**Project done on behalf of**

**Clean Stream Environmental Consultants**

# TWEEFONTEIN OPTIMISATION PROJECT AMENDMENT: AIR QUALITY SPECIALIST ASSESSMENT

**Report No.: 11CSE01b Rev 0.1**

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## REPORT DETAILS

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| Acknowledgements | Eskom is acknowledged for the provision of meteorological data for the inclusion into the study. |

# EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Limited was appointed by Clean Stream Environmental Consultants to undertake an air quality impact assessment for the Tweefontein Optimisation Project Amendment.

The aim of the investigation is to quantify the possible impacts resulting from the proposed activities on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

## Study Approach and Methodology

The investigation followed the methodology required for a specialist report, comprising the baseline characterisation and the impact assessment study.

### *Baseline Assessment*

The baseline study encompassed the analysis of meteorological data. Local meteorological data (including wind speed, wind direction and temperature) was obtained from the closest Eskom monitoring station at Kendal. The meteorological period used for dispersion modelling purposes included January 2009 to August 2012.

### *Impact Assessment Criteria*

Particulates represent the main pollutants of concern in the assessment of operations from the Project. Particulate matter is classified as a criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant. South Africa have established National Ambient Air Quality Standards (NAAQS) to regulate the ambient concentrations of this pollutant.

### *Emissions Inventory*

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Fugitive and point source emissions from vehicle entrainment, materials handling, crushing activities and windblown dust were quantified.

### *Impact Prediction Study*

Particulate, gaseous concentrations and dust deposition rates due to the Tweefontein Optimisation Project Amendment were simulated using the US-EPA approved AERMET/AERMOD dispersion modelling suite. Ambient concentrations were simulated to ascertain highest hourly, daily and annual averaging levels occurring as a result of the Project operations.

## Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important *limitations* of the air quality impact assessment are summarised as follows:

- The quantification of sources of emission was restricted to the Tweefontein Mine operations only. Although other background sources were identified, such sources were not quantified.
- Information required to calculate emissions from fugitive dust sources for the Project operations were provided. The assumption was made that this information was accurate and correct.
- Routine emissions from the operations were estimated and modelled. Atmospheric releases occurring as a result of accidents were not accounted for.
- A minimum of 1 year, and typically 3 to 5 years of meteorological data are generally recommended for use in atmospheric dispersion modelling for air quality impact assessment purposes. The meteorological period January 2009 to August 2012 was selected for atmospheric dispersion modelling.
- The impact assessment was limited to airborne particulates (including total suspended particulates (TSP), particulate matter of less than 10 µm in diameter (PM10) and particulate matter of less than 2.5 µm in diameter (PM2.5)). Although the

activities would also emit other gaseous pollutants, primarily by trucks and mining vehicles, the impact of these compounds was regarded to be low and was omitted from this study.

- Mining operations were assumed to be twenty-four hours over a 365 day year as a conservative approach.
- Particulate emissions from the upcast event shaft were based on the American Conference of Governmental Industrial Hygienist (ACGHIH) threshold limit value of 10 mg/m³ for total particulate matter. All particulate matter emissions from the upcast vent were assumed to be in the sub 10 micron range (i.e. $PM_{10}$ emissions).

## Conclusions

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative $SO_2$, $NO_2$ and $PM_{10}$ impact are surrounding mining activities, power generation operations, farming, biomass burning, windblown dust from open areas and vehicle entrainment on unpaved road surfaces.
- The predominant wind direction within the study area is from the west-northwest. An increase in west-northwesterly winds occurs during day-time conditions with an increase in easterly winds during night-time.
- The nearest sensitive receptors (in terms of human settlements) to the Project are Vlaklaagte, Makoupan, Saaiwater, Klippoortjie, Tavlands Estate, Ogies and Phola.
- Measured annual average $PM_{10}$ concentrations from Emahaleni were 83 µg/m³ for the period 2008/2009.

The main findings from the impact assessment due to the Tweefontein Optimisation Project operations were as follows:

- For unmitigated and mitigated operations predicted $PM_{2.5}$ impacts at Vlaklaagte (and individual farmsteads in the area), Saaiwater and Ogies were within NAAQS. At the sensitive receptor of Makoupan, as the mining throughput increases, the predicted $PM_{2.5}$ impacts due to unmitigated and mitigated operations exceeded daily NAAQS.

- For unmitigated and mitigated operations predicted $PM_{10}$ impacts at Saaiwater and Ogies were predicted to be within NAAQS. At the sensitive receptor of Vlaklaagte (and individual farmsteads in the area), as the mining throughput increases, the predicted $PM_{10}$ impacts due to unmitigated operations exceeded daily NAAQS but were within standards for mitigated operations. At the sensitive receptor of Makoupan the predicted $PM_{10}$ impacts due to unmitigated operations exceeded daily NAAQS. As the mining throughput increases, predicted $PM_{10}$ concentrations at Makoupan still exceeded NAAQS during mitigated operations.

- Predicted dustfall at all identified sensitive receptors within the study area were within the draft dust fallout regulations of 600 mg/m²/day (with the exception of Makoupan due to unmitigated operations during the period 2018) considered acceptable for residential areas.

## Recommendations

In light of the findings and the elevated particulate baseline ambient air quality levels, it was recommended that air quality management measures be implemented to ensure the lowest possible impacts on the surrounding environment from proposed operations.

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# TWEEFONTEIN OPTIMISATION PROJECT AMENDMENT: AIR QUALITY SPECIALIST ASSESSMENT

## 1 INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Clean Stream Environmental Consultants (hereafter referred to as CSEC) to undertake an air quality impact assessment for the Tweefontein Optimisation Project Amendment.

The aim of the investigation is to quantify the possible impacts resulting from the proposed activities on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

Typical of specialist investigations conducted, the air quality investigation comprises both a baseline study and an impact assessment. The baseline study includes the review of site-specific atmospheric dispersion potentials, in addition to the identification of potentially sensitive receptors.

Particulates represent the main pollutants of concern in the assessment of operations from the Project. Particulate matter is classified as criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant.

### 1.1 Terms of Reference

The following will be included in the *baseline* study:

- Description of the regional climate and site-specific atmospheric dispersion potential;
- The identification of the potential sensitive receptors within the vicinity of the site;
- A description of existing sources of atmospheric emissions and ambient air quality in the project area based on existing ambient monitoring data;

- A review of the legislative and regulatory context, including atmospheric emission limits and ambient air quality guidelines.

The following will be included in the *impact assessment* study:

- The compilation of an emissions inventory for the project, comprising the identification and quantification of all routine sources of emission.
- Atmospheric dispersion modelling.
- The evaluation of the potential for human health and environmental air quality impacts.
- The development of project specific air quality management plan that will link into the existing Air Quality Management plan for the mine. This will include recommendations for mitigation and monitoring affecting ambient air quality.

## 1.2 Methodological Approach

### 1.2.1 Atmospheric Dispersion Model Selection

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

It was decided to employ the most recently US Environmental Protection Agency's (US EPA) approved regulatory model. The most widely used US EPA model has been the Industrial Source Complex Short Term model (ISCST3). This model is based on a Gaussian plume model. However this model has been replaced by the new generation AERMET/AERMOD suite of models. AERMOD is a dispersion model, which was developed under the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna *et al.,* 1999). The AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

- AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources (Trinity Consultants, 2004). AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight line trajectory limitation of ISCST3 (Hanna *et al*, 1999).
- AERMET is a meteorological pre-processor for the AERMOD model. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters.
- AERMAP is a terrain pre-processor designed to simplify and standardize the input of terrain data for the AERMOD model. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Even if the field instrument accuracy is excellent, there can still be large uncertainties due to unrepresentative placement of the instrument (or taking of a sample for analysis). Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions. It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hourly) and long downwind distances. All of the above factors contribute to the inaccuracies not even associated with the mathematical models themselves.

Similar to the ISC model, a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Although the model has been shown to be an improvement on the ISC model, especially short-term predictions, the range of uncertainty of the model predictions is -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

Input data types required for the AERMOD model include: meteorological data, source data, and information on the nature of the receptor grid. Each of these data types will be described below.

### 1.2.2 Meteorological Data Requirements

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). Local meteorological data (including wind speed, wind direction and temperature) was obtained from the closest Eskom monitoring station located at Kendal Power Station. The meteorological period used for dispersion modelling purposes included January 2009 to August 2012.

### 1.2.3 Source Data Requirements

The AERMOD model is able to model point, area, volume and line sources. The vehicle entrainment and stockpile sources were modelled as area sources and the materials handling was modelled as volume sources.

### 1.2.4 Modelling Domain

The dispersion of pollutants was modelled for an area covering 16 km (north-south) by 20 km (east-west) for the Project site. This area was divided into a grid with a resolution of 200 m (north-south) by 200 m (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points.

## 1.3 Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important *limitations* of the air quality impact assessment are summarised as follows:

- The quantification of sources of emission was restricted to the Tweefontein Mine operations only. Although other background sources were identified, such sources were not quantified.
- Information required to calculate emissions from fugitive dust sources for the Project operations were provided. The assumption was made that this information was accurate and correct.
- Routine emissions from the operations were estimated and modelled. Atmospheric releases occurring as a result of accidents were not accounted for.
- A minimum of 1 year, and typically 3 to 5 years of meteorological data are generally recommended for use in atmospheric dispersion modelling for air quality impact assessment purposes. The meteorological period January 2009 to August 2012 was selected for atmospheric dispersion modelling.
- The impact assessment was limited to airborne particulates (including total suspended particulates (TSP), particulate matter of less than 10 µm in diameter (PM10) and particulate matter of less than 2.5 µm in diameter (PM2.5)). Although the activities would also emit other gaseous pollutants, primarily by trucks and mining vehicles, the impact of these compounds was regarded to be low and was omitted from this study.
- Mining operations were assumed to be twenty-four hours over a 365 day year as a conservative approach.
- Particulate emissions from the upcast event shaft were based on the American Conference of Governmental Industrial Hygienist (ACGHIH) threshold limit value of 10 mg/m$^3$ for total particulate matter. All particulate matter emissions from the upcast vent were assumed to be in the sub 10 micron range (i.e. $PM_{10}$ emissions).

## 1.4 Outline of report

The ambient air quality evaluation criteria are described in Section 2. The baseline characterisation comprising of atmospheric dispersion potential and existing sources of air pollution are discussed in the subsequent section. The impact assessment for the Project is provided in Section 4. Section 5 outlines the impact significance rating for the project with Management Plan provided in Section 6. The conclusions and recommendations are given in Section 7.

# 2 LEGAL REQUIREMENTS, HUMAN HEALTH CRITERIA AND EFFECTS ON ANIMALS AND VEGETATION

The air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. The air quality guidelines and standards are normally given for specific averaging periods.

Ambient air quality guidelines and standards and dust deposition are discussed in Section 2.1.1 and Section 2.1.2 respectively.

## 2.1 Ambient Air Quality Criteria

### 2.1.1 National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) was engaged to assist Department of Environmental Affairs (DEA) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for $PM_{2.5}$, $PM_{10}$, sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), carbon monoxide (CO), lead (Pb) and benzene (Table 2-1).

**Table 2-1: National ambient air quality standards**

| Substance | Molecular Formula / Notation | Averaging Period | Concentration (µg/m³) | Frequency of Exceedance | Compliance Date |
|---|---|---|---|---|---|
| Sulphur Dioxide | $SO_2$ | 10 minutes | 500 | 526 | Immediate |
| | | 1 hour | 350 | 88 | Immediate |
| | | 24 hours | 125 | 4 | Immediate |

| Substance | Molecular Formula / Notation | Averaging Period | Concentration (µg/m³) | Frequency of Exceedance | Compliance Date |
|---|---|---|---|---|---|
| | | 1 year | 50 | 0 | Immediate |
| Nitrogen Dioxide | $NO_2$ | 1 hour | 200 | 88 | Immediate |
| | | 1 year | 40 | 0 | Immediate |
| Particulate Matter | $PM_{2.5}$ | 24 hour | 65 | 4 | Immediate – 31 Dec 2015 |
| | | | 40 | 4 | 1 Jan 2016 – 31 Dec 2029 |
| | | | 25 | 4 | 1 Jan 2030 |
| | | 1 year | 25 | 0 | Immediate – 31 Dec 2015 |
| | | | 20 | 0 | 1 Jan 2016 – 31 Dec 2029 |
| | | | 15 | 0 | 1 Jan 2030 |
| | $PM_{10}$ | 24 hour | 120 | 4 | Immediate – 31 Dec 2014 |
| | | | 75 | 4 | 1 Jan 2015 |
| | | 1 year | 50 | 0 | Immediate – 31 Dec 2014 |
| | | | 40 | 0 | 1 Jan 2015 |
| Ozone | $O_3$ | 8 hours (running) | 120 | 11 | Immediate |
| Benzene | $C_6H_6$ | 1 year | 10 | 0 | Immediate – 31 December 2014 |
| | | | 5 | 0 | 1 January 2015 |

| Substance | Molecular Formula / Notation | Averaging Period | Concentration (µg/m³) | Frequency of Exceedance | Compliance Date |
|---|---|---|---|---|---|
| Lead | Pb | 1 year | 0.5 | 0 | Immediate |
| Carbon Monoxide | CO | 1 hour | 30 000 | 88 | Immediate |
| | | 8 hour (calculated on 1 hour averages) | 10 000 | 11 | Immediate |

### 2.1.2 National Regulations for Dust Deposition

A draft copy of the National Dust Control Regulation was published for comment on 7 December 2012 (Gazette No. 35931) which states no person may conduct any activity in such a way as to give rise to dust in such quantities and concentrations that:

- 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
- The dust remains visible in the ambient air beyond the premises where it originates: or
- The dust fall at the boundary or beyond the boundary of the premises where it originates exceeds:
  - 600 mg/m$^2$/day averaged over 30 days in residential and light commercial areas measured using reference method ASTM 01739; or
  - 1200 mg/m$^2$/day averaged over 30 days in areas other than residential and light commercial areas measured using reference method ASTM 01739.

## 2.2 Highveld Priority Area

Highveld Airshed Priority Area Air Quality Management Plan – the Highveld Airshed was declared the second priority area by the minister at the end of 2007. This requires that an Air Quality Management Plan for the area be developed. The plan includes the establishment of an emissions reduction strategies and intervention programmes based on the findings of a baseline characterisation of the area. The implication of this is that all contributing sources in the area will be assessed to determine the emission reduction targets to be achieved over the following few years.

The Project is within the footprint demarcated as the Highveld Priority Area. Emission reduction strategies will be included for the numerous operations in the area with specific targets associated with it. The DEA has in September 2011 published the management plan for the Highveld Priority Area. Included in this management plan are 7 goals, each of which has a further list of objectives that has to be met. The 7 goals for the Highveld Priority area are as follows:

- Goal 1: By 2015, organisational capacity in government is optimised to efficiently and effectively maintain, monitor and enforce compliance with ambient air quality standards
- Goal 2: By 2020, industrial emissions are equitably reduced to achieve compliance with ambient air quality standards and dust fallout limit values
- Goal 3: By 2020, air quality in all low-income settlements is in full compliance with ambient air quality standards
- Goal 4: By 2020, all vehicles comply with the requirements of the National Vehicle Emission Strategy
- Goal 5: By 2020, a measurable increase in awareness and knowledge of air quality exists
- Goal 6: By 2020, biomass burning and agricultural emissions will be 30% less than current
- Goal 7: By 2020, emissions from waste management are 40% less than current

Goal 2 applies directly to the Project, the objectives associated with this goal include:

- Emissions are quantified from all sources.
- Gaseous and particulate emissions are reduced.
- Fugitive emissions are minimised.
- Emissions from dust generating activities are reduced.
- Incidences of spontaneous combustion are reduced.
- Abatement technology is appropriate and operational.
- Industrial Air Quality Management (AQM) decision making is robust and well-informed, with necessary information available.
- Clean technologies and processes are implemented.
- Adequate resources are available for AQM in industry.
- Ambient air quality standard and dust fallout limit value exceedances as a result of industrial emissions are assessed.
- A line of communication exists between industry and communities.

Each of these objectives is further divided into activities, each of which has a timeframe, responsibility and indicator. Refer to the DEA (2011) Highveld Priority Management Plan for further details.

## 2.3 Effect of Dust on Vegetation, Animals and Susceptible Human Receptors

### 2.3.1 Dust Effects on Vegetation

Suspended particulate matter can produce a wide variety of effects on the physiology of vegetation that in many cases depend on the chemical composition of the particle. Heavy metals and other toxic particles have been shown to cause damage and death of some species as a result of both the phytotoxicity and the abrasive action during turbulent deposition (Harmens et al, 2005). Heavy loads of particle can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Harmens et al, 2005; Naidoo and Chirkoot, 2004; Hirano et al, 1995; Ricks & Williams, 1974), decreasing the efficiency of gaseous exchange (Harmens et al, 2005; Naidoo and Chirkoot, 2004, Ernst, 1981) and hence water loss (Harmens et al, 2005). They may also disrupt other physiological processes such as budbreak, pollination and light absorption/reflectance (Harmens et al, 2005). The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH (Spencer, 2001).

To determine the impact of dust deposition on vegetation, two factors are of importance: (i) does dust collect on vegetation and if it does, what are the factors influencing the rate of deposition (ii) once the dust has deposited, what is the impact of the dust on the vegetation?

Regarding the first question, there is adequate evidence that dust does collect on all types of vegetation. Any type of vegetation causes a change in the local wind fields, with an increase in turbulence which enhances the collection efficiency. The characteristics of the vegetation influences the rate; the larger the “collecting elements” (branches and leaves), the lower the impaction efficiency per element. This would seem to indicate that, for the same volume of tree/shrub canopy, finer leaves will have a better collection efficiency. However, the roughness of the leaves themselves and particularly the presence of hairs on the leaves and stems plays a significant role, with veinous surfaces increasing deposition of 1-5 micron particles by up to seven times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; for moderate wind speeds wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size (Tiwary and Colls 2010). In wind tunnel studies, windbreaks or “shelter belts” of three rows of trees has shown a decrease in 35 to 56% in the downwind mass transport of inorganic particles.

On the effect of particulate matter once it is deposited on vegetation, this depends on the composition of the dust. South African ambient standards are set in terms of $PM_{10}$ (particulate matter smaller than 10 µm aerodynamic diameter) but internationally it is recognised that there are major differences in the chemical composition of the fine PM (the fraction between 0 and 2.5 µm in aerodynamic diameter) and coarse PM (the fraction between 2.5 µm and 10 µm in aerodynamic diameter). The former is often the result of chemical reactions in the atmosphere and may have a high proportion of black carbon, sulphate and nitrate, whereas the latter often consist of primary particles resulting from abrasion, crushing, soil disturbances and wind erosion (Grantz et al. 2003). Sulphate is however often hygroscopic and may exist in significant fractions in coarse PM. This has been shown to be the case in South Africa, where the sulphate content of $PM_{10}$ at the Eskom measuring station at Elandsfontein has been shown to have between 15% (winter) and 49% (spring) sulphate (Alade 2009). Grantz et al (op. cit.) do however indicate that sulphate is much less phototoxic than gaseous sulphur dioxide and that “it is unusual for injurious levels of particular sulphate to be deposited upon vegetation”.

In general, according to the Canadian Environmental Protection Agency (CEPA), air pollution adversely affects plants in one of two ways. Either the quantity of output or yield is reduced or the quality of the product is lowered. The former (invisible) injury results from pollutant impacts on plant physiological or biochemical processes and can lead to significant loss of growth or yield in nutritional quality (e.g. protein content). The latter (visible) may take the form of discolouration of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g. lettuce and spinach).  Visible injury tends to be associated with acute exposures at high pollutant concentrations whilst invisible injury is generally a consequence of chronic exposures to moderately elevated pollutant concentrations. However given the limited information available, specifically the lack of quantitative dose-effect information, it is not possible to define a Reference Level for vegetation and particulate matter (CEPA, 1998).

Exposure to a given concentration of airborne PM may therefore lead to widely differing phytotoxic responses, depending on the mix of the deposited particles. The majority of documented toxic effects indicate responses to the chemical composition of the particles. Direct effects have most often been observed around heavily industrialised point sources, but even there, effects are often associated with the chemistry of the particulate rather than with the mass of particulate.

While there is little direct evidence of what the impact of dust fall on vegetation is under a South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in Sunflower and Cotton plants exposed to dust fall rates greater than 400 mg/m²/day.

### 2.3.2 Effects of Particulate Matter on Animals

As presented by the Canadian Environmental Protection Agency (CEPA, 1998) studies using experimental animals have not provided convincing evidence of particle toxicity at ambient levels. Acute exposures (4-6 hour single exposures) of laboratory animals to a variety of types of particles, almost always at concentrations well above those occurring in the environment have been shown to cause:

- decreases in ventilatory lung function;
- changes in mucociliary clearance of particles from the lower respiratory tract (front line of defence in the conducting airways);
- increased number of alveolar macrophages and polymorphonuclear leukocytes in the alveoli (primary line of defence of the alveolar region against inhaled particles);
- alterations in immunologic responses (particle composition a factor, since particles with known cytotoxic properties, such as metals, affect the immune system to a significantly greater degree);
- changes in airway defence mechanisms against microbial infections (appears to be related to particle composition and not strictly a particle effect);
- increase or decrease in the ability of macrophages to phagocytize particles (also related to particle composition);
- a range of histologic, cellular and biochemical disturbances, including the production of proinflammatory cytokines and other mediators by the lungs alveolar macrophages (may be related to particle size, with greater effects occurring with ultrafine particles);
- increased electrocardiographic abnormalities (an indication of cardiovascular disturbance);
- increased mortality.

Bronchial hypersensitivity to non-specific stimuli and increased morbidity and mortality from cardio-respiratory symptoms occurs most likely in animals with pre-existing cardio-respiratory diseases. Sub-chronic and chronic exposure tests involved repeated exposures for at least half the lifetime of the test species. Particle mass concentrations to which test animals were exposed were very high (> 1 mg/m³), greatly exceeding levels reported in the ambient environment. Exposure resulted in significant compromises in various lung functions similar to those seen in the acute studies, but including also:

- reductions in lung clearance;
- induction of histopathologic and cytologic changes (regardless of particle types, mass, concentration, duration of exposure or species examined);
- production of chronic alveolitis and fibrosis;
- production of lung cancer (a particle and/or chemical effect).

The epidemiological finding of an association between 24 hour ambient particle levels below 100 µg/m³ and mortality has not been substantiated by animal studies as far as $PM_{10}$ and $PM_{2.5}$ are concerned. With the exception of ultrafine particles (0.1µm), none of the other particle types and sizes used in animal inhalation studies cause such acute dramatic effects, including high mortality at ambient concentrations. The lowest concentration of $PM_{2.5}$ reported that caused acute death in rats with acute pulmonary inflammation or chronic bronchitis was 250 g/m³ (3 days, 6 hr/day), using continuous exposure to concentrated ambient particles.

Most of the literature regarding air quality impacts on cattle, refers to the impacts from feedlots on the surrounding environment, hence where the feedlot is seen as the source of pollution. This mainly pertains to odours and dust generation. The US.EPA has recently started to focus on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter (http://www.vetcite.org/publish/items/000944/index.html). The National Cattle Beef Association in the USA in response has disputed this decision based on the lack of evidence on health impacts associated with coarse dust (TSP) concentrations (http://hill.beef.org/newview.asp?DocumantID=16319).

A study was conducted by the State University of IOWA on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The study concurred the lack of information on the health effects and productivity problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulphide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. With regard to particulates, it was found that it is the fine inhalable fraction is mainly deriving from dried faecal dust (Holland et al., 2002). Another study conducted by DSM Nutritional Products North America indicated that calves exposed to a dust-stress environment continued to have lower serum vitamin E concentrations (http://www.dsm.com/en_US/html/dnpus/an_texas_study.htm).

Inhalation of confinement house dust and gases produces a complex set of respiratory responses. An individual's response depends on characteristics of the inhaled components (such as composition, particle size and antigenicity) and of the individual's susceptibility, which is tempered by extant respiratory conditions (http://www.cdc.gov/nasd/docs). Most of the studies concurred that the main implication of dusty environments are causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels these are having a negative effect. In this light it was decided to use the same screening criteria applied to human health, i.e. the South African National Ambient Air Quality Standards.

### 2.3.3 Effect of Particulate Matter on Susceptible Human Receptors

The World Health Organization states that the evidence on airborne particulates and public health is consistent in showing adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending to children and adults and to a number of large, susceptible groups within a general population. The epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. However, current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds have not been identified.

The Agency for Toxic Substances and Disease Registry (ATSDR, 2007) state that particulate matter causes a wide variety of health and environmental impacts. Many scientific studies have linked breathing particulate matter to a series of significant health problems, including:

- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis

- decreased lung function
- premature death

$PM_{10}$ is the standard measure of particulate air pollution used worldwide and studies suggest that asthma symptoms can be worsened by increases in the levels of $PM_{10}$, which is a complex mixture of particle types. $PM_{10}$ has many components and there is no general agreement regarding which component(s) could exacerbate asthma. However, pro-inflammatory effects of transition metals, hydrocarbons, ultrafine particles (due to combustion processes) and endotoxin- all present to varying degrees in $PM_{10}$ - could be important.

Exposure to motor traffic emissions can have a significant effect on respiratory function in children and adults. Studies show that children living near heavily travelled roadways have significantly higher rates of wheezing and diagnosed asthma. Epidemiologic studies suggest that diesel exhaust may be particularly aggravating to children.

A summary of adverse health effects from particulate matter exposure and susceptible populations is given in Table 2-2.

**Table 2-2: Summary of adverse health effects from particulate matter exposure and susceptible populations**

| Health Effects | Susceptible Groups | Notes |
|---|---|---|
| ***Acute (short-term) exposure*** | | |
| Mortality | Elderly, infants, persons with chronic cardiopulmonary disease, influenze or asthma | How much lie shortening is involved and how much is due to short-term mortality displacement is uncertain. |
| Hospitalisation / other health care visits | Elderly, infants, persons with chronic cardiopulmonary disease, pneumonia, influenza or asthma | Reflects substantive health impacts in terms of illness, discomfort, treatment costs, work or school time lost, etc. |
| Increased respiratory symptoms | Most consistently observed in people with astma, and children | Mostly transient with minimal overall health consequences, although for a few there may be short-term absence from work or school due to illness. |
| Decreased lung function | Observed in both children and adults | For most, effects seem to be small and transient. For a few, lung function losses may be clinically relevant. |
| ***Chronic (long-term) exposure*** | | |

| Health Effects | Susceptible Groups | Notes |
|---|---|---|
| Increased mortality rates, reduced survival times, chronic cardiopulmonary disease, reduced lung function, lung cancer | Observed in broad-based cohorts or samples of adults and children (including infants). All chronically exposed are potentially affected. | Long-term repeated exposure appears to increase the risk of cardiopulmonary disease and mortality. May result in lower lung function. Average loss of life expectancy is highly polluted cities may be as much as a few years. |

Source: Adopted from Pope (2000) and Pope et al (2002)

# 3 BASELINE CHARACTERISATION

## 3.1 Site Description and Sensitive Receptors

The Tweefontein Optimisation Project Amendment comprises of underground and opencast mining operations and associated processes. The current land uses in the region includes mining, power generation, farming, residential communities and individual homesteads with residential areas in close proximity to Tweefontein operations consisting of Vlaklaagte, Makoupan, Saaiwater, Klippoortjie, Tavlands Estate, Ogies and Phola (Figure 3-1).

