambient air quality complies with all national ambient air quality standards (Republic of South Africa, 2011a). Goal 2 which reads '*By 2020, industrial emissions are equitably reduced to achieve compliance with air quality standards and dust fallout limit values*' applies to the Arnot Power Station, i.e.:

1) Emissions are quantified from all sources
2) Gaseous and particulate emissions are reduced
3) Fugitive emissions are minimised
4) Emissions from dust-generating activities are reduced
5) Greenhouse gas emissions are reduced
6) Incidences of spontaneous combustion in coal storage piles and discard dumps are reduced
7) Abatement technology is appropriate and operational
8) Industrial AQM decision making is robust and well-informed, with available information
9) Clean technologies and processes are implemented
10) Adequate resources are available for AQM in industry
11) Ambient air quality standard and dust fallout limit value exceedances as a result of industrial emissions are assessed
12) A line of communication exists between industry and communities

The details of emission abatement for stack and diffuse sources during operations will need to be agreed on with the licensing authority and will be captured in Arnot Power Station's AEL. Examples to control/mitigate dust missions during construction and decommissioning are included in Table 9.1 for consideration in the EMP.

***Table 9.1 – Dust mitigation plan to be included in EMP***

| Mitigation: Action/control | Responsibility | Timeframe |
|---|---|---|
| Unpaved roads to accommodate the additional traffic bringing in biomass for the co-firing option could be tarred. Prior to this, traffic control measures are required to limit vehicle-entrained dust from unpaved roads e.g. by limiting vehicle speeds and by restricting traffic volumes. Alternatively, unpaved road surfaces can also be watered to maintain high moisture content which will bind the silt. | Construction Project Manager | During construction and decommissioning phases |
| Cover the load on trucks | Construction Project Manager | During construction and decommissioning phases |

| Mitigation: Action/control | Responsibility | Timeframe |
| --- | --- | --- |
| Load and unload in areas protected from wind where possible | Construction Project Manager | During construction and decommissioning phases |
| Wet or cover stockpiles of construction material | Construction Project Manager | During construction and decommissioning phases |
| Stabilise open areas with dust palliative, gravel or similar | Construction Project Manager | During construction and decommissioning phases |

## 10 CONCLUSIONS

Eskom's coal-fired Arnot Power Station which is located ~37 km south east of Middelburg, and close to Rietkuil in Mpumalanga has a base load generation capacity of 2 352 MW, generated in 6 units, each with a nominal capacity of between 350 to 400 MW. It is proposed that a small portion of the coal is displaced with biomass (wood pellets) as a co-firing fuel source. The main purpose of this project is to reduce the carbon footprint of Eskom (decreasing the carbon emissions), starting with this pilot biomass co-firing project. Savannah Environmental are conducting the required basic environmental assessment and appointed uMoya-NILU to conduct the air quality specialist study. Amongst others, the scope of work included:

» Description of the receiving environment with regard to ambient air quality;
» Description of the legal framework with respect to air quality;
» Development of an emissions inventory;
» Assessment of the impacts of the proposed project on ambient air quality by estimating the ambient concentrations of key pollutants for construction, operations including coal and coal/wood biomass mix, and decommissioning; by comparison of predicted ambient concentrations with South African Ambient Air Quality Standards.

The main findings of the air quality specialist study are:

For construction and decommissioning of the infrastructure for the biomass receipt, storage, milling and mixing, the impacts on ambient air quality concern particulate matter only. The impacts are expected to be of a nuisance nature only, and will be limited to less than 1 km from the source and may impact on Rietkuil. The impacts have a low significance.

Total particulates resulting from the combustion of coal and wood biomass are modelled as $PM_{10}$. This conservative approach thus provides an over-estimation of ambient $PM_{10}$ concentrations. For coal only the predicted ambient concentrations resulting from the Arnot Power Station are compliant with the current and future national ambient standards. Similarly predicted concentrations are compliant for the coal and wood biomass mix. The introduction of wood biomass results in a marginal reduction in predicted ambient $PM_{10}$ concentrations, but it is unlikely that the reduction can be measured. Particulate emissions from Arnot Power Station contribute to the current ambient $PM_{10}$ concentrations of the eastern highveld. However the modelled cumulative concentrations comply with the national ambient standards. The impacts associated with $PM_{10}$ have a low significance. Since the predicted concentrations of $PM_{10}$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project biomass co-firing is expected to have a positive impact on air quality.

For $SO_2$ the predicted annual average concentration complies with the national ambient standard for coal, and for coal and the wood biomass mix. The cumulative concentrations also comply with the annual standard. The predicted 24-hour maximum concentrations exceed the limit value in the national standard in a small area around Arnot Power Station for both fuel scenarios, but the predicted number of exceedances do not exceed the tolerances. Similarly the predicted 1-hour maximum concentrations exceed the limit value of the national standard, but over a considerably larger area around Arnot Power Station for both fuel scenarios. Again the predicted number of exceedances do not exceed the tolerances. In other words, the predicted 24-hour and 1-hour $SO_2$ concentrations comply with the national standards. The introduction of wood biomass results in a marginal reduction in predicted ambient $SO_2$ concentrations, but it is unlikely that the reduction can be measured. $SO_2$ emissions from Arnot Power Station contribute to the current ambient concentrations. However the modelled cumulative concentrations comply with the national ambient standards. Despite this the impacts associated with $SO_2$ have a medium significance. Since the predicted concentrations of $SO_2$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is expected to have a positive impact on air quality.

For $NO_x$ the predicted annual average concentration complies with the national ambient standard for $NO_2$ for coal and for coal and the wood biomass mix. The cumulative concentrations also comply with the annual standard. The predicted 1-hour maximum concentrations exceed the limit value of the national standard, over a considerably larger area around Arnot Power Station for both fuel scenarios. However the predicted number of exceedances do not exceed the tolerance. In other words, the predicted 1-hour $NO_x$ concentrations comply with the national standards. The introduction of wood biomass results in a marginal reduction in predicted ambient $NO_2$ concentrations, but it is unlikely that the reduction can be measured. $NO_2$ emissions from Arnot Power Station contribute to current ambient concentrations. However the modelled cumulative concentrations comply with the national ambient standards. Despite this the impacts associated with $NO_x$ have a medium significance. Since the predicted concentrations of $NO_x$ for the biomass co-firing scenario are lower than for the baseline scenario (coal only), the proposed project is expected to have a positive impact on air quality.

Indirect impacts associated with the $SO_2$ and $NO_x$ emissions relate to acidification, and those associated with CO and $CO_2$ relate to global warming. The magnitude of indirect impacts associated with the two operational scenarios relates to the relative contribution to acidification and global warming. While quantification of the relative contribution of Arnot Power Station is difficult, the contribution is considered to be relatively small in the national and global context, and somewhat less for the co-fired option. The significance of the indirect impacts is therefore anticipated to be low for both scenarios. The carbon content of wood is less than that of coal. Despite this, the $CO_2$ emission is expected to increase by 0.08% and 0.12% for 10% and 5% wood biomass substitution on one and three units, respectively. This is an equivalent increase of 31 ton/day of $CO_2$ for a 10% substitution in one unit and 48 ton/day for a 5% substitution in each of three units. The increase is counter intuitive and results as more wood is required than coal to generate an equivalent amount of heat due to its lower calorific value. The biomass co-firing option in one unit will however reduce Arnot Power Station's reliance on fossil fuel (coal) by 10% as biomass is a renewable source of energy.