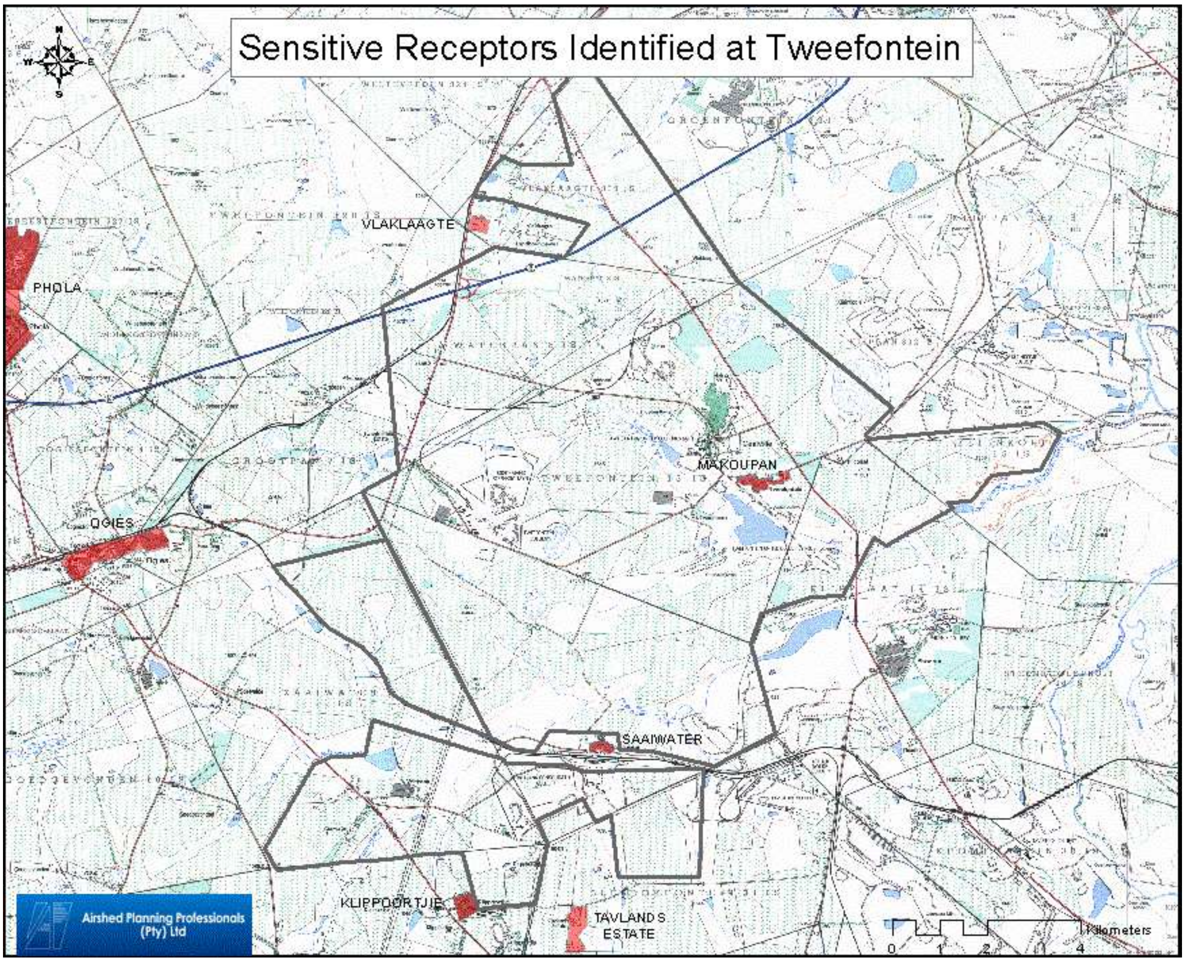


**Figure 3-1: Sensitive receptors in the immediate vicinity of Tweefontein**

## 3.2 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic systems determining the macro-ventilation potential of the region may be provided based on the review of pertinent literature. Meso-scale systems may be investigated through the analysis of meteorological data observed for the region.

### 3.2.1 Synoptic-Scale Circulations and Regional Atmospheric Dispersion Potential

Situated in the subtropical high-pressure belt, southern Africa is influenced by several high-pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over the subcontinent is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic High Pressure (HP), the South Indian HP off the east coast, and the continental HP over the interior.

Seasonal variations in the positioning and intensity of the HP cells determine the extent to which the circumpolar westerlies impact on the atmosphere over the region. In winter, the high-pressure belt intensifies and moves northward and the upper level circumpolar westerlies are able to impact significantly on the region. The winter weather of the region is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or ridging anticyclones moving eastwards around the South African coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards and the influence of the circumpolar westerlies diminishes. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic wintertime circulation (Preston-Whyte and Tyson, 1988; Schulze, 1980).

The general circulation of the atmosphere over southern Africa as a whole is anticyclonic throughout the year above the 700 hPa level (i.e. altitude of ~3 000m). Anticyclones are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions and little to no rainfall occur as a result of such airflow. The climatology of the highveld region has been studied extensively in the past, where the frequency of anticyclonic conditions reaches a maximum in winter. The dominant effect of the winter subsidence is that, averaged over the year, the mean vertical motion is downward. The clear, dry air and light winds, often associated with anticyclonic circulation are ideal for surface radiation inversions of temperature, responsible for limited dispersion of especially low level pollution emissions (e.g. domestic coal fires). Surface inversions increase in frequency during nighttime and varies in depth between ~300 m to more than 500 m. The mean inversion strength during the winter is about 5°C – 6°C, whereas, in summer the strength is less than 2°C.

Circumpolar westerly waves are characterised by concomitant surface convergence and upper-level divergence that produce sustained uplift, cloud and the potential for precipitation. Cold fronts, which are associated with westerly waves, occur predominantly during winter when the amplitude of such disturbances is greatest. The passage of a cold front is characterised by distinctive cloud bands and pronounced variations in wind direction, wind speed, temperature, humidity, and surface pressure. Airflow ahead of a front passing over has a distinct north-northeasterly component and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. Following the passage of the cold front the north-easterly wind is replaced by winds with a distinct southerly component. The low-level convergence in the south-westerly airflow to the rear of the front produce favourable conditions for convection. Temperature decreases immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiation cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures

The tropical easterlies, and the occurrence of easterly waves and lows affect most of southern Africa throughout the year, but occur almost exclusively during summer months. The easterly waves and lows are largely responsible for the summer rainfall pattern and the northeasterly wind component that occurs over the region (Weather Services, 1986; Preston-Whyte and Tyson, 1988).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the persistence of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, destroy, weaken, or increase the altitude of elevated inversions. Easterly and westerly wave disturbances therefore facilitate the dispersion and dilution of accumulated atmospheric pollution.

### 3.2.2 Trans-Boundary Transportation of Air Masses over Southern Africa

The two main transport modes of air masses consist of direct transport, in which air masses are advected directly from the subcontinent to the oceans beyond, and re-circulated transport, in which air masses re-circulates to the point of origin (Tyson et al., 1996a, Tyson et al., 1996c) (Figure 3-2).

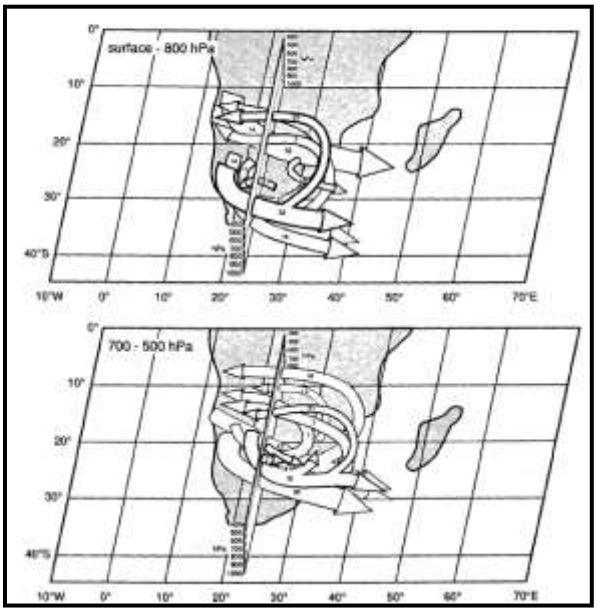


**Figure 3-2: Schematic representation of major low-level transport trajectory models likely to result easterly or westerly exiting of material from southern African or in recirculation over the subcontinent (Tyson et al, 1996c)**

Direct transport is made up of the four cardinal compass directions, viz. westerly, easterly, northerly and southerly. Westerly transport (within the Natal Plume) is influenced by the westerly waves (Fishman, 1991; Pickering et al., 1994; Krishnamurti et al., 1993; Benkovitz et al., 1994; Tyson et al., 1996a, Tyson et al., 1996b) moving air from the highveld to the Indian Ocean at north-to-central Kwa-Zulu Natal or southern Mozambique (Tyson et al., 1996a). Air transported in the Natal Plume takes place at high levels of ~525 hPa (Tyson et al., 1996a). Easterly transport takes place by means of easterly waves to move air masses to the Atlantic Ocean. Air masses that move towards the Atlantic Ocean are transported in the Angolan Plume at low levels due to the subsidence over the western subcontinent and South Atlantic Ocean. Northerly and southerly transport moves air masses to equatorial Africa and to the South Indian Ocean respectively (Tyson et al., 1996a).

Re-circulated transport is confined to levels of less than 200 hPa and is mainly anticyclonic (Tyson et al., 1996a). Local and regional recirculation extends over the highveld and surrounding neighbouring countries, such as Mozambique, Zimbabwe and Botswana (Tyson et al., 1996a; Tyson and Gatebe, 2001). Analysis of trajectory fields undertaken by Tyson et al. (1996c) has revealed that air masses emanating from a particular point of origin follow anticyclonic curving streams with radii of 500 – 700 km. The recirculation vortex is evident from the surface to the persistent stable layer of 500 hPa. Above 500 hPa, due to the influence of the circumpolar westerlies, recirculation diminishes rapidly and transport patterns become more zonal. Local and sub-continental re-circulation over the interior makes up for ~44% of total air mass transportation (Tyson et al., 1996c; Tyson and Gatebe, 2001) with a recirculation time frame of 2-9 days (Tyson et al., 1996a). Up to a quarter of re-circulated air masses are observed to re-circulate a second time (Tyson et al., 1996c). Thus, the greatest impact of pollutants on neighbouring countries is under re-circulating air and prolonged residence time (Tyson et al., 1996a).

More than 75% of all air circulating over the southern African continent exits to the Indian Ocean, either by direct or re-circulated transportation (Tyson and Gatebe, 2001).

### 3.2.3 Meso-scale ventilation and site-specific dispersion potential

Xstrata Coal South Africa (XCSA) operates a meteorological station onsite at their Witbank Group operations (which includes Tweefontein). The data, however, could not be provided for the current assessment. Eskom operate an ambient and meteorological station at the Kendal Power Station (to the west of the Tweefontein Colliery operations). Data was obtained for the period January 2009 to August 2012 for this station.

#### 3.2.3.1 Local wind field

Period and seasonal wind roses for the Kendal meteorological station operated by Eskom for the period January 2009 to August 2012 are presented in Figure 3-3 and Figure 3-4 respectively.

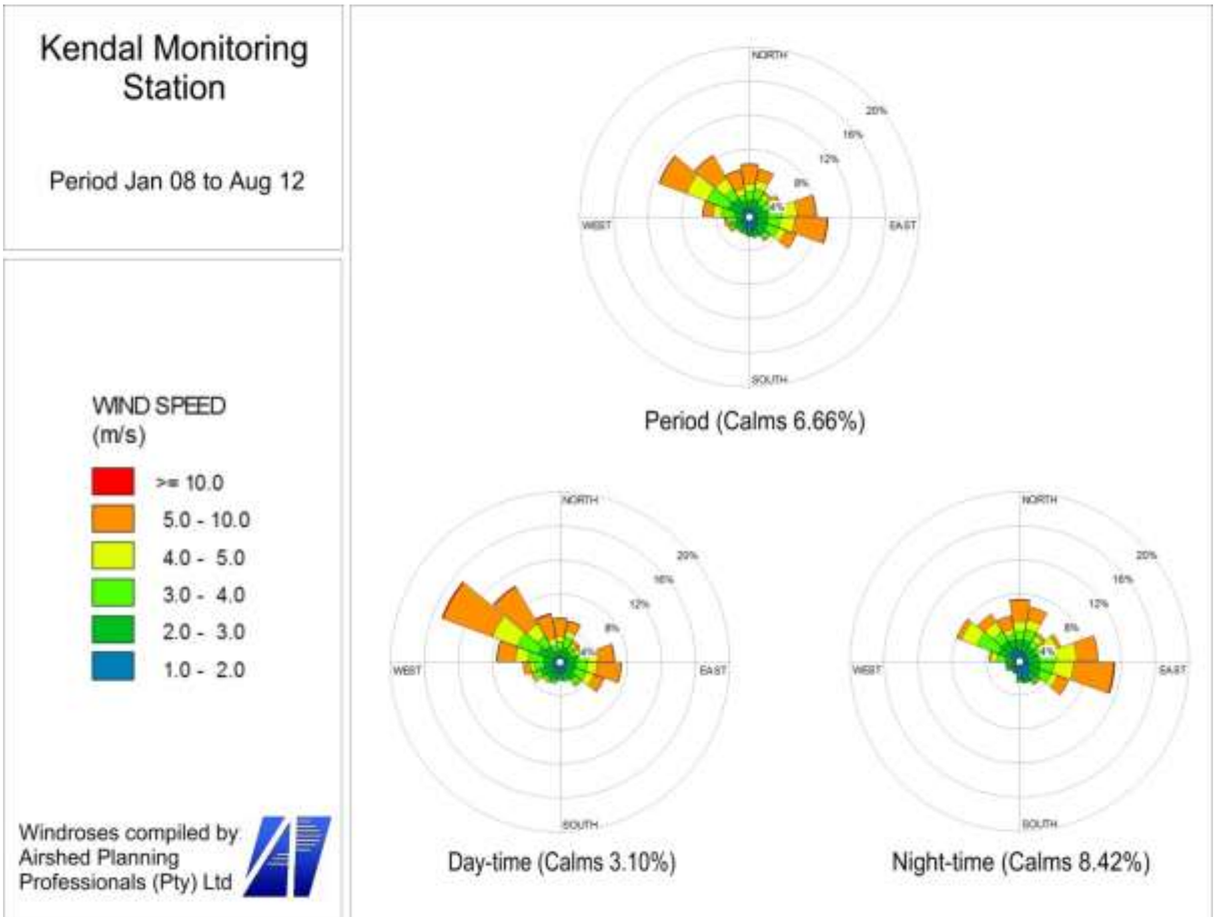


**Figure 3-3: Period, day- and night-time wind roses for the Kendal monitoring station (January 2009 to August 2012)**

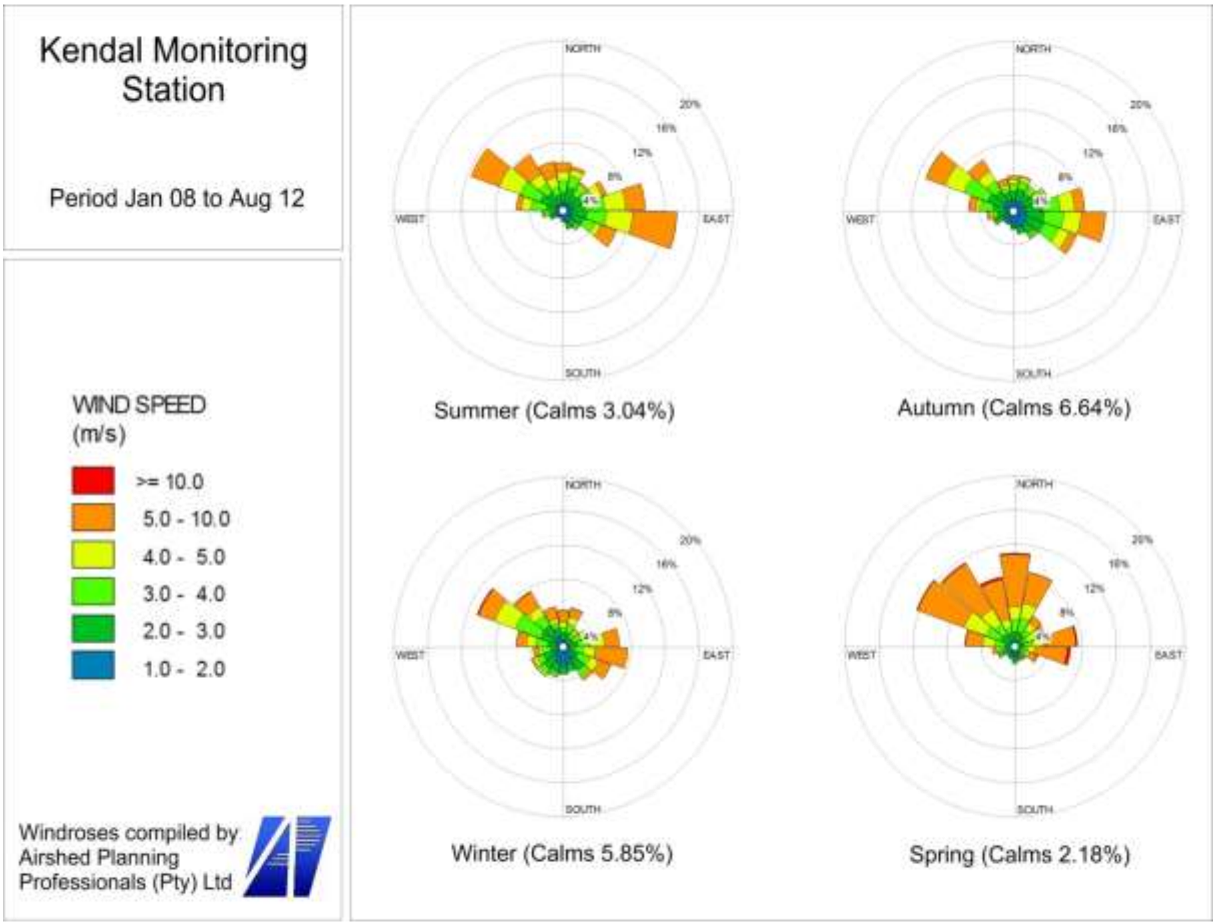


**Figure 3-4: Seasonal wind roses for the Kendal monitoring station (January 2009 to August 2012)**

The predominant wind direction at Kendal for the period January 2009 to August 2012 is from the west-northwest (~11% frequency of occurrence). Calm periods and low wind speeds are more prevalent during the night-time, as is to be expected. An increase in west-northwesterly winds occurs during day-time conditions with an increase in easterly winds during night-time. An increase in westerly wave occurrences is observed in summer and an increase in easterly waves in winter as to be expected due to synoptic circulations (Figure 3-4).

#### *3.2.3.2 Ambient Temperature*

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers. Minimum, mean and maximum temperatures for Kendal for the period January 2009 to August 2012 are illustrated in Figure 3-5.

Annual average maximum, minimum and mean temperatures for Kendal are given as 26°C, 9.6°C and 16°C, respectively, based on the January 2009 to August 2012 record. Average daily maximum temperatures range from 19.9°C in June to 31.5°C in December, with daily minima ranging from 2.1°C in July to 14.9°C in January.

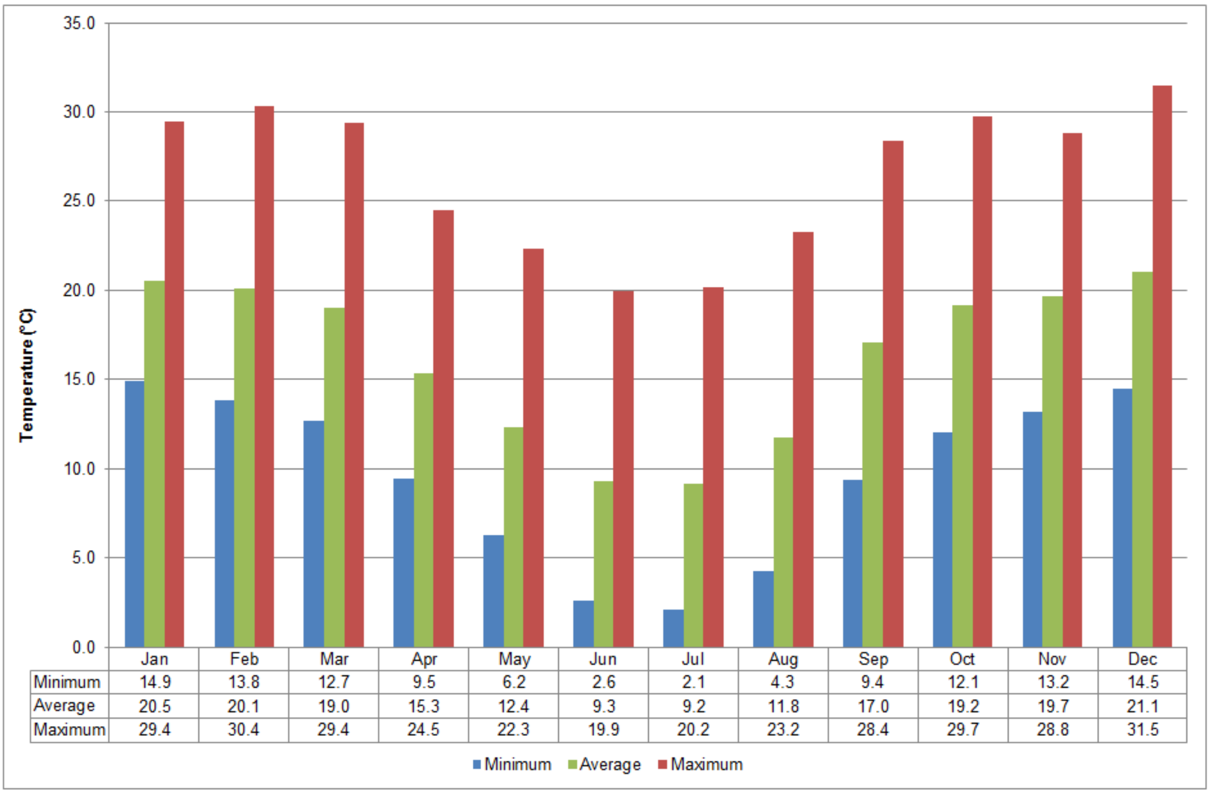


**Figure 3-5: Diurnal temperature profile at Kendal for the period January 2009 to August 2012**

### *3.2.3.3 Precipitation*

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Rainfall for the period 2008 to 2010 for the South African Weather Service (SAWS) station at EMalahleni is provided in Figure 3-6. Precipitation falls mainly in summer with more than 90% of the precipitation occurring from October to April.

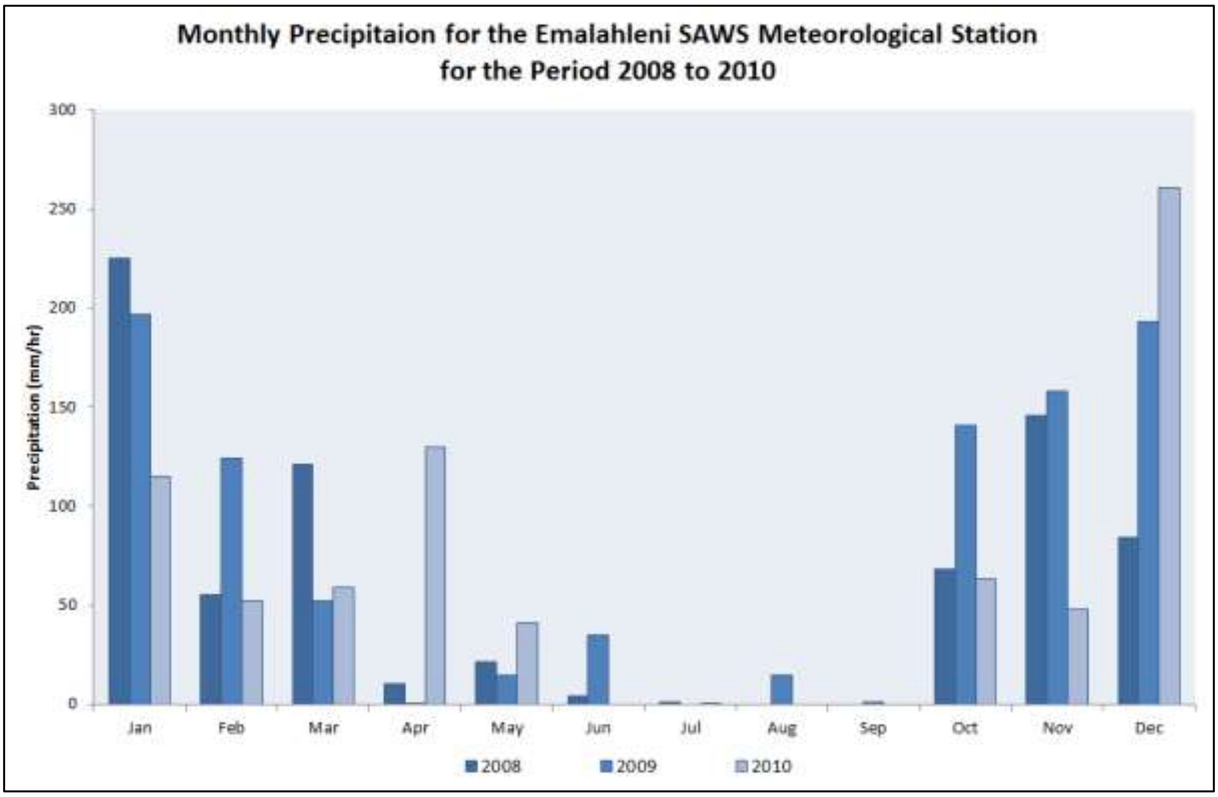


**Figure 3-6: Monthly precipitation at EMalahleni for the period 2008 to 2010**

#### *3.2.3.4 Atmospheric Stability and Mixing Depth*

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions and the erosion of the mixing layer (Figure 3-7).