Particulate emissions at the Arnot Power Station are well controlled using bag filters, and some control measures are in place to control diffuse sources at the power station. With the imminent publication of the AQMP for the HPA, despite the fuel mix, Arnot Power Station will need to evaluate all aspects of its operation in order to comply with Goal 2 of the AQMP which reads '*By 2020, industrial emissions are equitably reduced to achieve compliance with air quality standards and dust fallout limit values*'. Objectives of this goal include, amongst others:

1) Quantification of emissions from all sources
2) Reduction of gaseous and particulate emissions
3) Minimisation of fugitive emissions
4) Reduction in emissions from dust-generating activities
5) Reduction on Greenhouse gas emissions
6) Reduction in the incidences of spontaneous combustion in coal storage piles and discard dumps
7) Optimum operation of appropriate abatement technology, and
8) Exceedances of ambient air quality standards and dust fallout limit value s as a result of plant emissions are assessed.

In conclusion, this study shows that the introduction of wood biomass as a substitute for up to 10% coal at Arnot Power Station reduces ambient concentrations of $PM_{10}$, $SO_2$ and $NO_x$ marginally. It is however unlikely that this small difference is measurable. Predicted ambient concentrations of these pollutants comply with all ambient air quality standards when coal and when coal and wood biomass mix are used. The significance of the impact of $PM_{10}$ on ambient air quality is low, and medium for $SO_2$ and $NO_x$ as a result of their contribution to regional scale acidification.

## 11 ASSESSMENT CONFIDENCE

The confidence in the air quality prediction is dependent on two primary factors. The first is the representativeness of the available data to describe the existing state of air quality and as input to the predictive model. Coupled to this, the second is the appropriateness of the selected model and the parameterisation thereof.

## 11.1 Data

The SAWS meteorological monitoring station at Witbank is the closest source of reliable hourly surface meteorological that is representative of a larger area. The lack of upper air meteorological data is a considerable gap, particularly for air dispersion studies. The lack of a reasonable record of monitored ambient air pollution data is also a gap, considering that the Arnot Power Station is a relatively significant source of emissions.

Emission measurements over a period of time have provided reliable data on the point sources at the Arnot Power Station. Operational variations however result in temporal variations in the point source emissions and deviations from the measure data. The variations create some uncertainty in the representativeness of the measured point source emission data.

Diffuse and fugitive emissions particularly from roads and activities associated with the coal stockpiles, are extremely difficult to measure. These emissions are therefore estimated based on the parameterisation of activity data, raw material throughput, the installed air pollution abatement technology, the operational processes and emission factors. Each of these aspects is subjected to assumptions and hence uncertainty in the resultant emissions. The diffuse and fugitive emissions therefore may be considered a reasonable estimation.

## 11.2 Model evaluation

***Meteorology***

Meteorology varies throughout the modelling domain is not well represented by the measurements at a single monitoring station. Modelling the meteorology improves the representativeness by producing surface and upper air wind and temperature fields that account for variance induced by topographical variations. This approach improves the representivity of the surface meteorological data and addresses the lack of upper air data.

***Ambient concentrations***

The CALPUFF air dispersion model has been validated and approved by the US EPA as a regulatory model. It is therefore appropriate for modelling dispersion from the suite of sources at the Arnot Power Station. The use of a 500 m grid adequately resolves the topography in the modelling domain and provides a relatively high degree of confidence in the dispersion.

The uncertainties inherent in the emission data account for uncertainties in the predicted ambient concentration of the respective pollutants. The degree of uncertainty is best quantified through a statistical comparison of the predicted ambient concentrations with measured ambient data. As a monitoring station is influenced by emissions from all sources, a meaningful statistical comparison requires that all possible sources of the respective pollutants are included in the model emission inventory and in the dispersion simulation. This was not the case in this study where point and diffuse sources only from the Arnot Power Station were included. A statistical comparison was therefore not conducted considering this point and the unavailability of monitored data during the 3-year modelling period.

Based on the assumption that the point source emissions are accurate and the diffuse emissions are a reasonable estimation, there is a moderate degree of confidence in the predicted ambient concentrations.

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