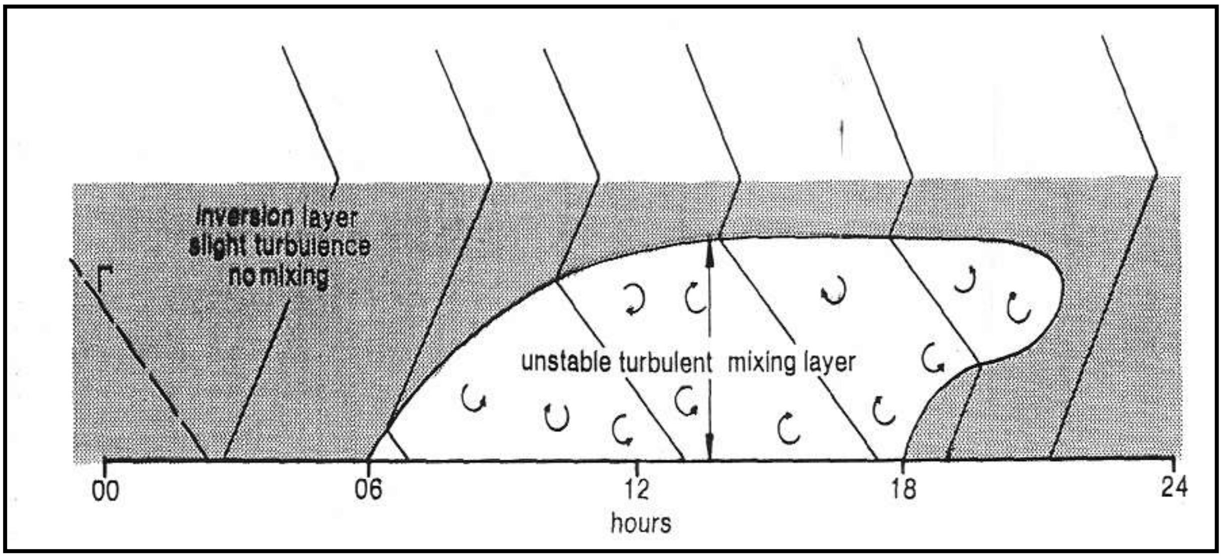


**Figure 3-7: Daytime development of a turbulent mixing layer (Preston-Whyte & Tyson, 1988)**

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5 to 6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004).

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential.

## 3.3 Existing Sources of Emissions within the Study Area

Sources of $SO_2$ and $NO_x$ that occur in the region include veld burning, vehicle exhaust emissions and household fuel burning.

Various local and far-a-field sources are expected to contribute to the suspended fine particulate concentrations in the region. Local sources include wind erosion from exposed areas, fugitive dust from agricultural operations, vehicle entrainment from roadways and veld burning. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has also been found to contribute significantly to background fine particulate concentrations over the interior (Andrea et al., 1996; Garstang et al., 1996; Piketh, 1996).

### 3.3.1 Wind-blow Dust from Eskom's Ash Dams and Dumps

Parameters which have the potential to impact on the rate of emission from ash dam/dump facilities include the extent of surface compaction, moisture content, ground cover, the shape of the dam, particle size distribution, wind speed and precipitation.

Ash dumps in close proximity to the proposed activities consists of the existing Kendal ash dump.

### 3.3.2 Materials handling

Materials handling operations associated with mining and power station activities in the area include the transfer of coal by means of tipping, loading and off-loading of trucks. The quantity of dust that will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled.

### 3.3.3 Industrial Emissions

Industrial sources within the Mpumalanga region include the following:

- Emissions from coal combustion by power generation, metallurgical and petrochemical industries represents the greatest contribution to total emissions from the industrial / institutional / commercial fuel use sector within the Mpumalanga region.

- The metallurgical group is estimated to be responsible for at least ~50% of the particulate emissions from this sector. This group includes iron and steel, ferro-chrome, ferro-alloy and stainless steel manufacturers (includes Highveld Steel & Vanadium, Ferrometals, Columbus Stainless, Transalloys, Middelburg Ferrochrome).

- Petrochemical and chemical industries are primarily situated in Secunda (viz. Sasol Chemical Industries). The use of coal for power generation and the coal gasification process represent significant sources of sulphur dioxide emissions. (Particulate emissions are controlled through the implementation of stack gas cleaning equipment.)

- Other industrial sources include: brick manufacturers which use coal (e.g. Witbank Brickworks, Quality Bricks, Corobrik, Hoeveld Stene, Middelwit Stene) and woodburning and wood drying by various sawmills (Bruply, Busby, M&N Sawmills) and other heavy industries (use coal and to a lesser extent HFO for steam generation). The contribution of fuel combustion (primarily coal) by institutions such as schools and hospitals to total emissions is relatively due to the extent of emissions from other groups.

In the immediate vicinity of the proposed operations, the industrial activities consist of the Kendal Power Station and the proposed Kusile Power Station.

### 3.3.4 Vehicle Exhaust Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide ($CO_2$), carbon monoxide (CO), hydrocarbon compounds (HC), sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$) and particulate matter (PM). Secondary pollutants include nitrogen dioxide ($NO_2$), photochemical oxidants (e.g. ozone), hydrocarbon compounds (HC), sulphur acid, sulphates, nitric acid and nitrate aerosols.

### 3.3.5 Biomass Burning

The biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions.

The biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left is the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held et al, 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content.

### 3.3.6 Fugitive Dust Emissions from Mining

Mines are associated with significant dust emissions, sources of which include land clearing, materials handling, vehicle entrainment, crushing, screening, dragline activities (etc.). Mines in the immediately adjacent to Tweefontein consist of further XCSA collieries including

Tweefontein South, iMpunzi and Goedgevonden and the Anglo Kleinkopje operations located adjacent to the east of Tweefontein activities.

### 3.3.7 Spontaneous Combustion

Spontaneous combustion is an oxidation reaction that occurs without an external heat source. The process changes the internal heat profile of the material leading to a rise in temperature. This can eventually lead to open flame and burning of the material (Coaltech, 2009).

In underground mines, the primary cause of spontaneous combustion is crushed coal (either left in goaf areas or in highly stressed pillars) that is in contact with a sluggish airflow. Good ventilation will remove heat, preventing a rise in temperature, while extremely poor ventilation will not supply sufficient oxygen to support the process. On surface the major problems are usually associated with the stockpiling of coal, or waste dumps containing rejected coal material, in unconsolidated heaps where oxygen can come into contact with the coal and heat cannot dissipate. The problem is compounded when rainfall causes erosion, thereby progressively exposing more coal to the oxygen in the atmosphere. Very high ash carbonaceous shales will also spontaneously combust under the right conditions, particularly if they contain high levels of kerogen (a mixture of organic chemical compounds that make up a portion of the organic matter in sedimentary rocks.) These shales provide a major source of additional fuel for coal induced fires. Many strip mines have severe spontaneous combustion in the spoil heaps.

Notable toxic gases produced by spontaneous combustion include:

- Sulphur dioxide ($SO_2$)
- Oxides of nitrogen ($NO_x$),
- Hydrogen sulphide ($H_2S$) (also flammable)
- Carbon monoxide (CO) (also flammable).

### 3.3.8 Other Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling) and mining. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways.

## 3.4 Measured Baseline Air Quality

### 3.4.1 Dust Fallout

Tweefontein North operates a dust fallout monitoring network. The dust fallout network as provided in the first quarter of 2012 is given in Figure 3-8.

The measured dust fallout levels for the period 2011/2012 that was provided for the assessment are illustrated in Figure 3-9 to Figure 3-11 and provided in Table 3-1.

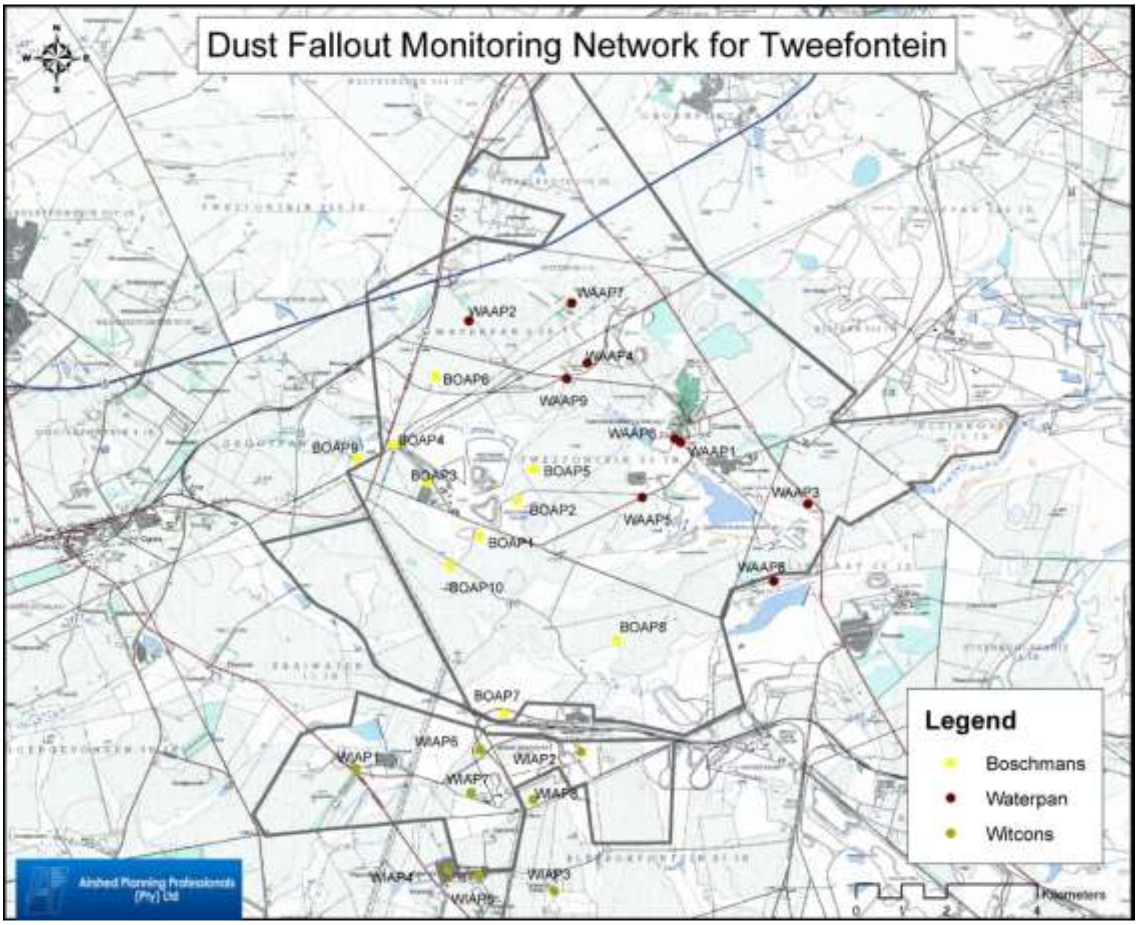


**Figure 3-8: Tweefontein dust fallout network (as provided in 2012)**

**Table 3-1: Dust fallout sampling (mg/m²/day) for Tweefontein North dust deposition monitoring network (January 2011 to April 2012) [(a)]**

| Site | Jan - 11 | Feb - 11 | Mar - 11 | Apr - 11 | May - 11 | Jun - 11 | Jul - 11 | Aug - 11 | Sep - 11 | Oct - 11 | Nov - 11 | Dec - 11 | Jan - 12 | Feb - 12 | Mar - 12 | Apr - 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOAP1 | | | | 565 | 125 | | | 207 | 629 | 443 | 669 | | | 689 | | |
| BOAP2 | | | 229 | 231 | 137 | | | 281 | 674 | 361 | 303 | | 284 | 246 | 0 | 221 |
| BOAP3 | | | 251 | 211 | 78 | | 153 | 323 | 323 | 654 | 389 | | 412 | 535 | 0 | 351 |
| BOAP4 | | | 188 | | | | 230 | 276 | 607 | 793 | 425 | | 992 | 376 | 1 | 110 |
| BOAP5 | | | 132 | 339 | 127 | | | 279 | 688 | 1177 | 677 | | 537 | 219 | 0 | 499 |
| BOAP6 | | | | | | | | 231 | 283 | 295 | 505 | | 185 | 364 | 0 | 633 |
| BOAP7 | | | | | | | | | | | | | | | | |
| BOAP8 | | | 341 | | 33 | | 108 | 380 | 519 | 287 | 401 | | 591 | 537 | 1 | 662 |
| BOAP9 | | | 129 | 99 | 79 | | 97 | 172 | 210 | 471 | 256 | | 219 | 238 | 0 | 205 |
| BOAP10 | | | | | 137 | | | 373 | | 1096 | 1083 | | 1585 | 1029 | 0 | 141 |
| WAAP1 | | | 583 | 338 | 290 | | 289 | 348 | 302 | 802 | 687 | | 462 | 857 | 0 | 631 |
| WAAP2 | | | | 419 | 294 | | 182 | 195 | 526 | 474 | 468 | | 207 | 241 | 0 | 454 |
| WAAP3 | | | 250 | | | | | | | | | | 397 | 836 | 0 | 454 |
| WAAP4 | | | | 140 | 359 | | 145 | 273 | 530 | 347 | 293 | | 226 | 642 | 0 | 389 |
| WAAP5 | | | 4481 | 2011 | 1120 | | 2263 | 1762 | 626 | 4366 | 2298 | | 2476 | | | 284 |
| WAAP6 | | | 382 | 244 | 89 | | 655 | 642 | 656 | 668 | 2203 | | 575 | 418 | 1 | 151 |
| WAAP7 | | | | | 197 | | 203 | 193 | 310 | 355 | 473 | | 467 | 1170 | 1 | 248 |
| WAAP8 | | | | 784 | 148 | | | 165 | 690 | 586 | 472 | | 746 | 777 | 0 | 281 |
| WAAP9 | | | 1085 | 977 | 6146 | | 1223 | 1793 | 3471 | 4192 | 1988 | | 3027 | | | 434 |
| WIAP1 | | | 173 | 289 | 125 | | 121 | 209 | 503 | 293 | 254 | | 192 | 172 | 0 | 137 |
| WIAP2 | | | 231 | 116 | 256 | | 216 | 581 | 608 | 602 | 507 | | 313 | 369 | 0 | 345 |

| Site | Jan - 11 | Feb - 11 | Mar - 11 | Apr - 11 | May - 11 | Jun - 11 | Jul - 11 | Aug - 11 | Sep - 11 | Oct - 11 | Nov - 11 | Dec - 11 | Jan - 12 | Feb - 12 | Mar - 12 | Apr - 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WIAP3 | | | | | | | | | | | | | | | | |
| WIAP4 | | | 266 | 125 | 193 | | 121 | 646 | 478 | 397 | 521 | | 378 | 187 | 0 | 347 |
| WIAP5 | | | 270 | 216 | 163 | | 235 | 513 | 1063 | 703 | 1341 | | 259 | 331 | 0 | 428 |
| WIAP6 | | | | | | | | 158 | 759 | 465 | 228 | | 169 | 196 | 0 | 187 |
| WIAP7 | | | | | | | | 1 | | 189 | 291 | | 264 | 211 | | 217 |
| WIAP8 | | | | | | | | | | | | | | | | |

(a) Directional buckets are highlighted in blue

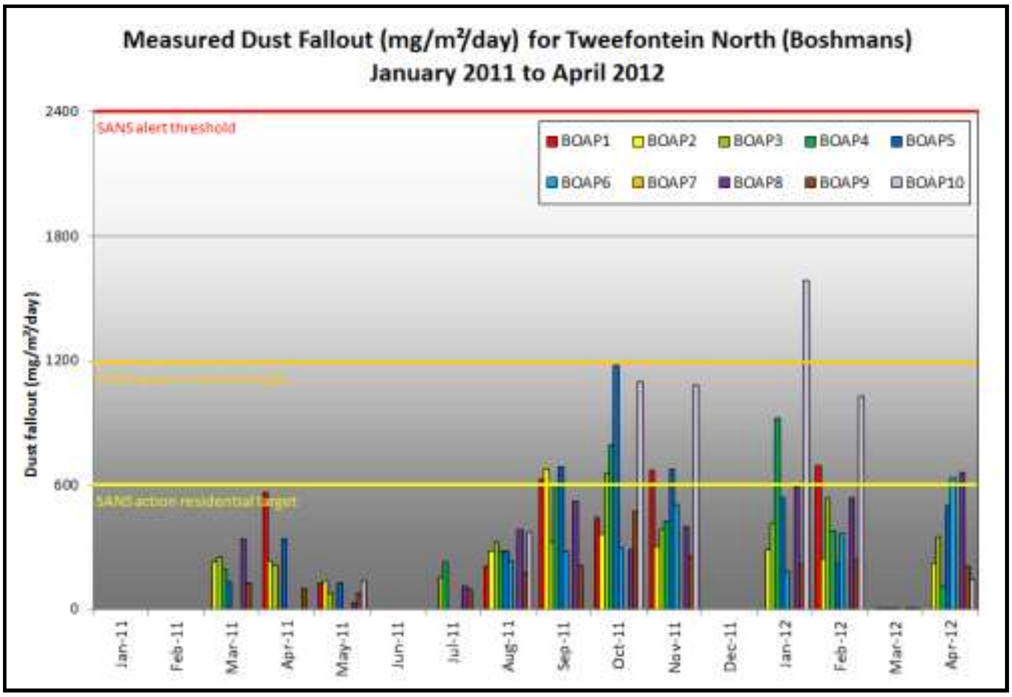


**Figure 3-9: Dustfall sampling for the Tweefontein Colliery (Boshmans) dust deposition monitoring network (January 2011 to April 2012)**

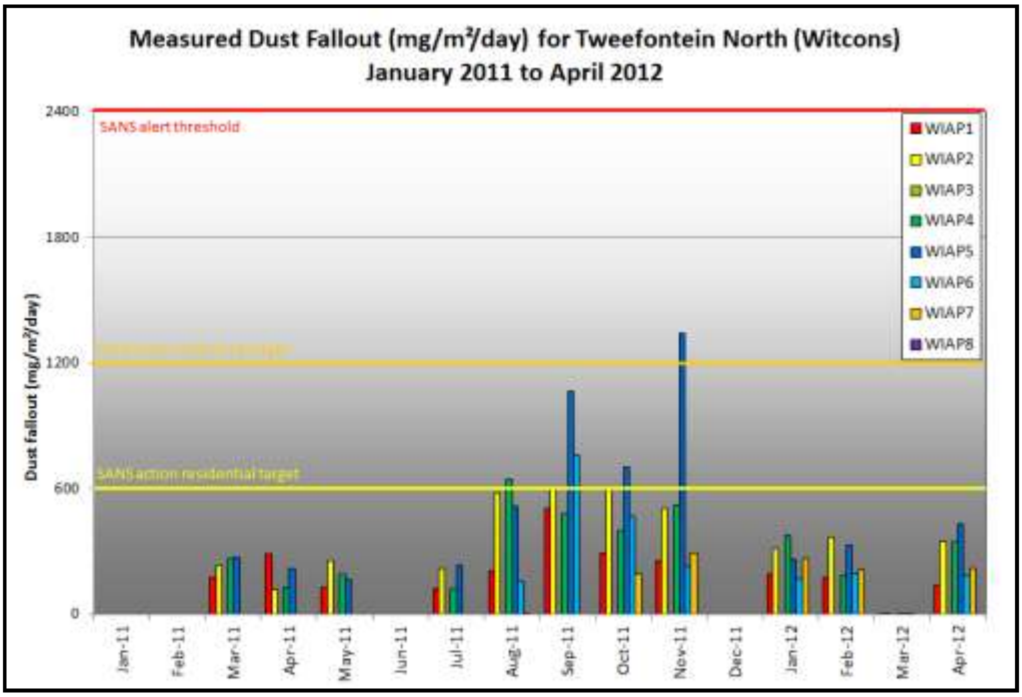


**Figure 3-10: Dustfall sampling for the Tweefontein Colliery (Witcons) dust deposition monitoring network (January 2011 to April 2012)**

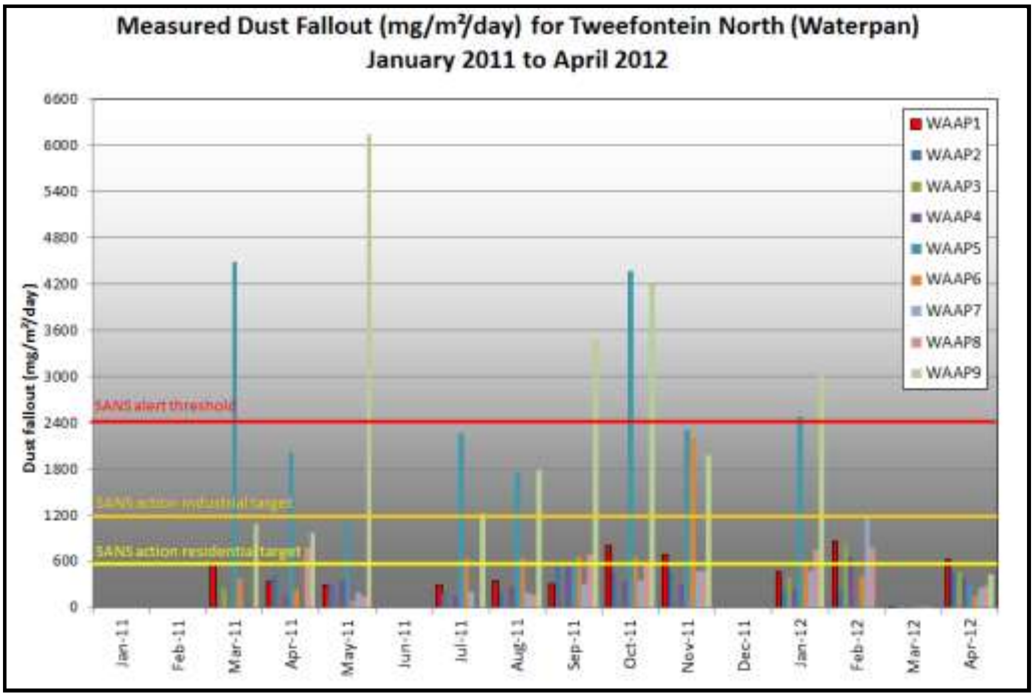


**Figure 3-11: Dustfall sampling for the Tweefontein Colliery (Waterpan) dust deposition monitoring network (January 2011 to April 2012)**

### 3.4.2 Inhalable Particulate Matter

The poor ambient air quality in Emahaleni is a result of emissions from power generation, metallurgical manufacturing processes, open-cast coal mining and residential fuel burning; where industrial processes dominate the source contribution (DEA, 2011). Dispersion modelling, undertaken as part of the Highveld Priority Area Air Quality Management Plan, projected exceedances of the daily $PM_{10}$ limit for more than 12 days across Emahaleni (DEA, 2011). Monitored daily $PM_{10}$ concentrations within the area, at Witbank and Greendale High School show regular exceedances of the daily limit, between 2008 and 2012 (Figure 3-12). The Highveld Priority Area Air Quality Management Plan Air Quality Management Plan (2011) reported exceedance of the annual national ambient air quality standard for $PM_{10}$, for 2008 / 2009, at one of the two monitoring stations in Emahaleni (viz. Witbank) with an annual average of ~83 µg/m³.

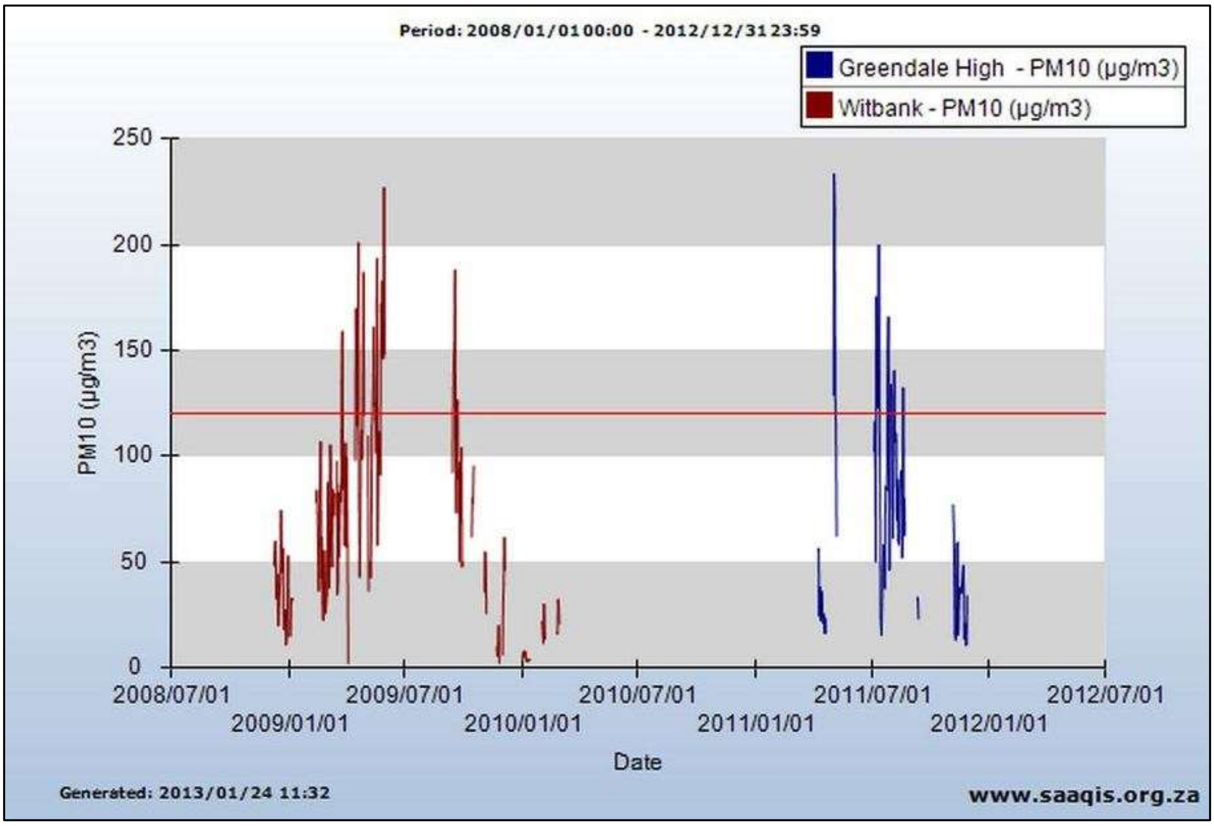


**Figure 3-12: Daily $PM_{10}$ concentrations monitored at two stations in the Emahaleni Hot Spot between 2008 and 2012 (from www.saaqis.org.za). The horizontal red line indicates the current daily limit of 120 µg/m³.**

# 4 AIR QUALITY IMPACT ASSESSMENT

## 4.1 Construction Activities

### 4.1.1 Identification of Environmental Aspects and Impact Classification

Construction normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. It is anticipated that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle.

A list of all the potential dust generation activities expected during the construction phase is provided in Table 4-1. Unmitigated construction activities provide the potential for impacts on local communities, primarily due to nuisance and aesthetic impacts associated with fugitive dust emissions. On-site dustfall may also represent a nuisance to employees.

**Table 4-1: Typical sources of fugitive particulate emission associated with construction**

| Impact | Source | Activity |
|---|---|---|
| TSP, $PM_{10}$ and $PM_{2.5}$ | Plant/mine site | Clearing of groundcover |
| | | Levelling of area |
| | | Infrastructure edifice (on site roads, storage areas, plant infrastructure, offices, workshops) |
| | | Wind erosion from open areas |
| | | Materials handling |
| | Transport infrastructure | Clearing of vegetation and topsoil |
| | | Levelling of proposed transportation route areas |

### 4.1.2 Mitigation Measures Recommended

Incremental $PM_{2.5}$, $PM_{10}$ concentrations and deposition rates due to the Construction Phase will be of relatively short-term and of local impact. The implementation of effective controls, however, during this phase would also serve to set the president for mitigation during the operational phase.

Dust control measures which may be implemented during the construction phase are outlined in Table 4-2. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures.

**Table 4-2: Dust control measures that may be implemented during construction activities**

| Construction Activity | Recommended Control Measure(s) |
|---|---|
| Debris handling | Wet suppression |
| Truck transport and road dust entrainment | Wet suppression or chemical stabilization of unpaved roads<br>Haul trucks to be restricted to specified haul roads<br>Reduction of unnecessary traffic<br>Strict speed control |
| Materials storage, handling and transfer operations | Wet suppression where feasible |
| Earthmoving operations | Wet suppression where feasible |
| Open areas (wind-blown emissions) | Reduction of extent of open areas<br>Reduction of frequency of disturbance<br>Early re-vegetation<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil |

## 4.2 Operational Phase

The operations at the Tweefontein Optimisation Project Amendment comprise of underground and opencast mining operation, road, rail, crushing and screening, dragline activities and materials handling. The throughput of Run of Mine (ROM) material was provided for the calculation of the emissions from operations (Table 4-3).

**Table 4-3: Run of Mine throughput for the Tweefontein Optimisation Project Amendment**

| Operational Year | Complex Total (tpa) | | |
|---|---|---|---|
| | Underground | Opencast | Underground and Opencast |
| 2013 | 6 696 461 | 5 981 287 | 12 677 747 |
| 2014 | 6 442 903 | 4 217 620 | 10 660 522 |
| 2015 | 7 233 728 | 5 892 472 | 13 126 201 |
| 2016 | 7 920 000 | 7 902 567 | 15 822 567 |
| 2017 | 7 920 000 | 10 545 926 | 18 465 926 |
| 2018 | 7 770 000 | 11 761 764 | 19 531 764 |
| 2019 | 7 200 000 | 11 308 489 | 18 508 489 |
| 2020 | 7 118 286 | 11 494 594 | 18 612 880 |
| 2021 | 5 280 000 | 13 766 951 | 19 046 951 |
| 2022 | 5 280 000 | 12 140 352 | 17 420 352 |
| 2023 | 4 991 062 | 11 200 543 | 16 191 605 |
| 2024 | 3 120 000 | 13 341 632 | 16 461 632 |
| 2025 | 3 120 000 | 13 337 829 | 16 457 829 |
| 2026 | 3 120 000 | 13 341 860 | 16 461 860 |
| 2027 | 3 120 000 | 13 044 381 | 16 164 381 |
| 2028 | 2 484 949 | 13 259 278 | 15 744 227 |
| 2029 | - | 19 243 385 | 19 243 385 |
| 2030 | - | 15 021 819 | 15 021 819 |
| 2031 | - | 12 177 150 | 12 177 150 |
| 2032 | - | 11 745 885 | 11 745 885 |
| 2033 | - | 10 320 025 | 10 320 025 |
| 2034 | - | 9 435 741 | 9 435 741 |
| 2035 | - | 6 739 465 | 6 739 465 |
| 2036 | - | 1 489 630 | 1 489 630 |
| 2037 | | | - |

Four scenarios were selected for the impact assessment, namely:

- Year 2013: baseline operations;
- Year 2018: maximum ROM throughput for the Tweefontein Optimisation Project Amendment;
- Year 2029: maximum ROM throughput from opencast mining activities for the Tweefontein Optimisation Project Amendment;
- Year 2036: final year of ROM throughput information provided.

### 4.2.1 Emissions Inventory

A detailed description of the emission factors used for the current assessment is given in Appendix A.

#### 4.2.1.1 Wind Erosion

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger, et al., 1995).

An hourly emissions file was created for the storage piles and tailings facilities at the site. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model.

The particle size distribution of the storage pile material used for the assessment was assumed from similar operations and is given in Table 4-4.

**Table 4-4: Particle size distribution (as a fraction) for the storage pile material**

| Size µm | Product | Discard | Export | ROM |
|---|---|---|---|---|
| 754 | 0.0000 | 0.0254 | 0.0026 | 0.0047 |
| 647 | 0.0019 | 0.0484 | 0.0079 | 0.0083 |
| 409 | 0.0616 | 0.2251 | 0.0537 | 0.0424 |
| 301 | 0.1187 | 0.1615 | 0.0577 | 0.0535 |
| 190 | 0.2171 | 0.1840 | 0.0984 | 0.1123 |
| 103 | 0.1785 | 0.1388 | 0.1407 | 0.1428 |
| 76 | 0.0521 | 0.0387 | 0.0736 | 0.1168 |
| 56 | 0.0450 | 0.0275 | 0.0708 | 0.0728 |
| 30 | 0.0866 | 0.0365 | 0.1198 | 0.1135 |
| 19 | 0.0557 | 0.0197 | 0.0720 | 0.0664 |
| 16 | 0.0160 | 0.0061 | 0.0221 | 0.0200 |
| 10 | 0.0421 | 0.0179 | 0.0627 | 0.0563 |

| Size µm | Product | Discard | Export | ROM |
|---|---|---|---|---|
| 4 | 0.0652 | 0.0327 | 0.1056 | 0.0940 |
| 2 | 0.0340 | 0.0195 | 0.0596 | 0.0523 |
| 1 | 0.0255 | 0.0182 | 0.0528 | 0.0439 |

#### *4.2.1.2 Crushing and Screening Operations*

Crushing represents significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of crushers also gives rise to the potential for the re-entrained of dust emitted by vehicles or by the wind at a later date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne.

A single valued NPi emission factor was used in the quantification of possible emissions due to crushing activities (with high moisture ore of more than 4%).

#### *4.2.1.3 Fugitive Dust Emissions from Materials Handling Operations*

Materials handling operations associated with the activities for the Project include the transfer of material by means of tipping, loading and off-loading. The quantity of dust that will be generated from such operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

The quantity of dust generated from the material transfer points for Tweefontein Optimisation Project Amendment was based on the throughput of material provided.

The $PM_{2.5}$ and $PM_{10}$ fraction of the TSP was assumed to be 5.3% and 35% respectively. An average wind speed of 3.47 m/s was used based on meteorological data for the period January 2009 to August 2012.

**Table 4-5: Average throughput of material due to materials handling activities**

| Description | tph |
|---|---|
| **Year 2013** | |
| Loading of ore at opencast pit (3 opencast areas) | 228 |
| Tipping of ore at pit into haul trucks (3 opencast areas) | 228 |
| Offloaded of ore at plant | 683 |
| Loading of ore at plant | 1 447 |
| Tipping of ore to crusher | 1 447 |
| Tipped from crusher to stockpile | 1 447 |
| Reclaimed from stockpile | 1 447 |
| Tipped into rail carts | 548 |
| Loading of waste at pit (3 opencast areas) | 669 |
| Tipping of waste into haul trucks (3 opencast areas) | 669 |
| Backfilling (3 opencast areas) | 669 |
| Tipping of ore from underground operations to haul truck | 764 |
| Offloading of ore from underground operations at plant | 764 |
| **Year 2018** | |
| Loading of ore at opencast pit (3 opencast areas) | 448 |
| Tipping of ore at pit into haul trucks (3 opencast areas) | 448 |
| Offloaded of ore at plant | 1 343 |
| Loading of ore at plant | 2 230 |
| Tipping of ore to crusher | 2 230 |
| Tipped from crusher to stockpile | 2 230 |
| Reclaimed from stockpile | 2 230 |
| Tipped into rail carts | 548 |
| Loading of waste at pit (3 opencast areas) | 1 316 |
| Tipping of waste into haul trucks (3 opencast areas) | 1 316 |
| Backfilling (3 opencast areas) | 1 316 |
| Tipping of ore from underground operations to haul truck | 887 |
| Offloading of ore from underground operations at plant | 887 |
| **Year 2029** | |
| Loading of ore at opencast pit (3 opencast areas) | 732 |
| Tipping of ore at pit into haul trucks (3 opencast areas) | 732 |
| Offloaded of ore at plant | 2 197 |
| Loading of ore at plant | 2 197 |
| Tipping of ore to crusher | 2 197 |
| Tipped from crusher to stockpile | 2 197 |
| Reclaimed from stockpile | 2 197 |
| Tipped into rail carts | 548 |
| Loading of waste at pit (3 opencast areas) | 2 153 |
| Tipping of waste into haul trucks (3 opencast areas) | 2 153 |
| Backfilling (3 opencast areas) | 2 153 |
| **Year 2036** | |
| Loading of ore at opencast pit (2 opencast areas) | 85 |
| Tipping of ore at pit into haul trucks (2 opencast areas) | 85 |
| Offloaded of ore at plant | 170 |

| Description | tph |
|---|---|
| Loading of ore at plant | 170 |
| Tipping of ore to crusher | 170 |
| Tipped from crusher to stockpile | 170 |
| Reclaimed from stockpile | 170 |
| Tipped into rail carts | 548 |
| Loading of waste at pit (2 opencast areas) | 250 |
| Tipping of waste into haul trucks (2 opencast areas) | 250 |
| Backfilling (2 opencast areas) | 250 |

#### *4.2.1.4 Vehicle Entrained Dust from Roads*

In the absence of site specific silt data, use was made of US EPA default mean silt content of 8.4%. The trucks used for Tweefontein operations were provided as 140t trucks. This information was used to calculate the emissions from this fugitive dust source for the movement of material onsite. These fugitive dust sources were modelled as unmitigated and mitigated activities were 75% control efficiency was assumed through the use of water suppression.

#### *4.2.1.5 Drilling and Blasting*

Drilling and blasting operations represent intermittent sources of fugitive dust emissions. The drilling and blasting parameters utilised for the quantification of these fugitive sources were provided (Table 4-6). No control efficiencies were assumed for the drilling activities.

**Table 4-6: Information received to quantify drilling and blasting activities**

| Description | Information received |
|---|---|
| Drilling Information | Coal:<br>• Burden: 5m<br>• Spacing: 5m<br>Interburden:<br>• Burden: 7m<br>• Spacing: 11m<br>Overburden: |

| Description | Information received |
| --- | --- |
| | • Burden: 6m<br>• Spacing: 6m |
| Number of blasts per week (per source) | 2 to 3/per week |
| Horizontal surface area being blasted at one time ($m^2$) | 15000m² |

#### *4.2.1.6 Vent Shafts*

Vent shaft parameter data was provided (Table 4-7). The Occupational Exposure Limit (OEL) of 10 mg/m³ for respirable particulate matter was assumed for the vent exhaust concentration.

**Table 4-7: Parameters for the vent shafts**

| Description | Quantity | Unit |
| --- | --- | --- |
| Release height | 3.5 | m |
| Exit velocity | 12 | m/s |
| Diameter | 6.5 | m |
| Temperature | 25 | °C |
| Inhalable particulate matter | 10 | mg/m³ |

#### *4.2.1.7 Summary of Emissions*

Emissions calculated for various source types are given in Table 4-8 and Table 4-9. TSP, $PM_{10}$ and $PM_{2.5}$ source contributions are provided in Figure 4-1 to Figure 4-4 for unmitigated operations. For unmitigated Tweefontein Optimisation Project Amendment operations, emissions due to vehicle entrainment represent the largest source of particulate emissions (TSP and $PM_{10}$).

**Table 4-8: Calculated particulate emissions for unmitigated Tweefontein Optimisation Project Amendment activities**

| Description | Emissions (TPA) | | |
| --- | --- | --- | --- |
| | TSP | $PM_{10}$ | $PM_{2.5}$ |
| **2013** | | | |
| Vehicle entrainment | 1 286.55 | 696.78 | 69.68 |
| Materials Handling | 218.70 | 103.44 | 15.66 |

| Description | Emissions (TPA) | | |
|---|---|---|---|
| | TSP | $PM_{10}$ | $PM_{2.5}$ |
| Crushing and screening | 735.31 | 273.84 | 50.66 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 275.71 | 109.68 | 78.81 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *2 867.74* | *1 311.25* | *293.17* |
| **2018** | | | |
| Vehicle entrainment | 1 695.21 | 918.10 | 91.81 |
| Materials Handling | 372.05 | 175.97 | 26.65 |
| Crushing and screening | 1 132.84 | 421.89 | 78.05 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 274.89 | 109.35 | 78.32 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *3 826.46* | *1 752.82* | *353.18* |
| **2029** | | | |
| Vehicle entrainment | 2 428.82 | 1 315.42 | 131.54 |
| Materials Handling | 371.24 | 175.59 | 26.59 |
| Crushing and screening | 1 116.12 | 415.66 | 76.90 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 298.50 | 118.98 | 92.49 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *4 566.15* | *2 153.15* | *405.87* |
| **2036** | | | |
| Vehicle entrainment | 374.47 | 202.81 | 20.28 |
| Materials Handling | 35.68 | 16.87 | 2.56 |
| Crushing and screening | 86.40 | 32.18 | 5.95 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 271.36 | 107.91 | 76.20 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *1 119.38* | *487.28* | *183.35* |

**Table 4-9: Calculated particulate emissions for mitigated[(a)] Tweefontein Optimisation Project Amendment activities**

| Description | Emissions (TPA) | | |
|---|---|---|---|
| | TSP | $PM_{10}$ | $PM_{2.5}$ |
| **2013** | | | |
| Vehicle entrainment | 322 | 174 | 17 |
| Materials Handling | 204.80 | 96.86 | 14.67 |
| Crushing and screening | 367.65 | 136.92 | 25.33 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 275.71 | 109.68 | 78.81 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *1 521.28* | *645.17* | *214.59* |
| **2018** | | | |
| Vehicle entrainment | 423.80 | 229.53 | 22.95 |
| Materials Handling | 350.63 | 165.84 | 25.11 |
| Crushing and screening | 566.42 | 210.94 | 39.02 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |

| Description | Emissions (TPA) | | |
|---|---|---|---|
| | TSP | $PM_{10}$ | $PM_{2.5}$ |
| Wind erosion | 274.89 | 109.35 | 78.32 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *1 967.22* | *843.17* | *243.77* |
| **2029** | | | |
| Vehicle entrainment | 607.20 | 328.85 | 32.89 |
| Materials Handling | 350.14 | 165.61 | 25.08 |
| Crushing and screening | 558.06 | 207.83 | 38.45 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 298.50 | 118.98 | 92.49 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *2 165.37* | *948.78* | *267.26* |
| **2036** | | | |
| Vehicle entrainment | 93.62 | 50.70 | 5.07 |
| Materials Handling | 34.04 | 16.10 | 2.44 |
| Crushing and screening | 43.20 | 16.09 | 2.98 |
| Drilling and blasting | 100.32 | 52.17 | 3.01 |
| Wind erosion | 271.36 | 107.91 | 76.20 |
| Ventilation shafts | 251.15 | 75.35 | 75.35 |
| *Total* | *793.69* | *318.31* | *165.04* |

(a) 75% control efficiency on haul roads and 50% control efficiency on crushing activities

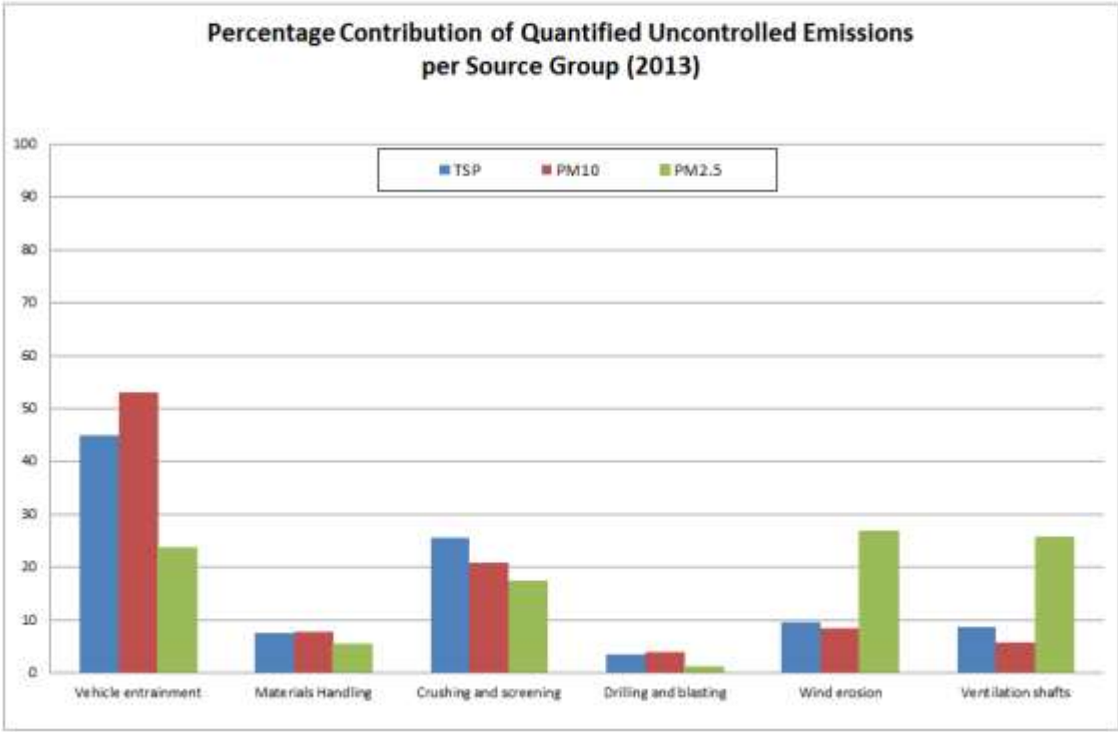


**Figure 4-1: Calculated particulate emissions due to unmitigated Tweefontein Optimisation Project Amendment operations for the year 2013**

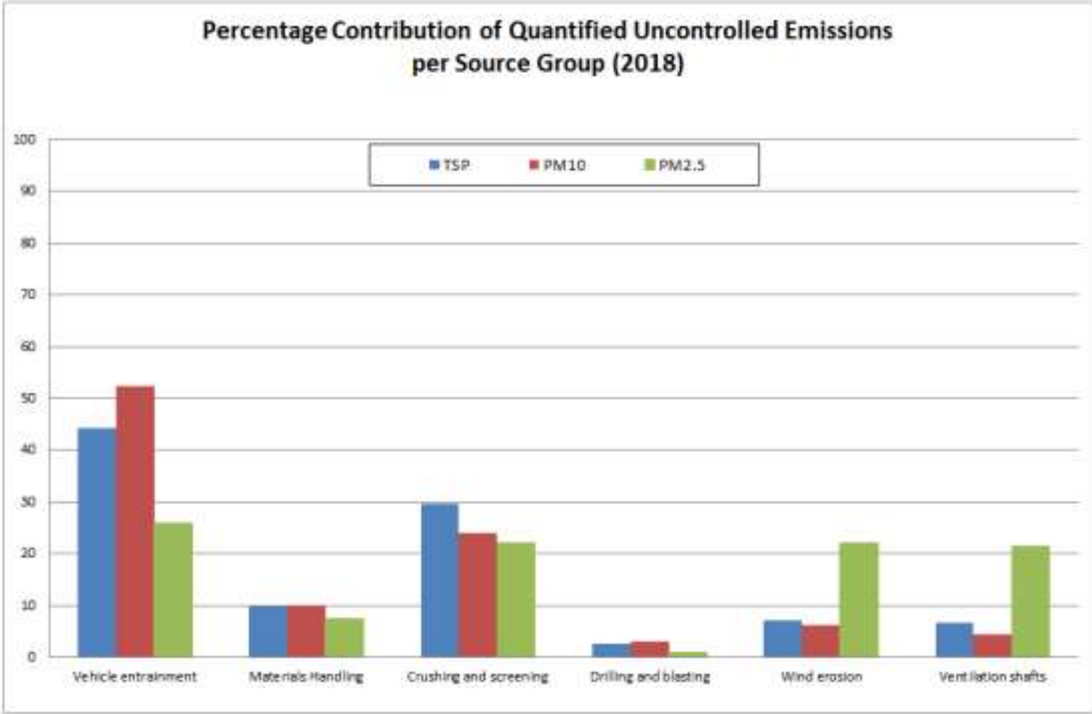


**Figure 4-2: Calculated particulate emissions due to unmitigated Tweefontein Optimisation Project Amendment operations for the year 2018**

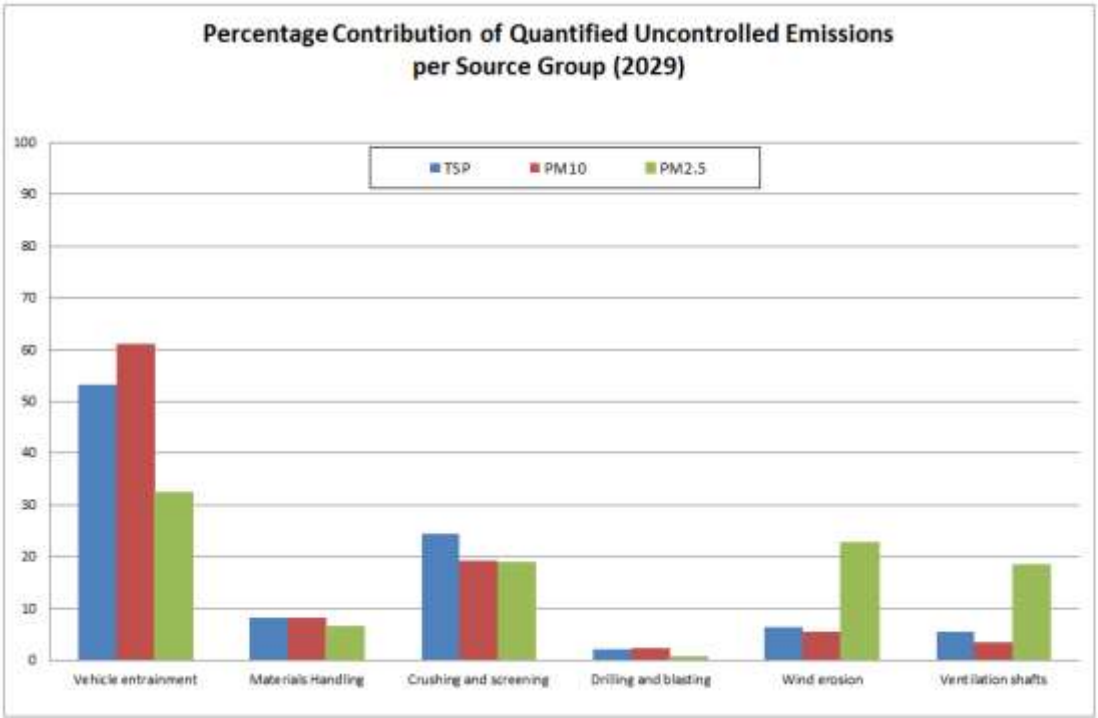


**Figure 4-3: Calculated particulate emissions due to unmitigated Tweefontein Optimisation Project Amendment operations for the year 2029**

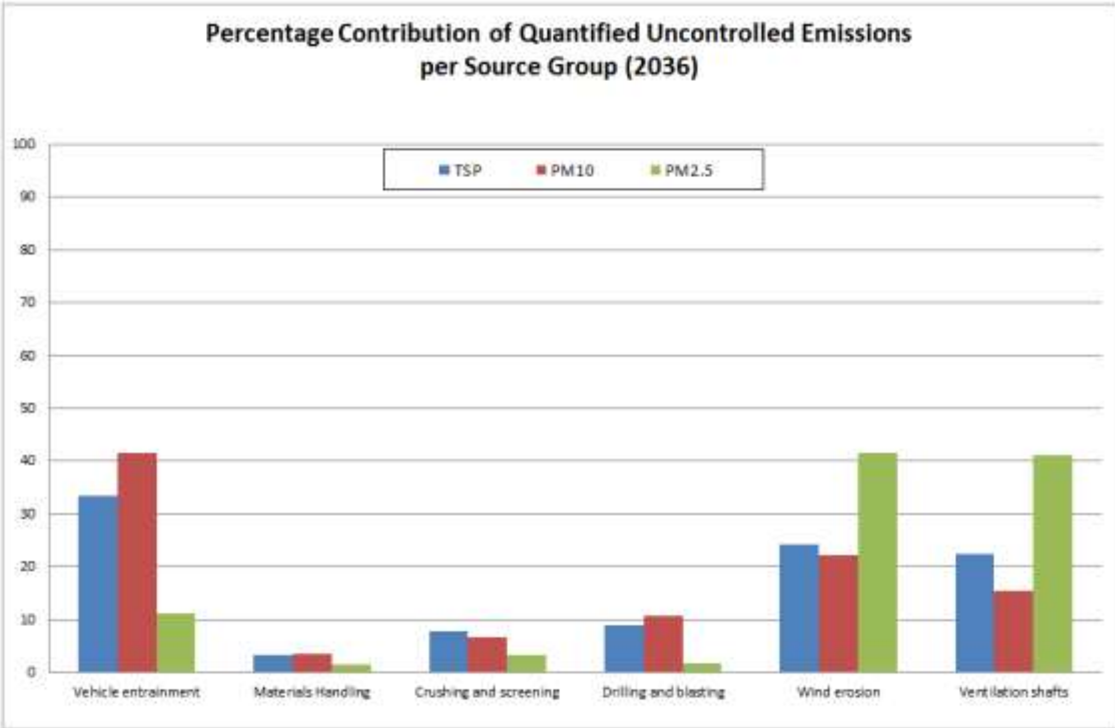


**Figure 4-4: Calculated particulate emissions due to unmitigated Tweefontein Optimisation Project Amendment operations for the year 2036**

### 4.2.2 Dispersion Simulation Results

The plots provided for the relevant pollutants of concern are given in Table 4-10. Only plots where exceedances of the National Ambient Air Quality Standards (NAAQS) were included. Deposition impacts were also included in the current section. The predicted impacts are due to operations at the Tweefontein Optimisation Project Amendment only.

Isopleth plots reflecting hourly/daily averaging periods contain only the highest predicted ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. *It is therefore possible that even though a high hourly/daily concentration is predicted to occur at certain locations, that this may only be true for one hour/day during the entire period.*

**Table 4-10: Isopleth plots presented in the current section**

| Operating Year | Phase | Pollutant | Averaging Period | Figure |
|---|---|---|---|---|
| *2013* | *Operation (no mitigation)* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-5<br>4-13 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-21<br>4-29 |
| | | Dustfall | Maximum daily | 4-37 |
| | *Operation (mitigated operations [(a)])* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-6<br>4-14 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-22<br>4-30 |
| | | Dustfall | Maximum daily | 4-38 |
| *2018* | *Operation (no mitigation)* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-7<br>4-15 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-23<br>4-31 |
| | | Dustfall | Maximum daily | 4-39 |
| | *Operation (mitigated operations [(a)])* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-8<br>4-16 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-24<br>4-32 |
| | | Dustfall | Maximum daily | 4-40 |
| *2029* | *Operation (no mitigation)* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-9<br>4-17 |

| Operating Year | Phase | Pollutant | Averaging Period | Figure |
|---|---|---|---|---|
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-25<br>4-33 |
| | | Dustfall | Maximum daily | 4-41 |
| | *Operation (mitigated operations [(a)])* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-10<br>4-18 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-26<br>4-34 |
| | | Dustfall | Maximum daily | 4-42 |
| *2036* | *Operation (no mitigation)* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-11<br>4-19 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-27<br>4-35 |
| | | Dustfall | Maximum daily | 4-43 |
| | *Operation (mitigated operations [(a)])* | $PM_{2.5}$ | Highest daily<br>Annual average | 4-12<br>4-20 |
| | | $PM_{10}$ | Highest daily<br>Annual average | 4-28<br>4-36 |
| | | Dustfall | Maximum daily | 4-44 |

(a) 75% control efficiency on haul roads and 50% control efficiency on crushing activities

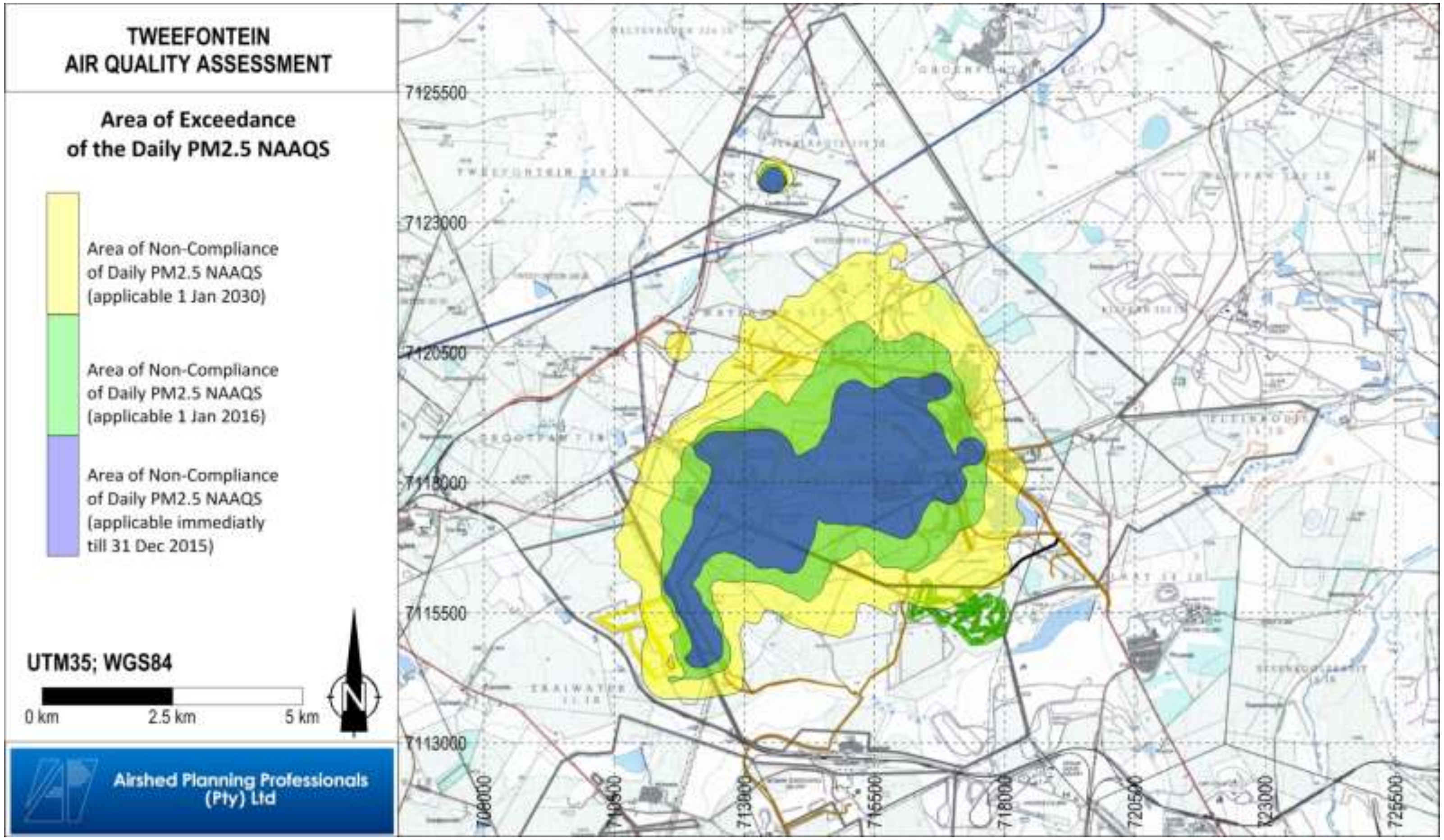


**Figure 4-5: Area of exceedance of daily $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

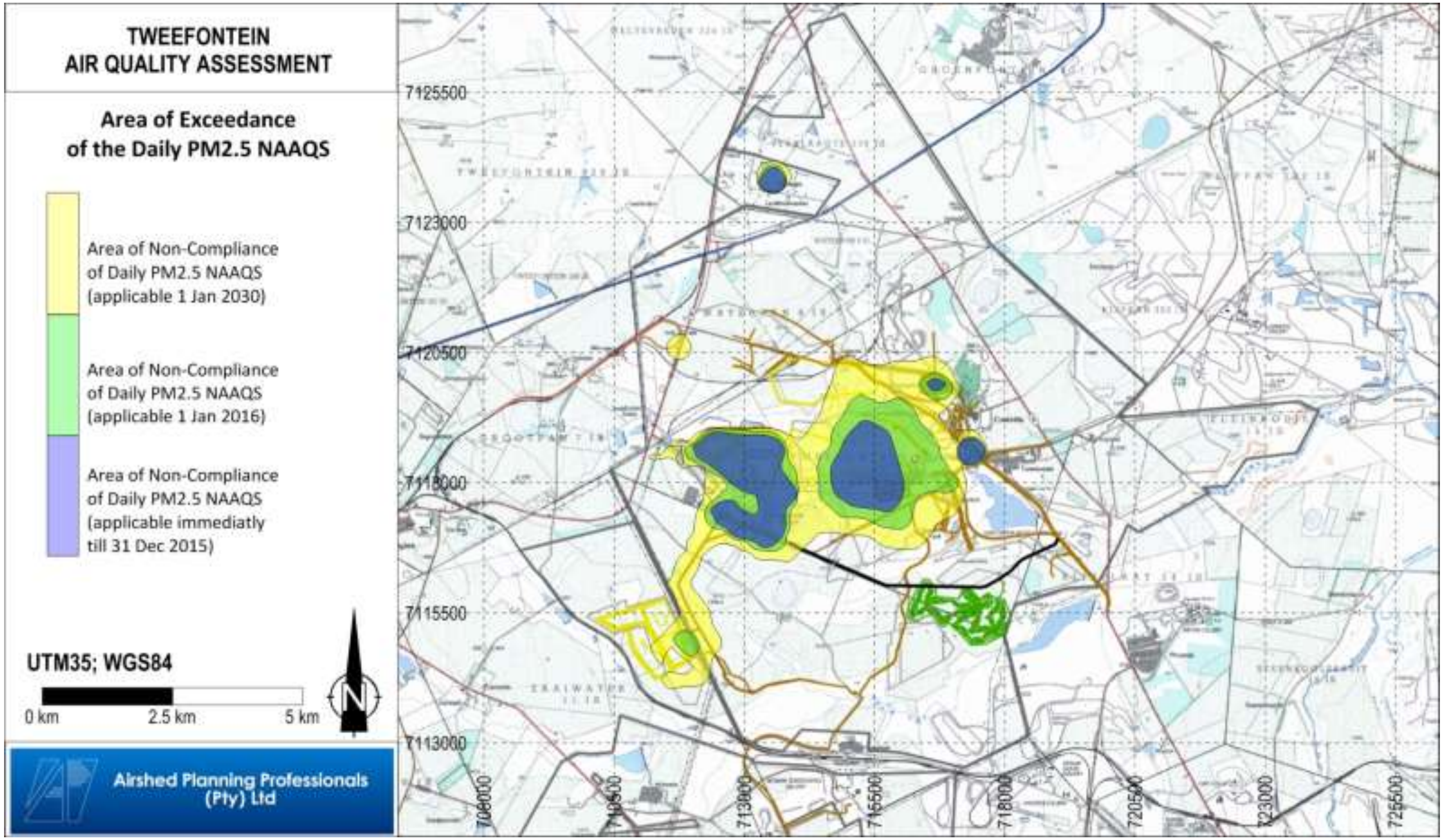


**Figure 4-6: Area of exceedance of daily $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

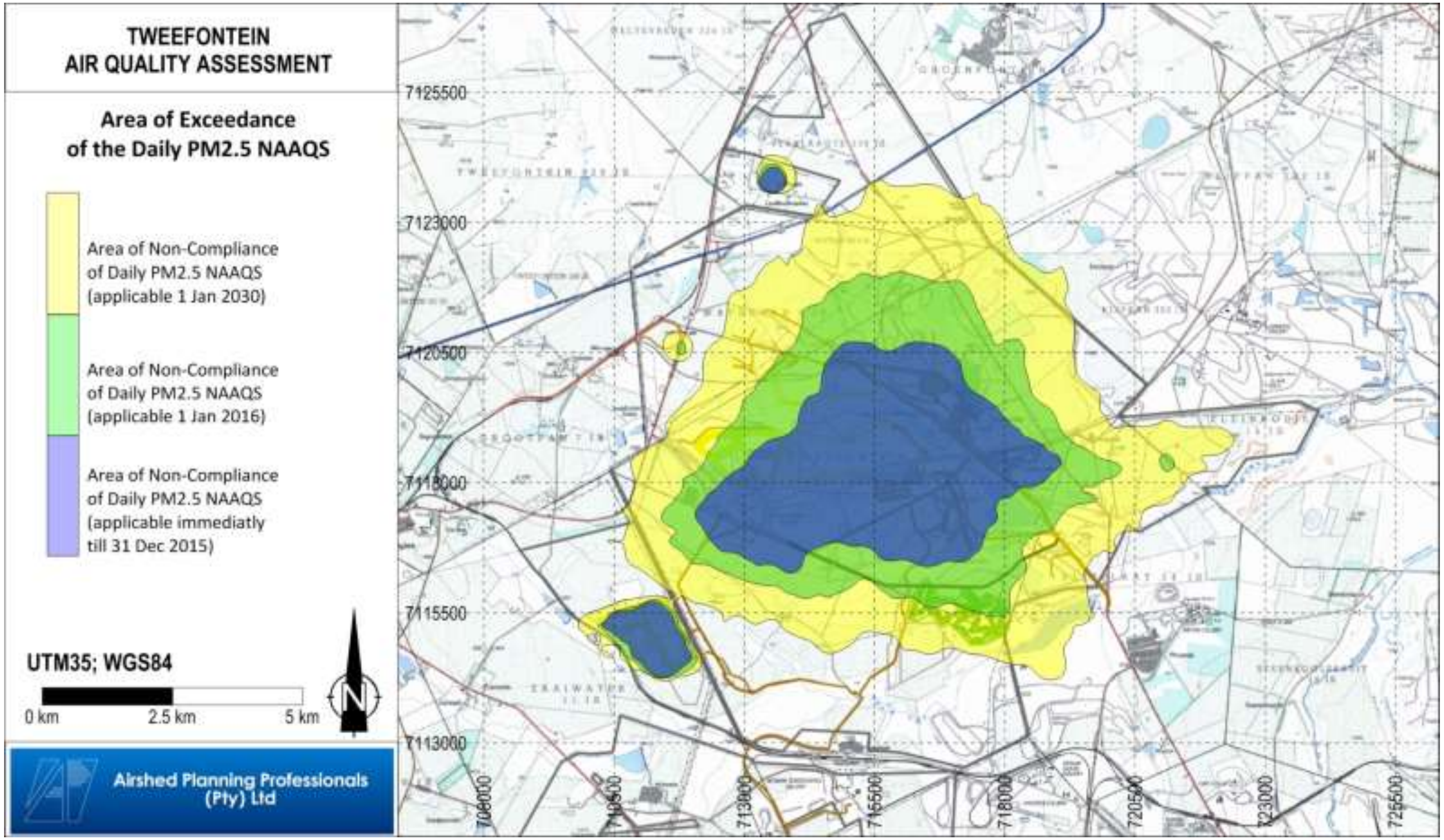


**Figure 4-7: Area of exceedance of daily $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

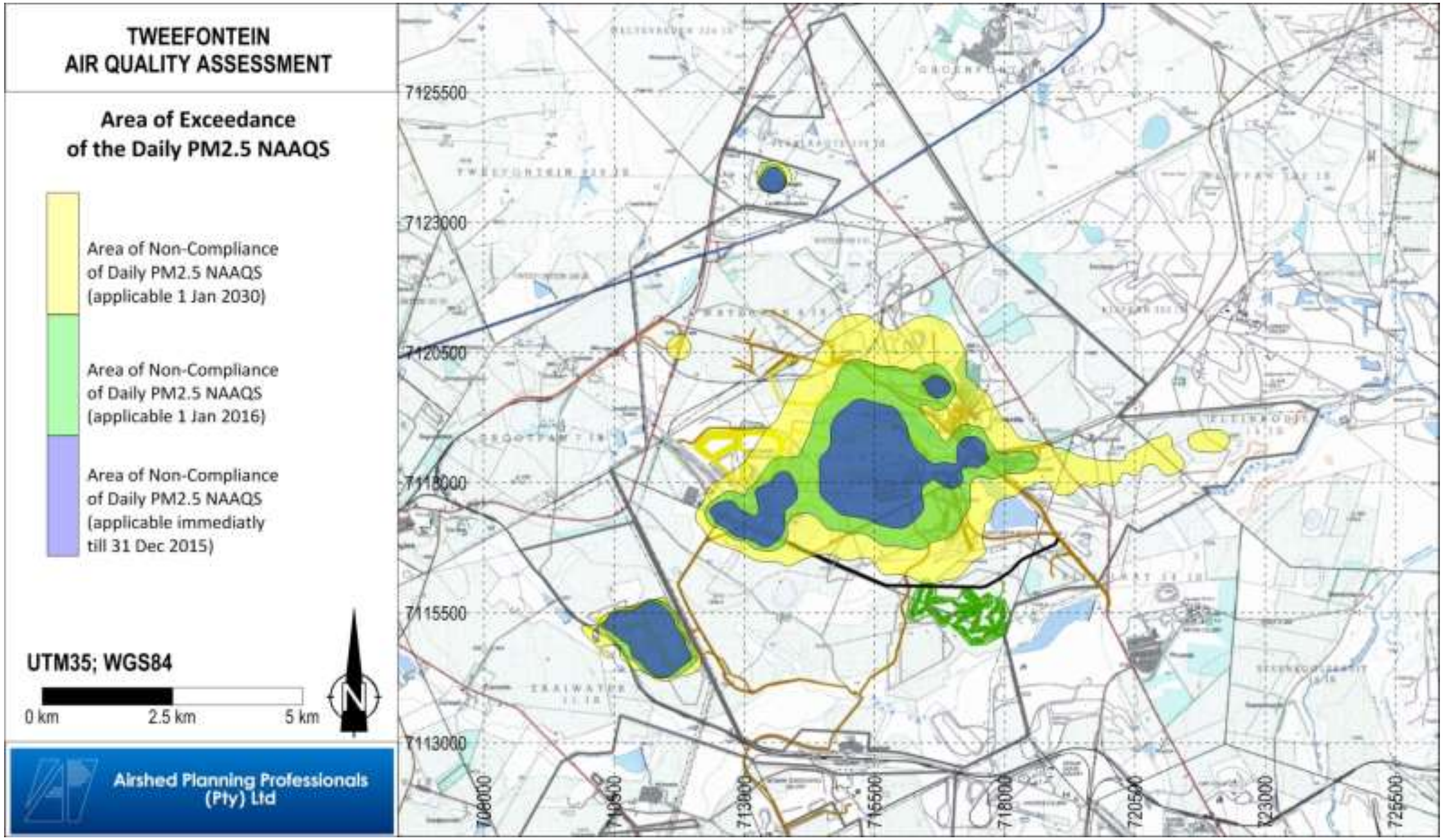


**Figure 4-8: Area of exceedance of daily $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

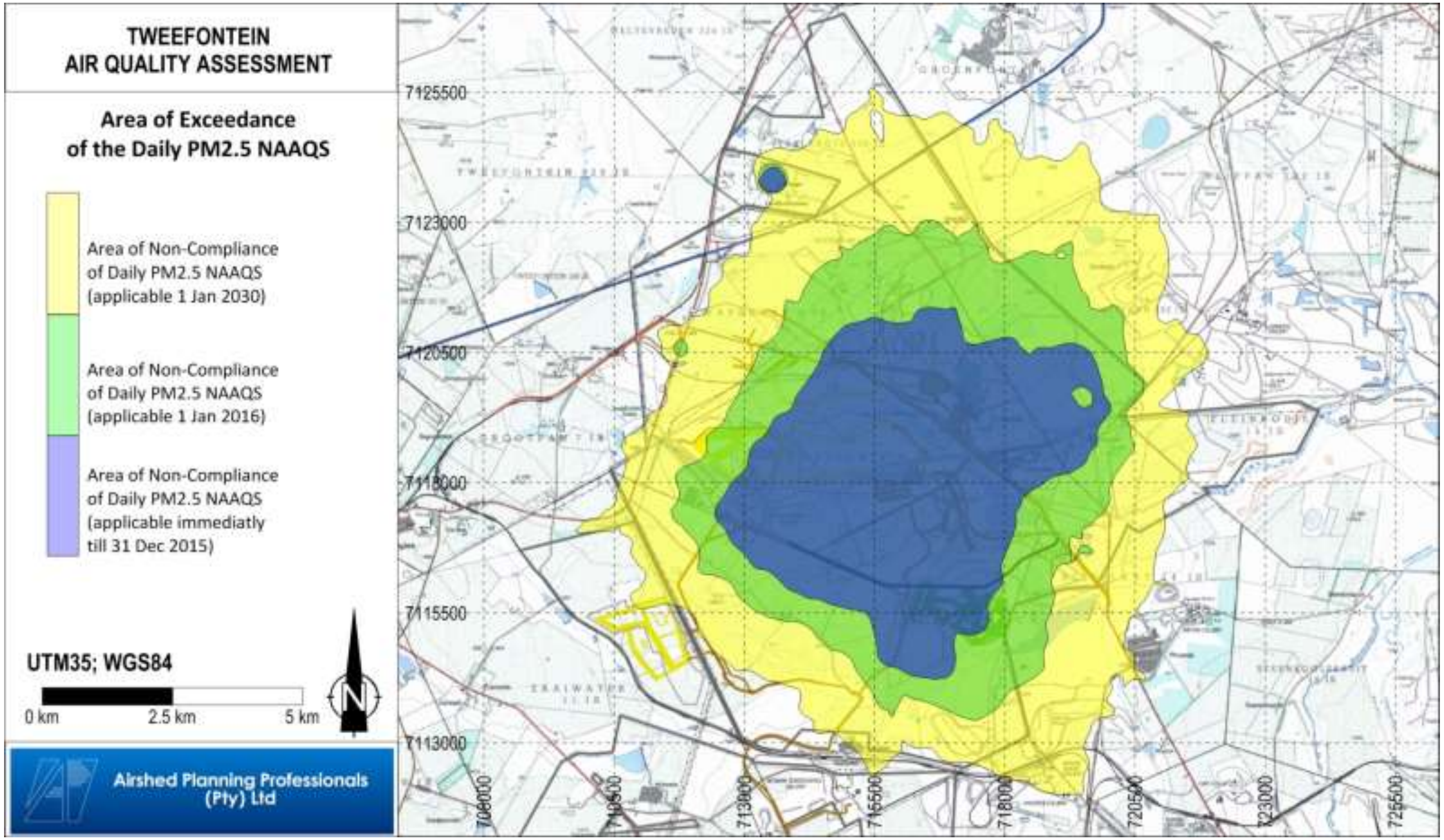


**Figure 4-9: Area of exceedance of daily $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

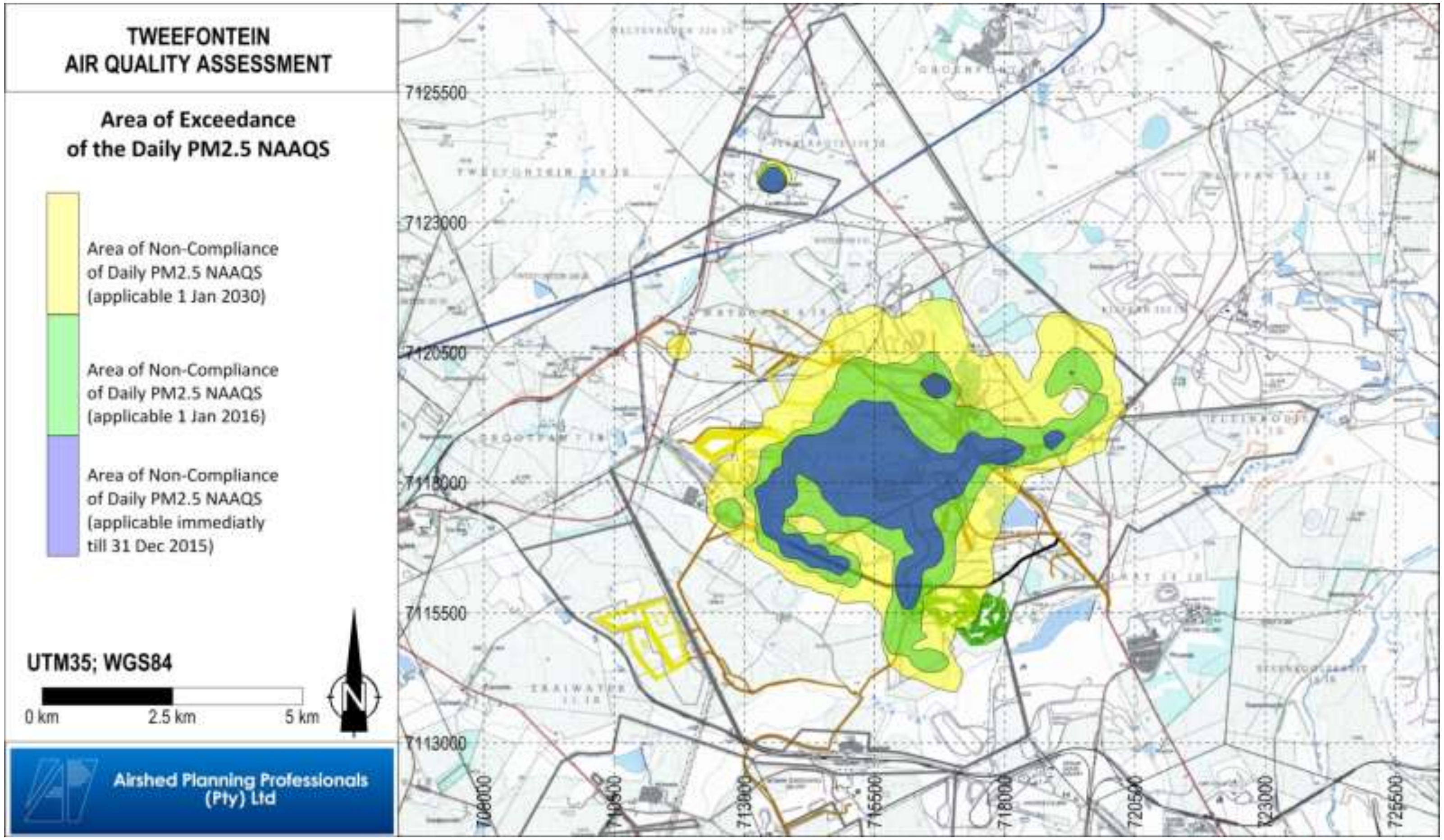


**Figure 4-10: Area of exceedance of daily $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

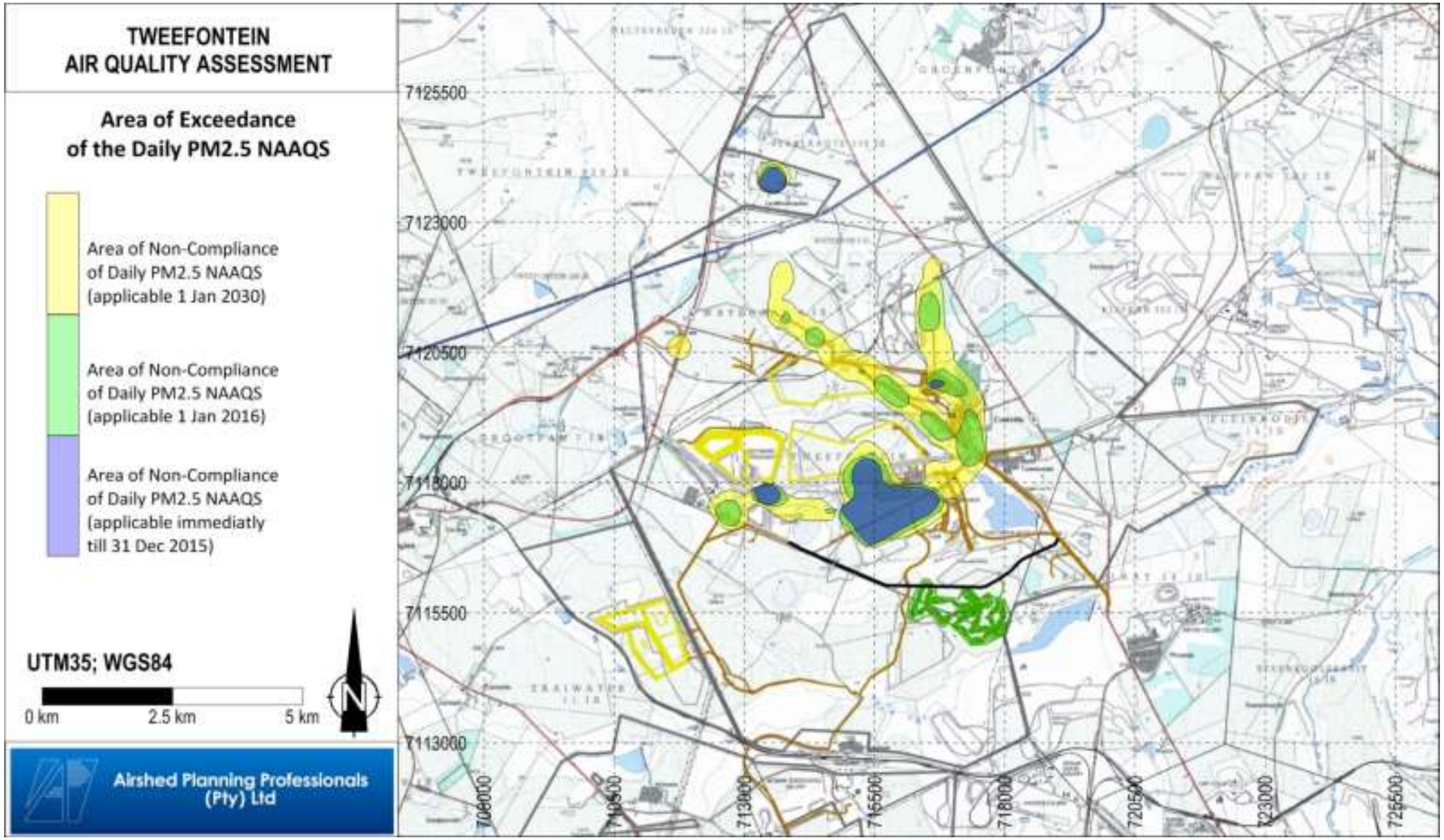


**Figure 4-11: Area of exceedance of daily $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

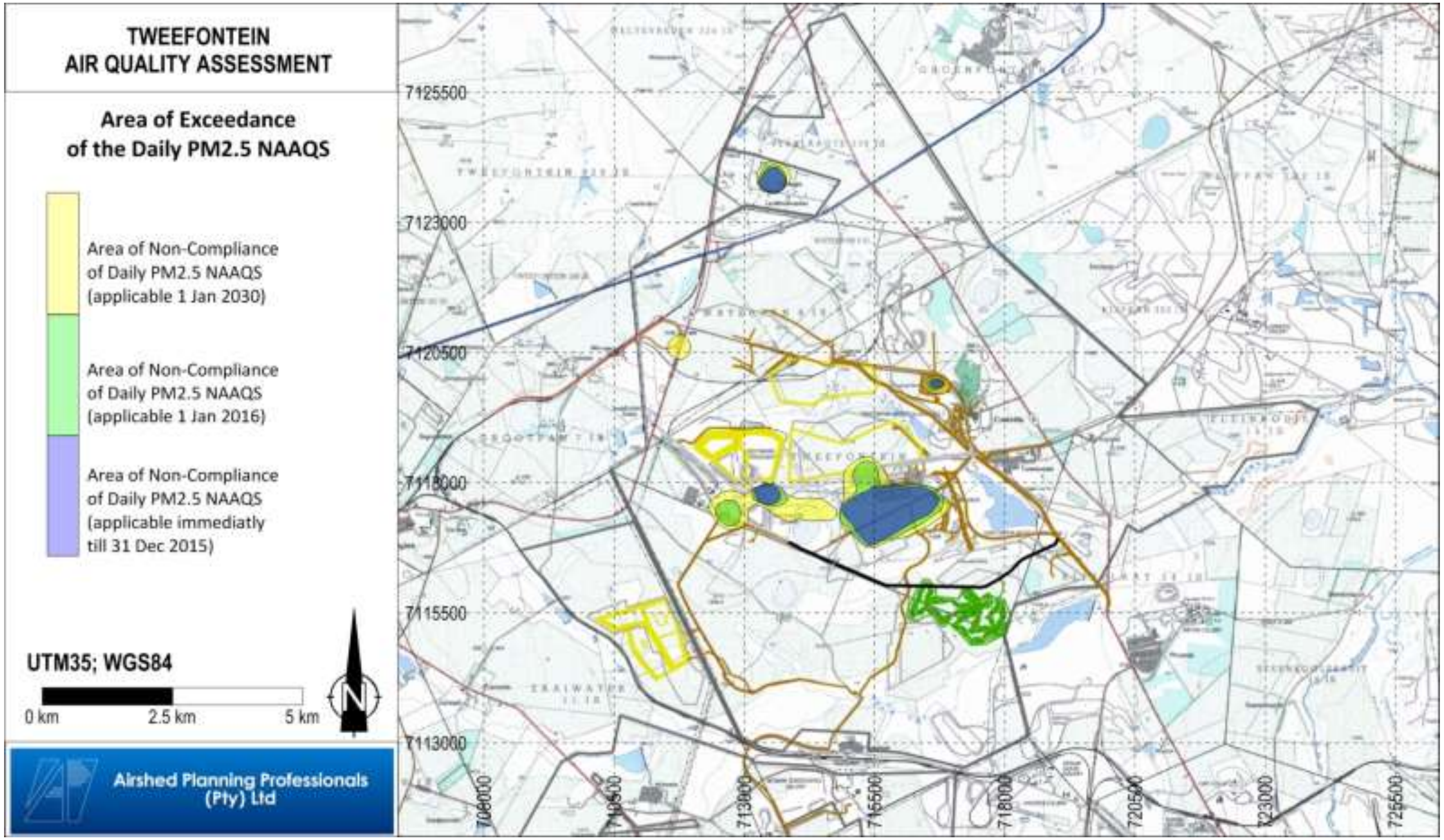


**Figure 4-12: Area of exceedance of daily $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

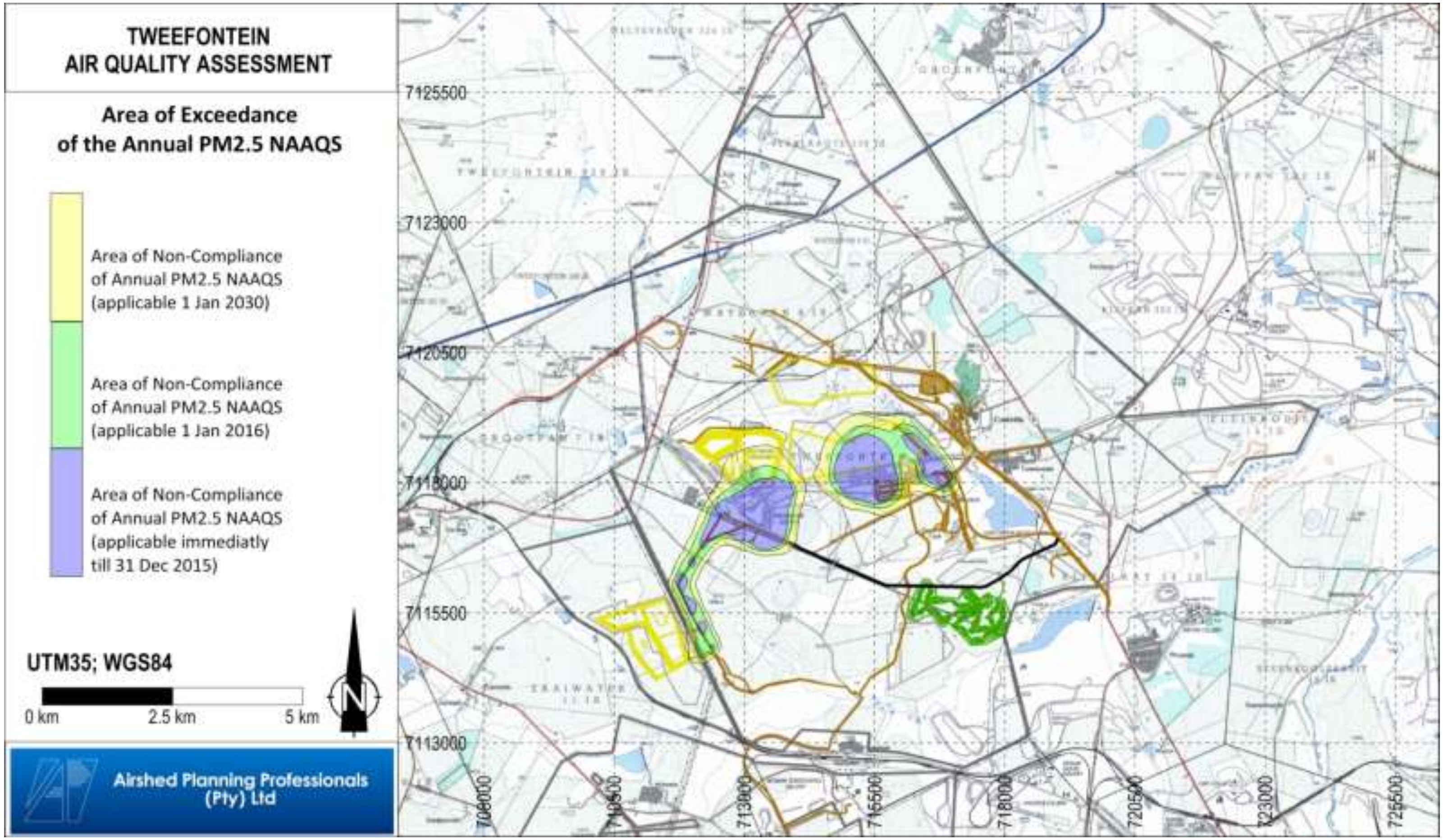


**Figure 4-13: Area of exceedance of annual $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

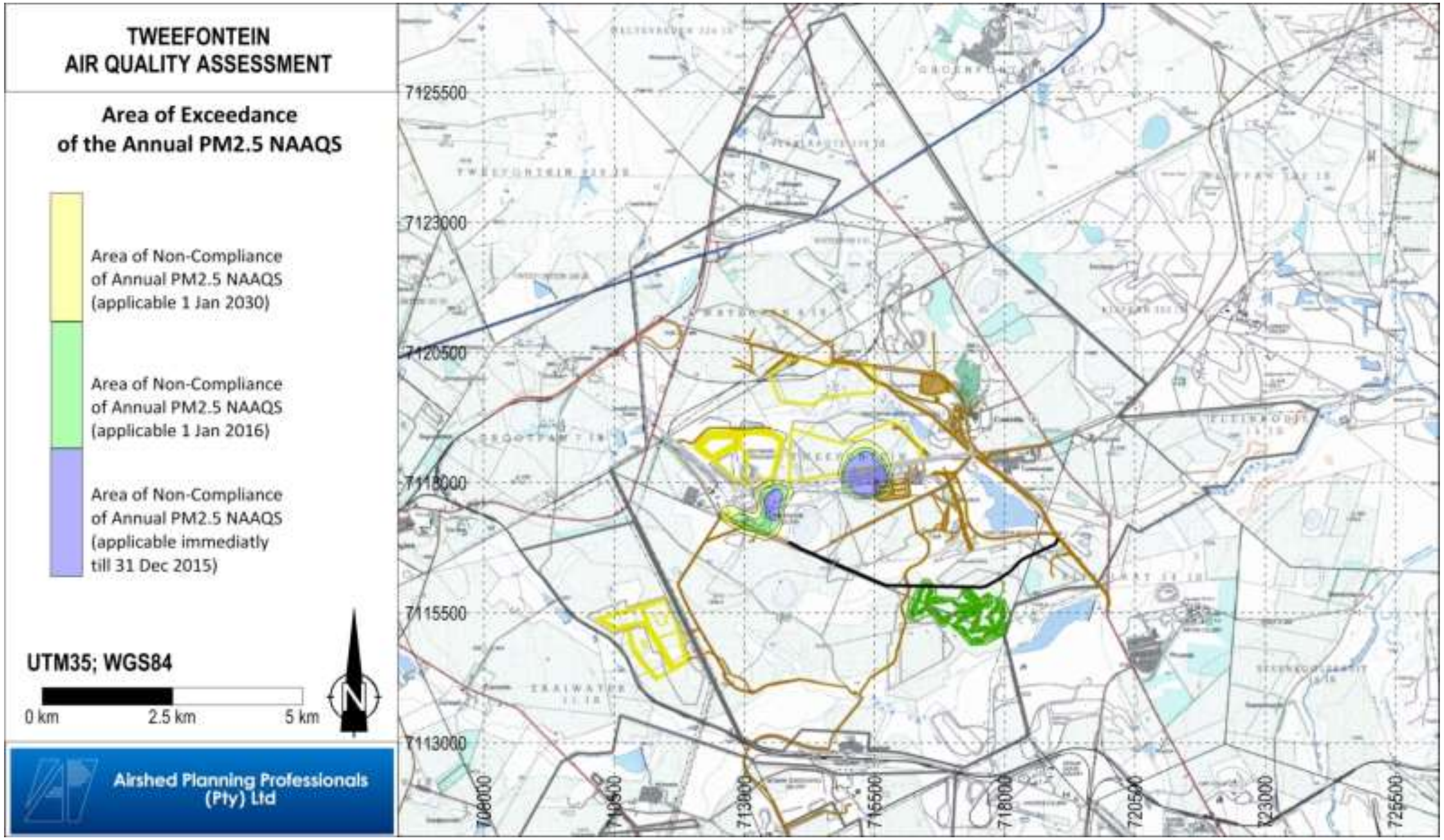


**Figure 4-14: Area of exceedance of annual $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

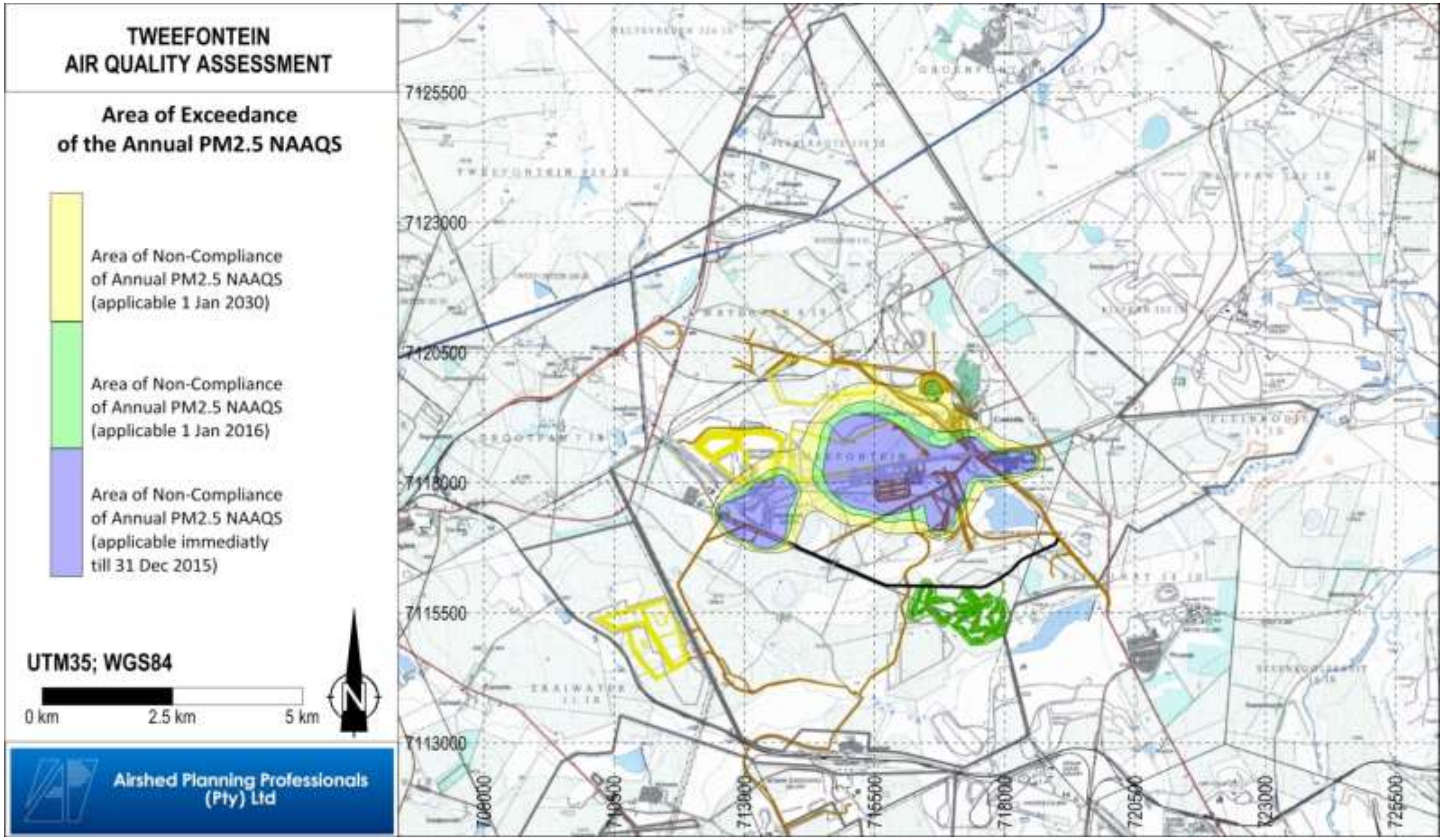


**Figure 4-15: Area of exceedance of annual $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

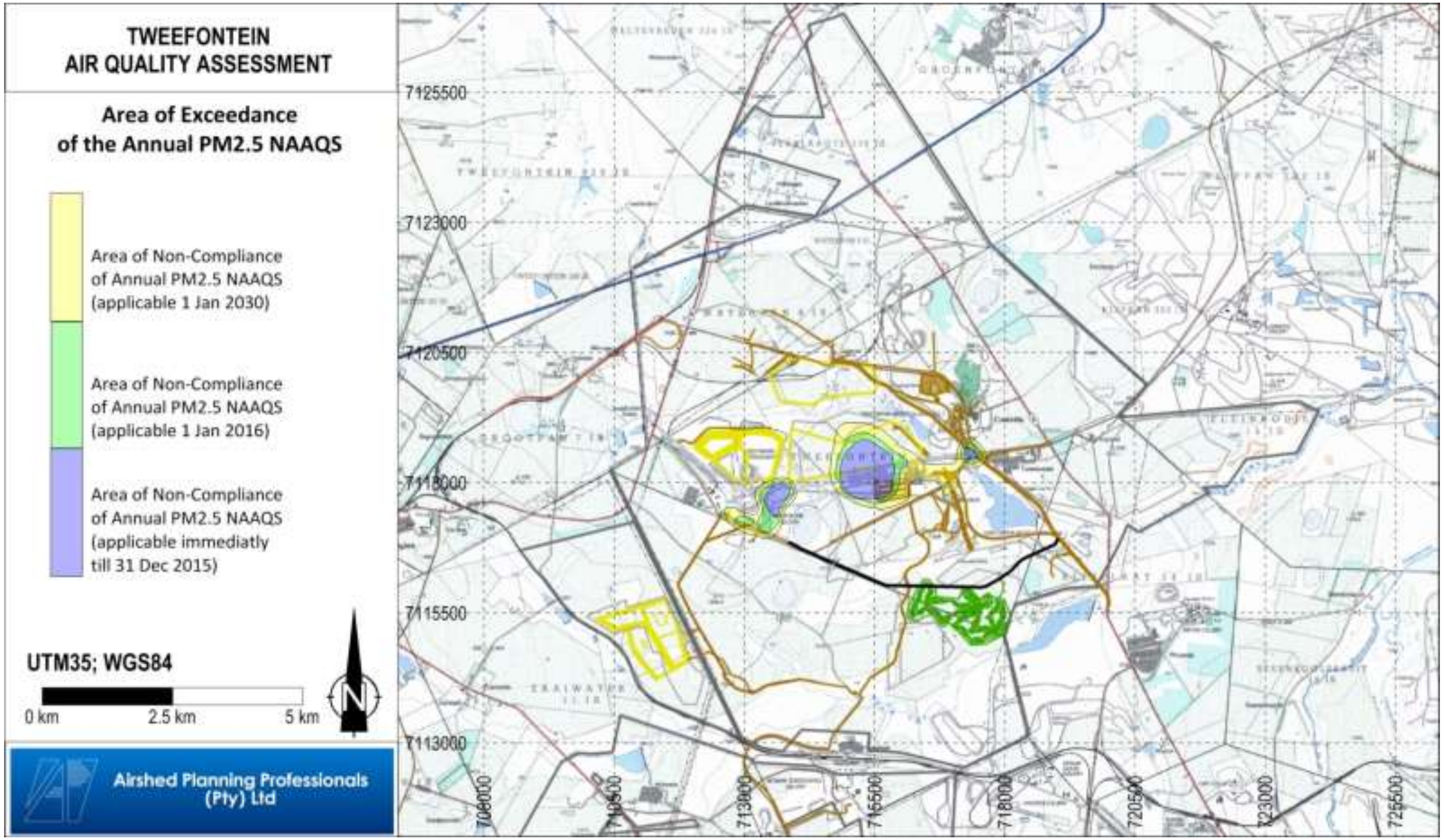


**Figure 4-16: Area of exceedance of annual $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

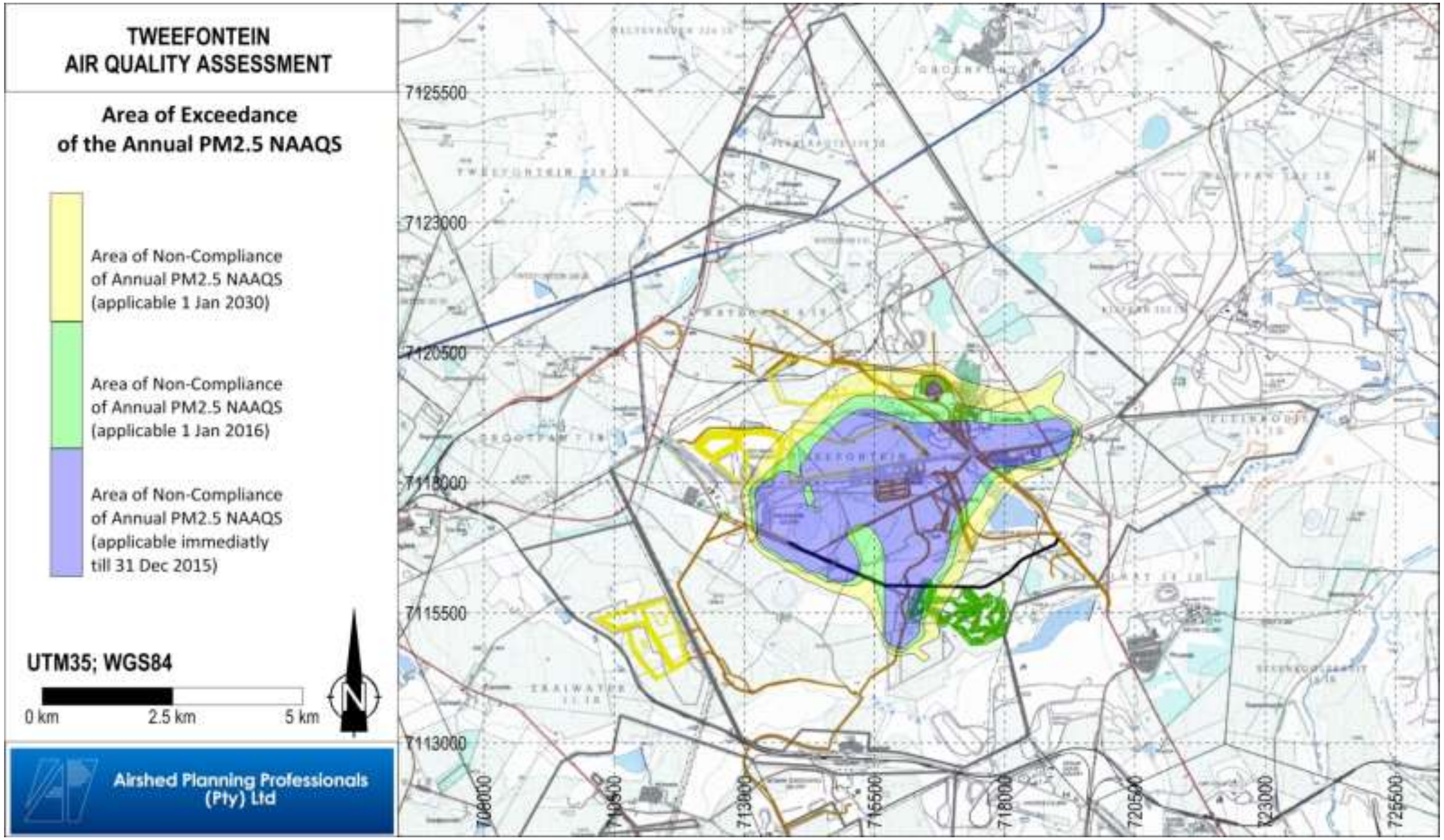


**Figure 4-17: Area of exceedance of annual $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

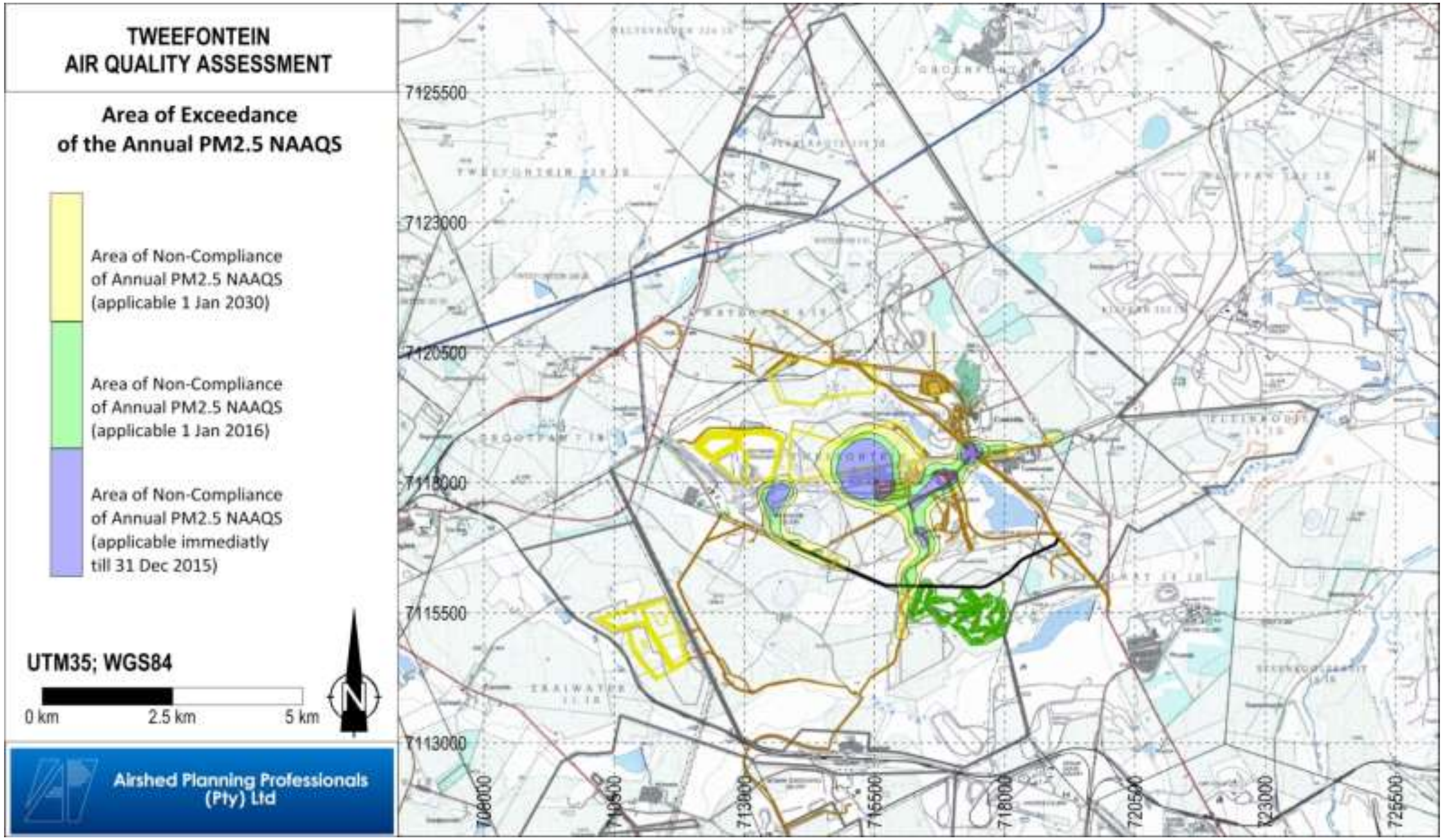


**Figure 4-18: Area of exceedance of annual $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

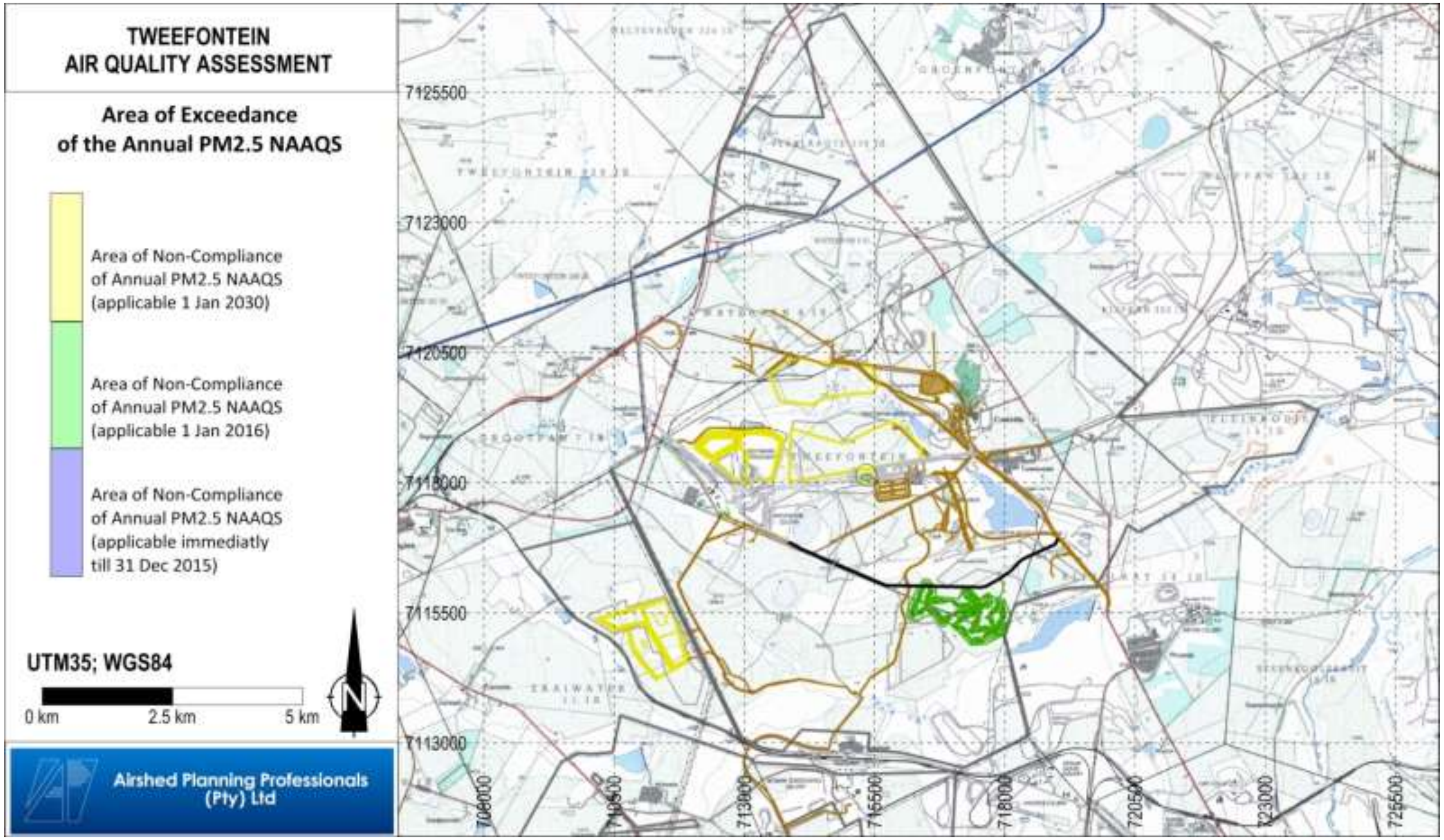


**Figure 4-19: Area of exceedance of annual $PM_{2.5}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

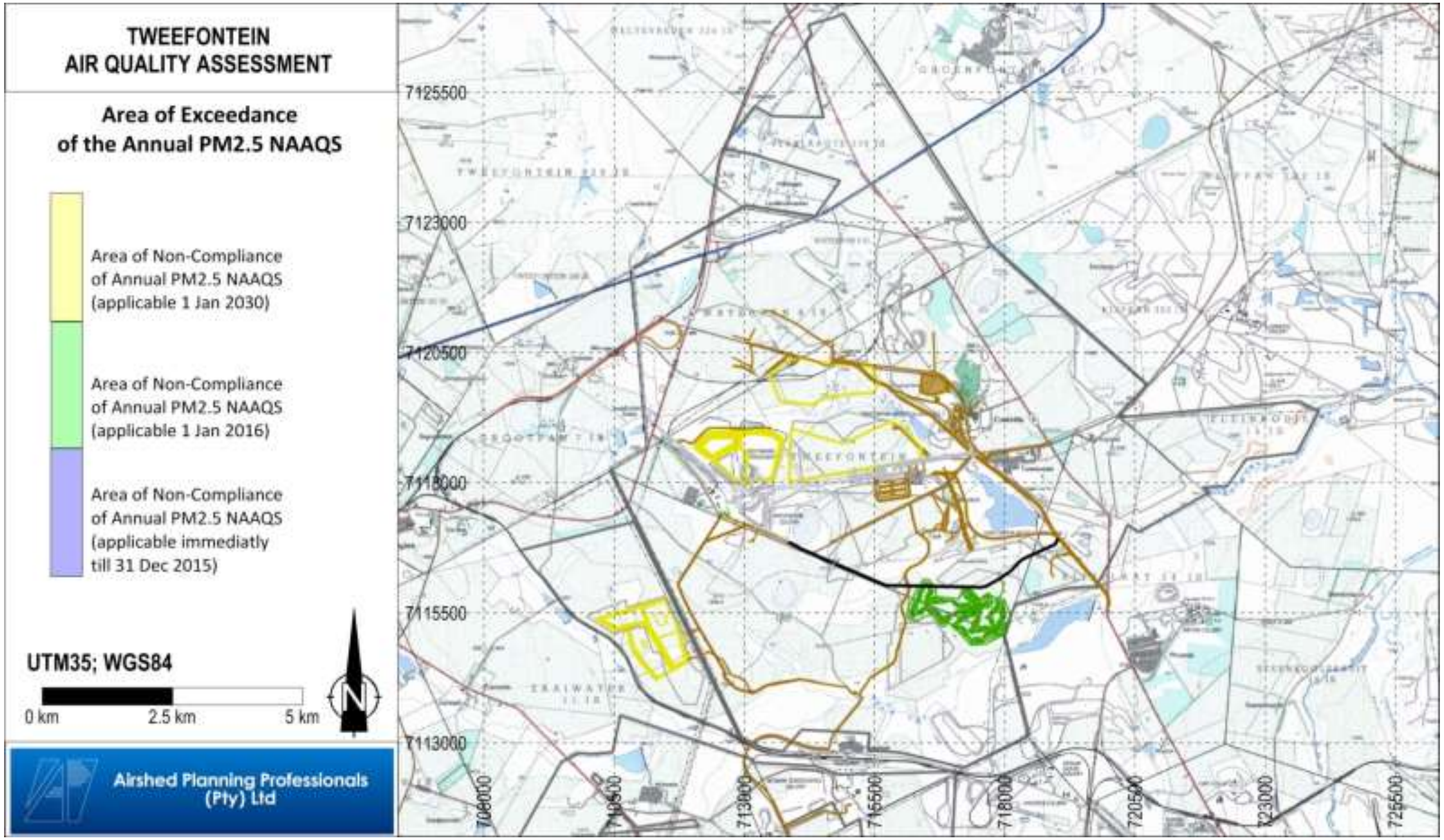


**Figure 4-20: Area of exceedance of annual $PM_{2.5}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

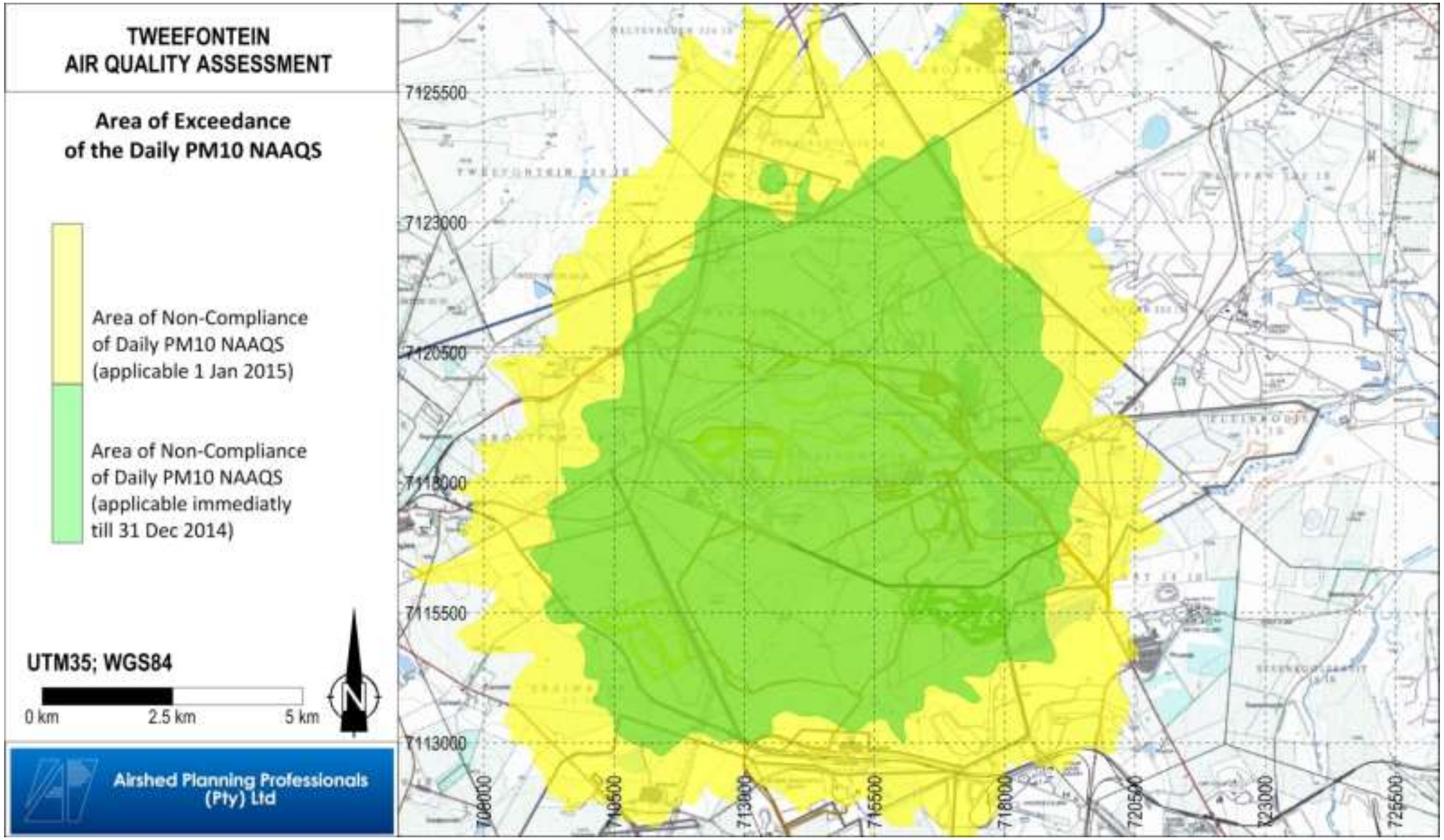


**Figure 4-21: Area of exceedance of daily $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

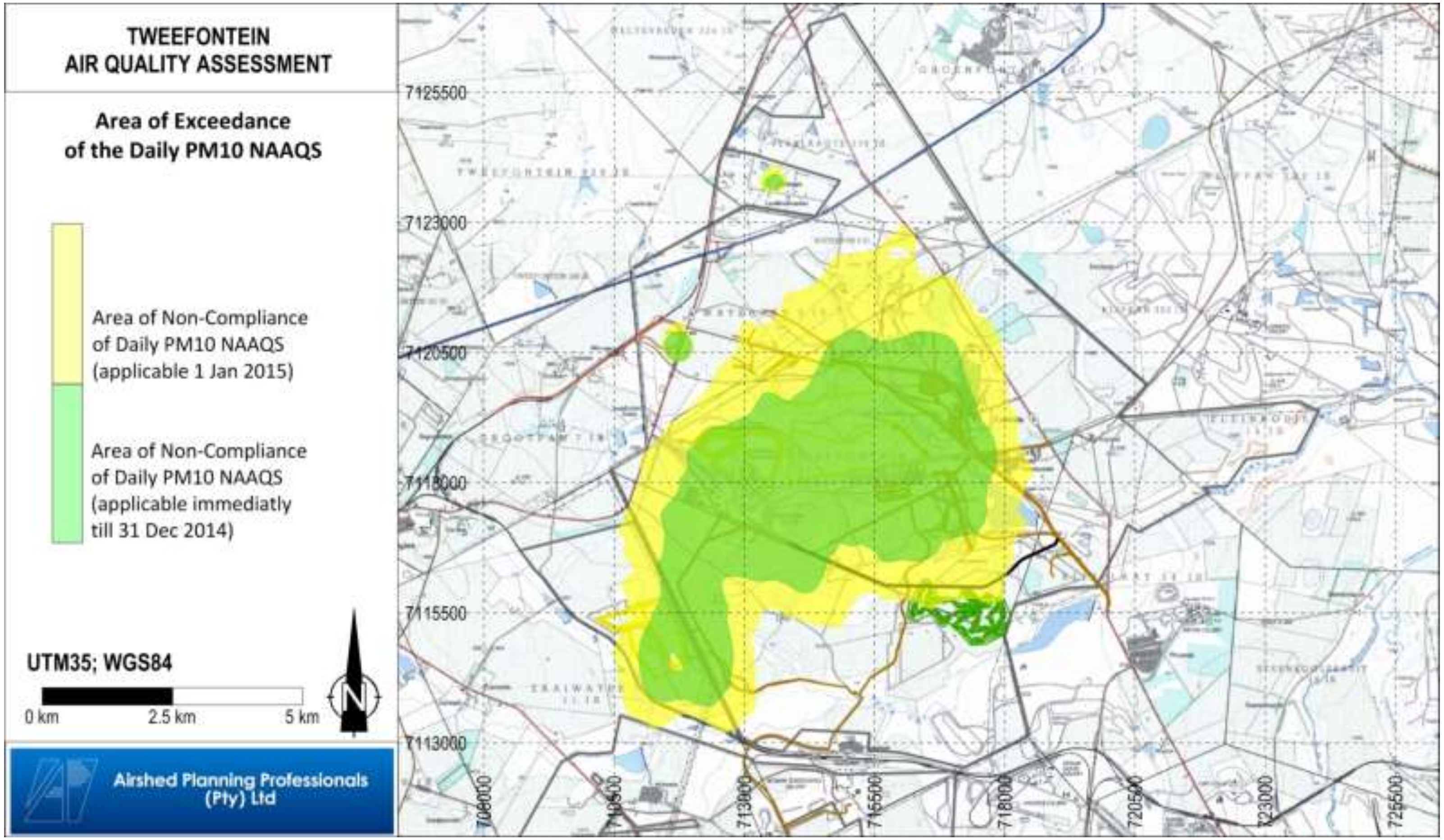


**Figure 4-22: Area of exceedance of daily $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

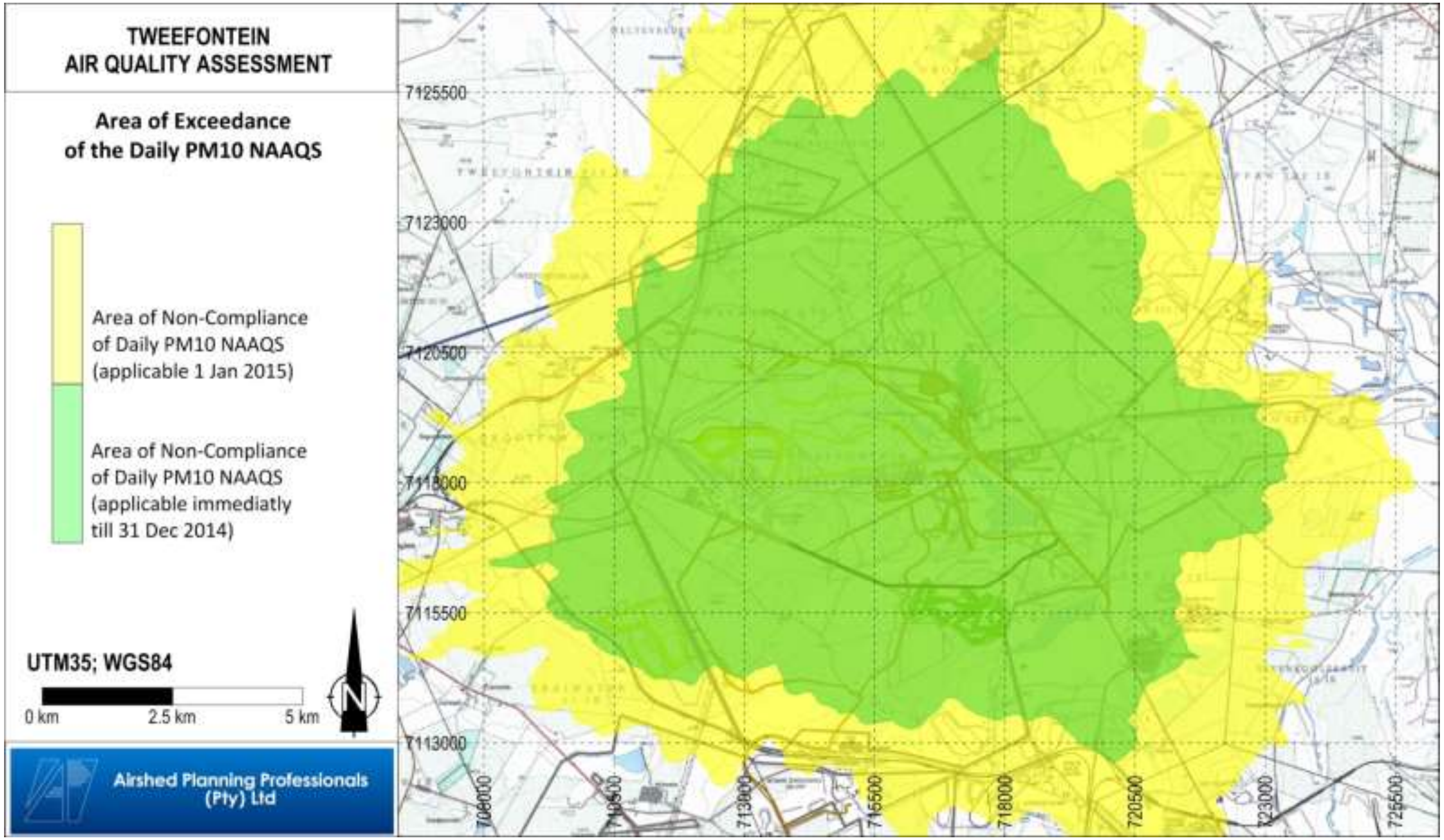


**Figure 4-23: Area of exceedance of daily $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

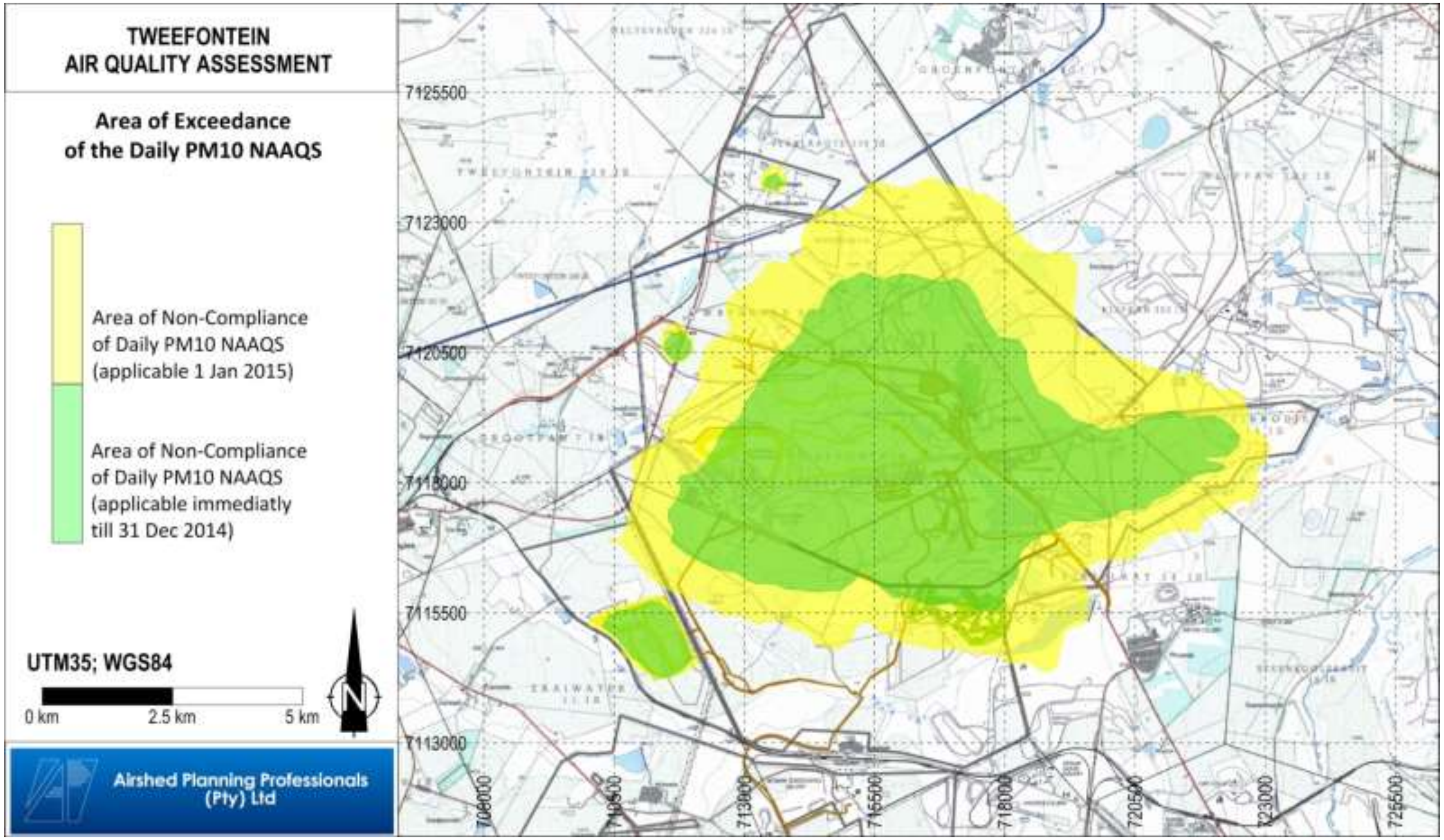


**Figure 4-24: Area of exceedance of daily $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

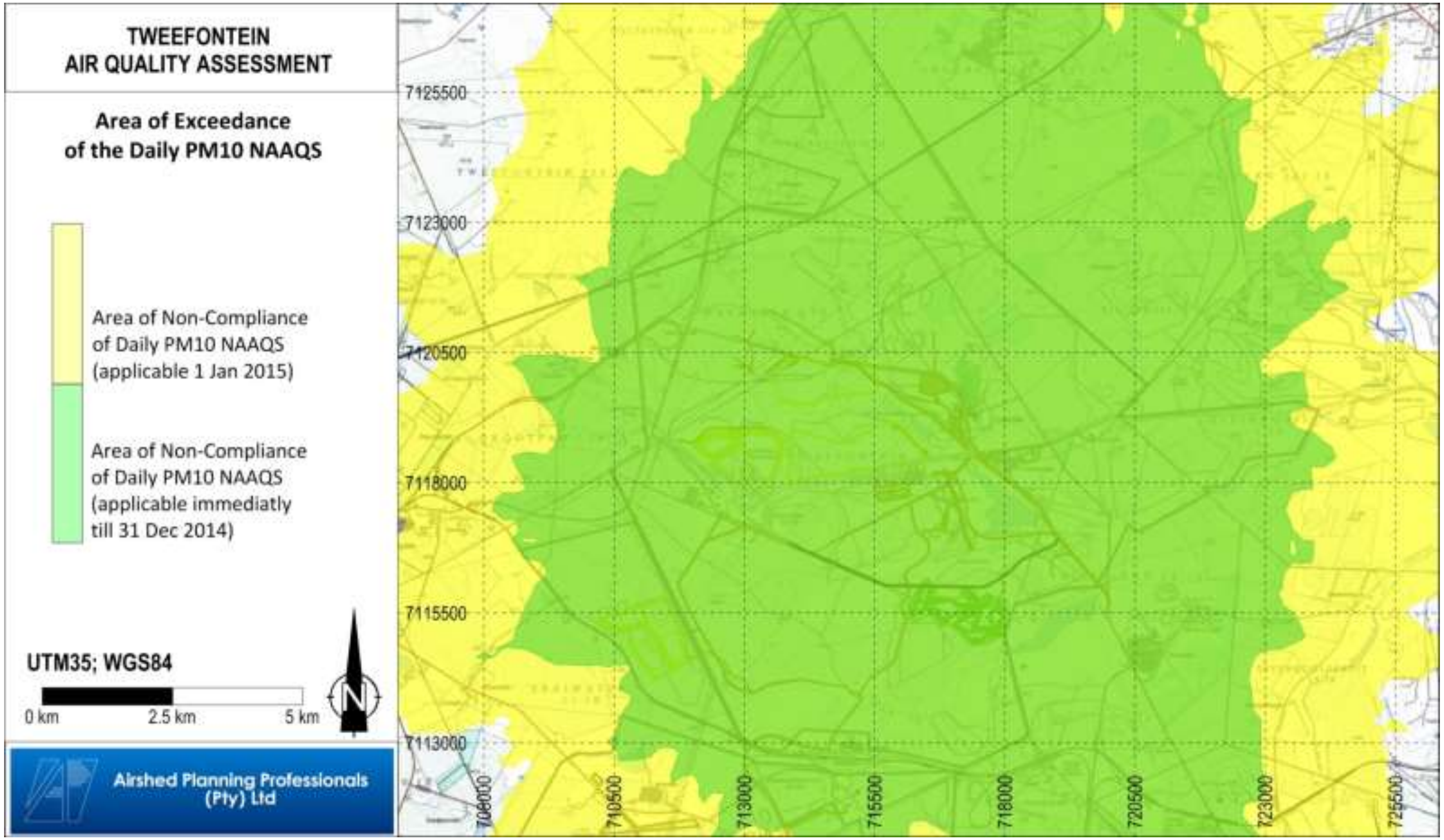


**Figure 4-25: Area of exceedance of daily $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

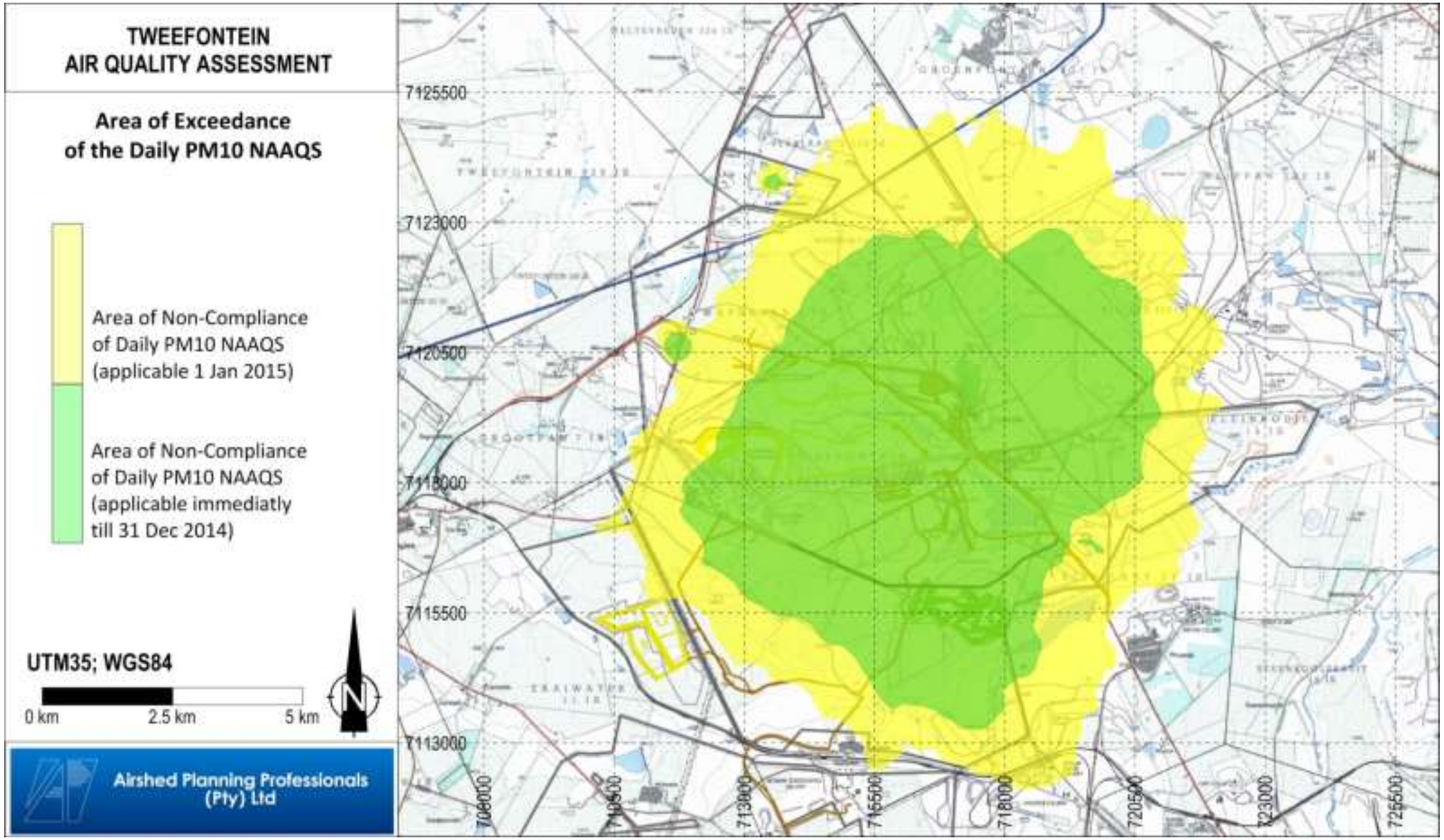


**Figure 4-26: Area of exceedance of daily $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

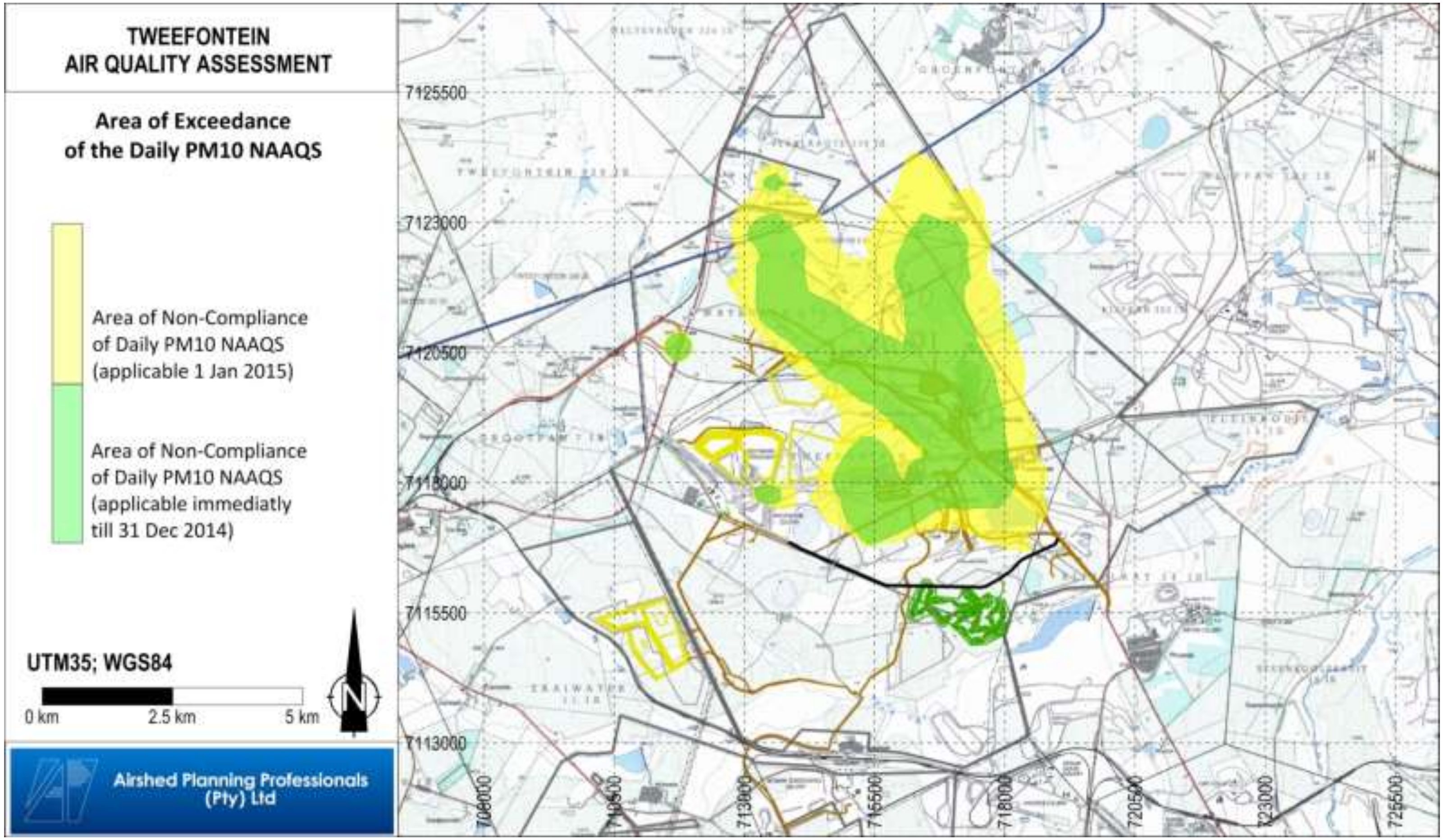


**Figure 4-27: Area of exceedance of daily $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

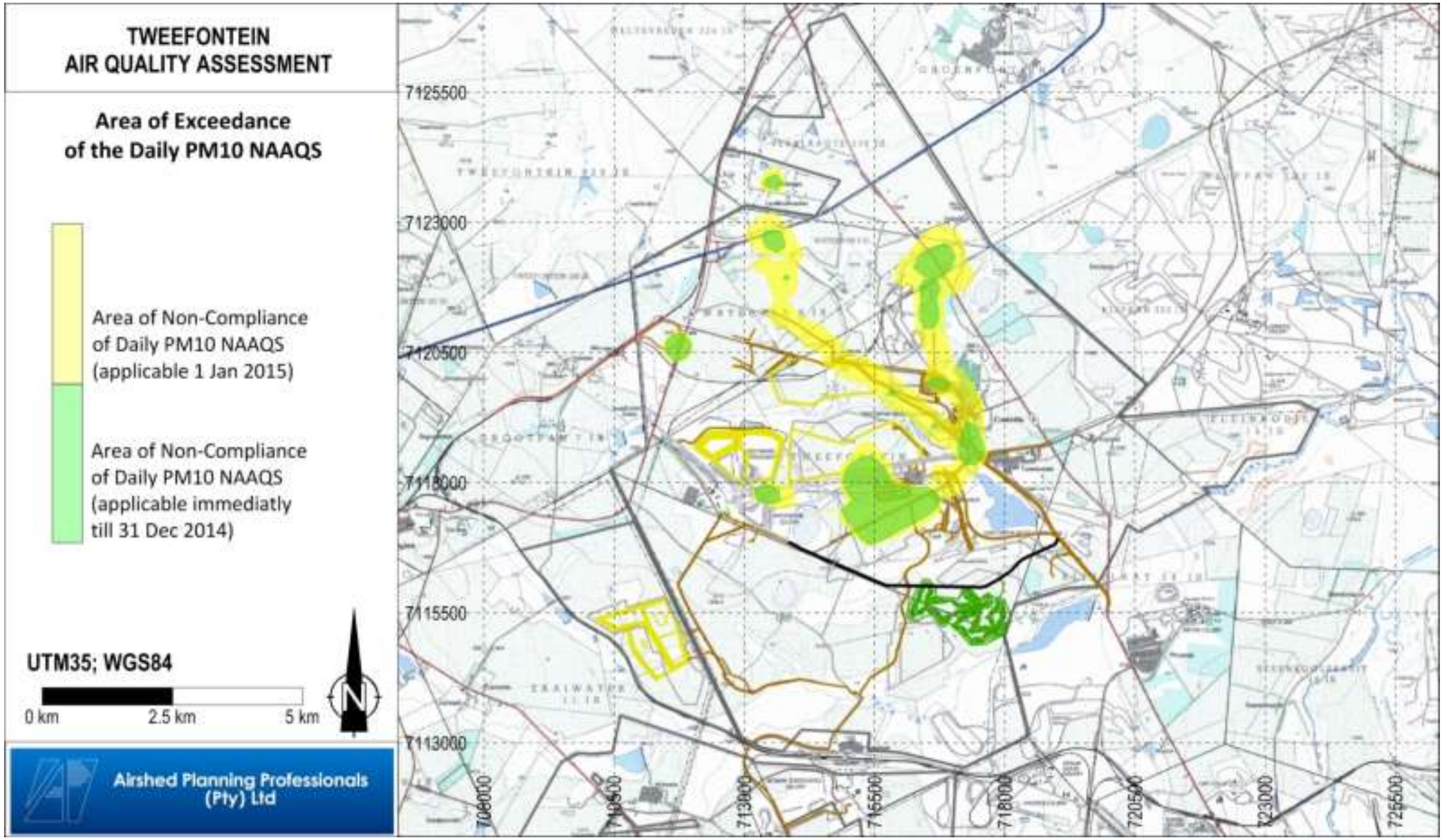


**Figure 4-28: Area of exceedance of daily $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

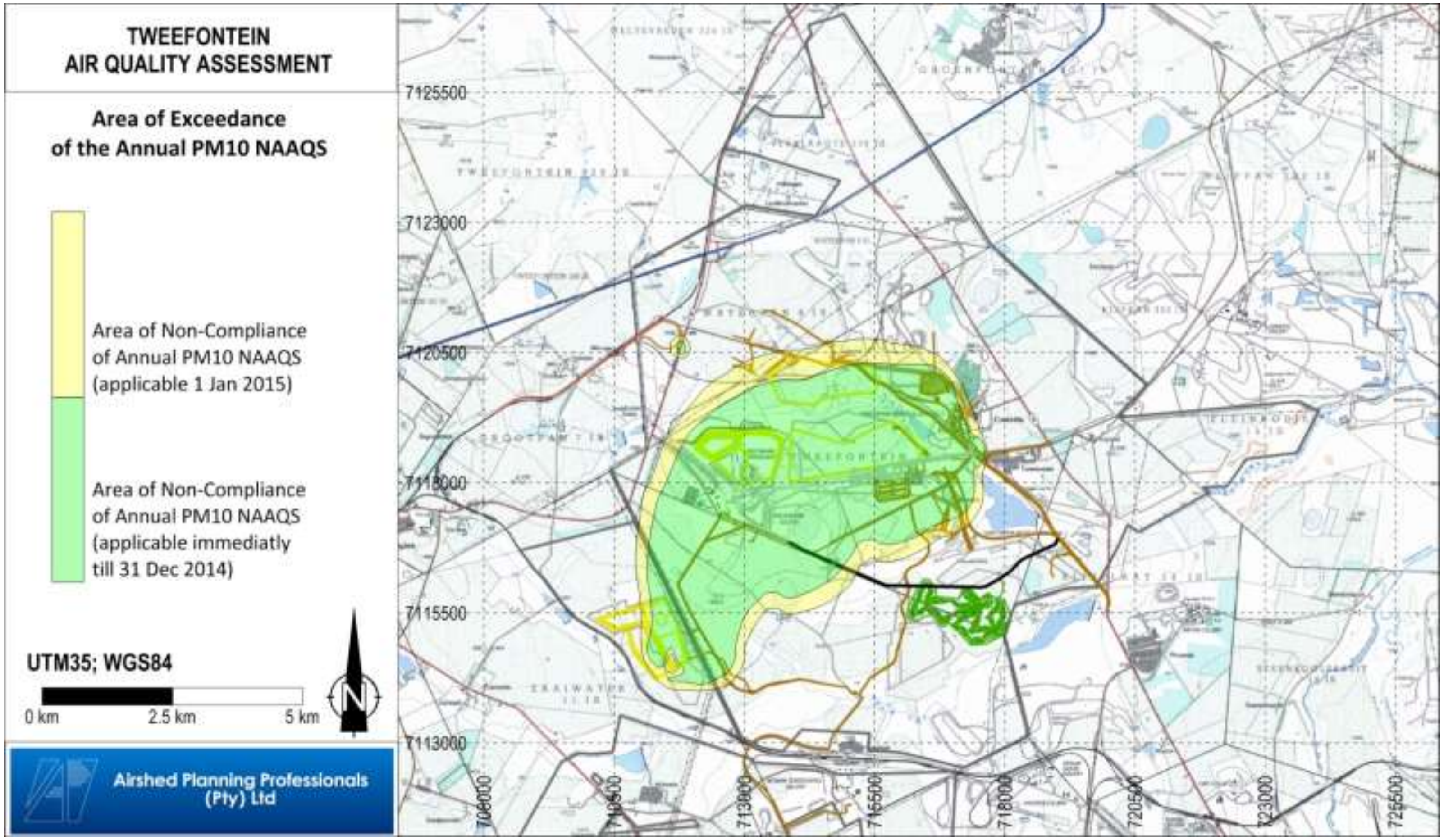


**Figure 4-29: Area of exceedance of annual $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

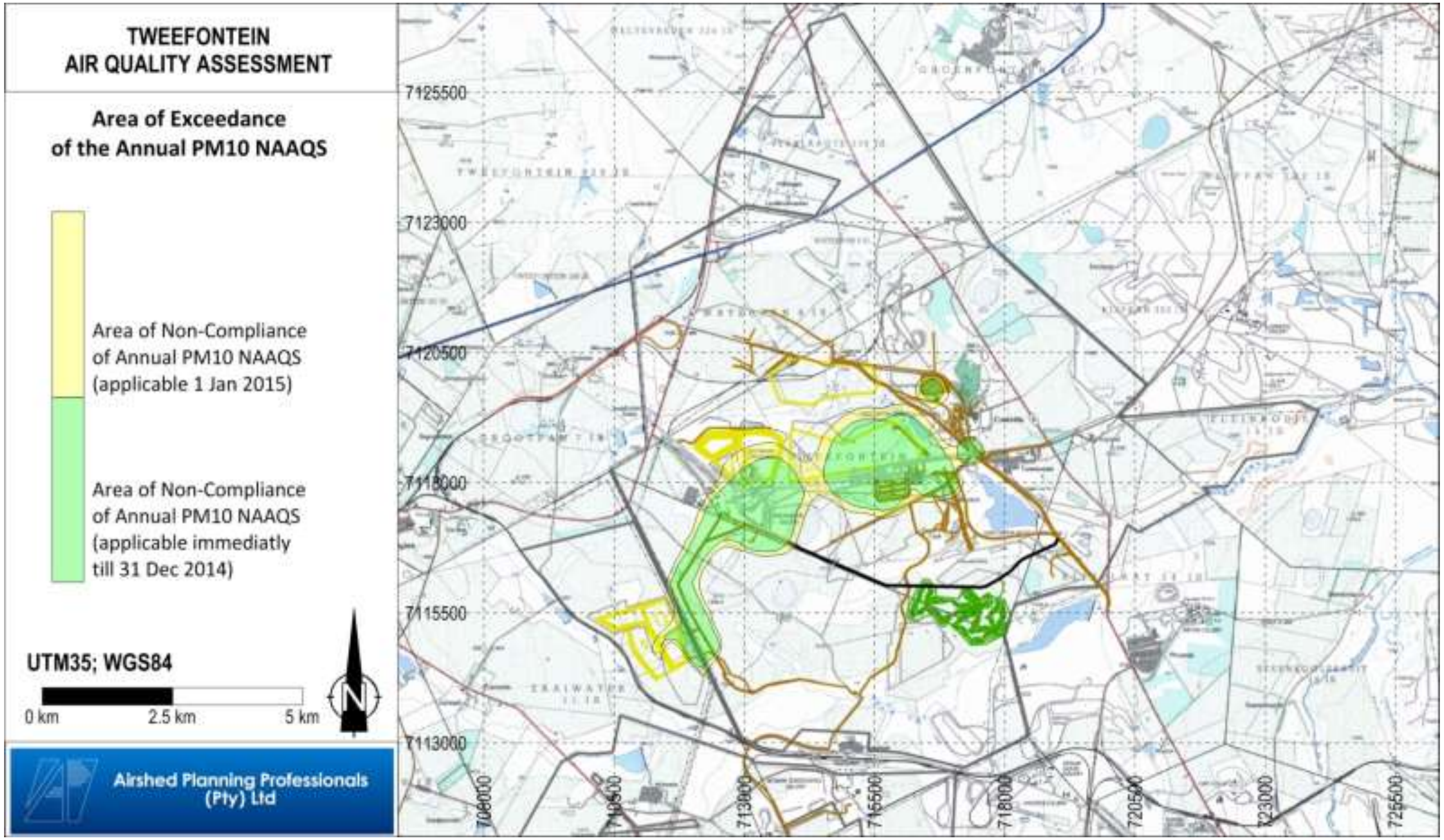


**Figure 4-30: Area of exceedance of annual $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

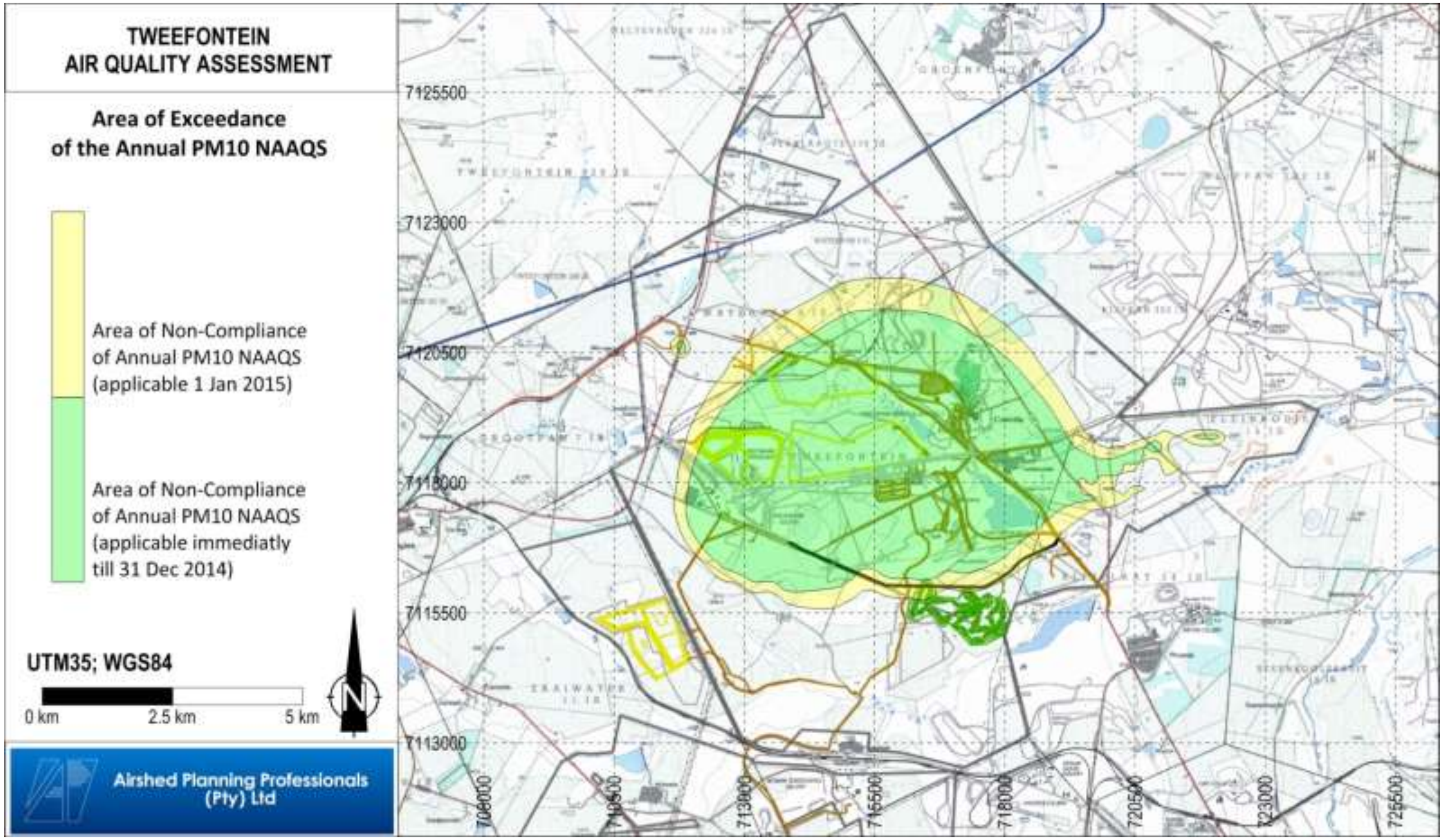


**Figure 4-31: Area of exceedance of annual $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

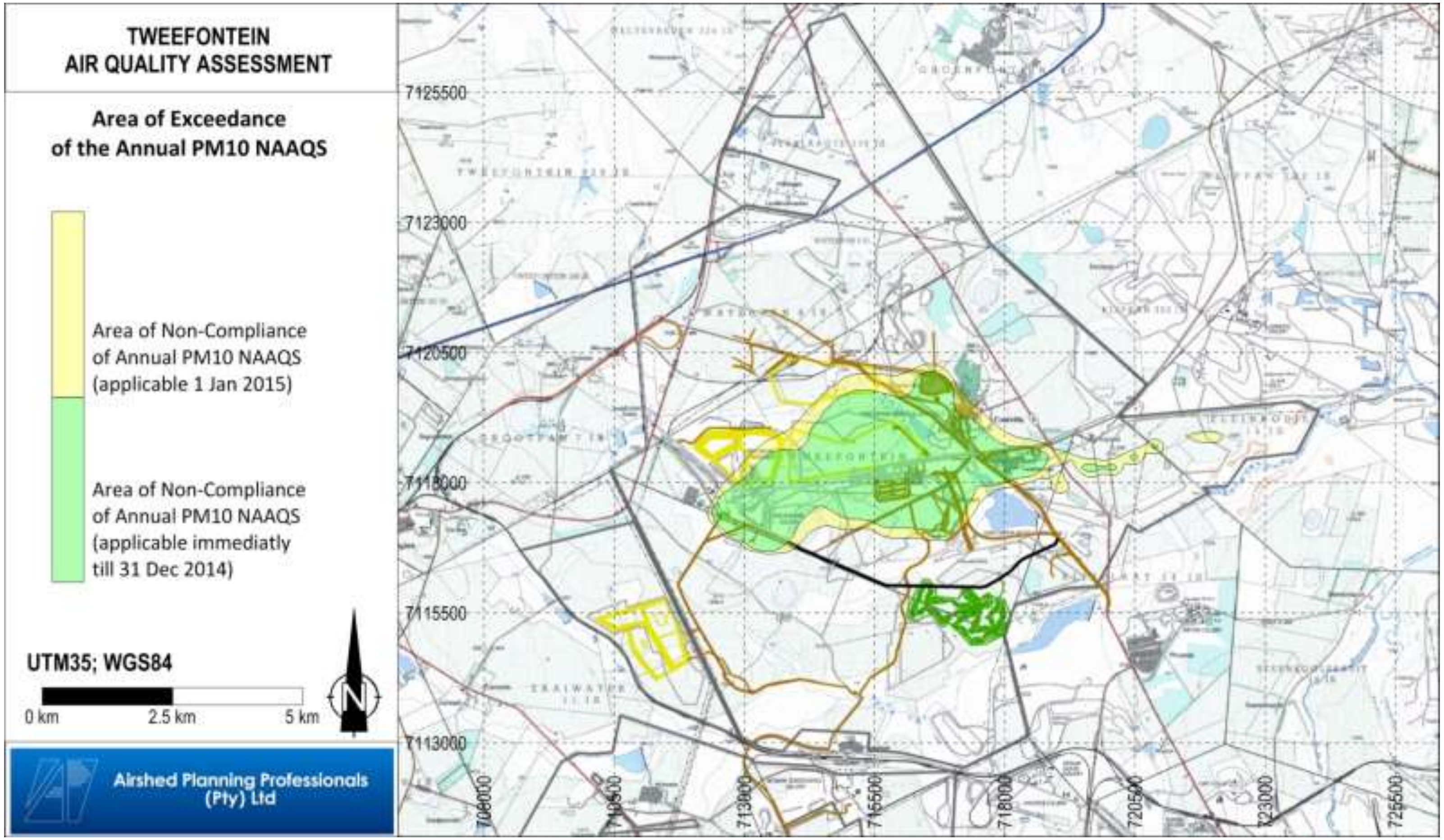


**Figure 4-32: Area of exceedance of annual $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

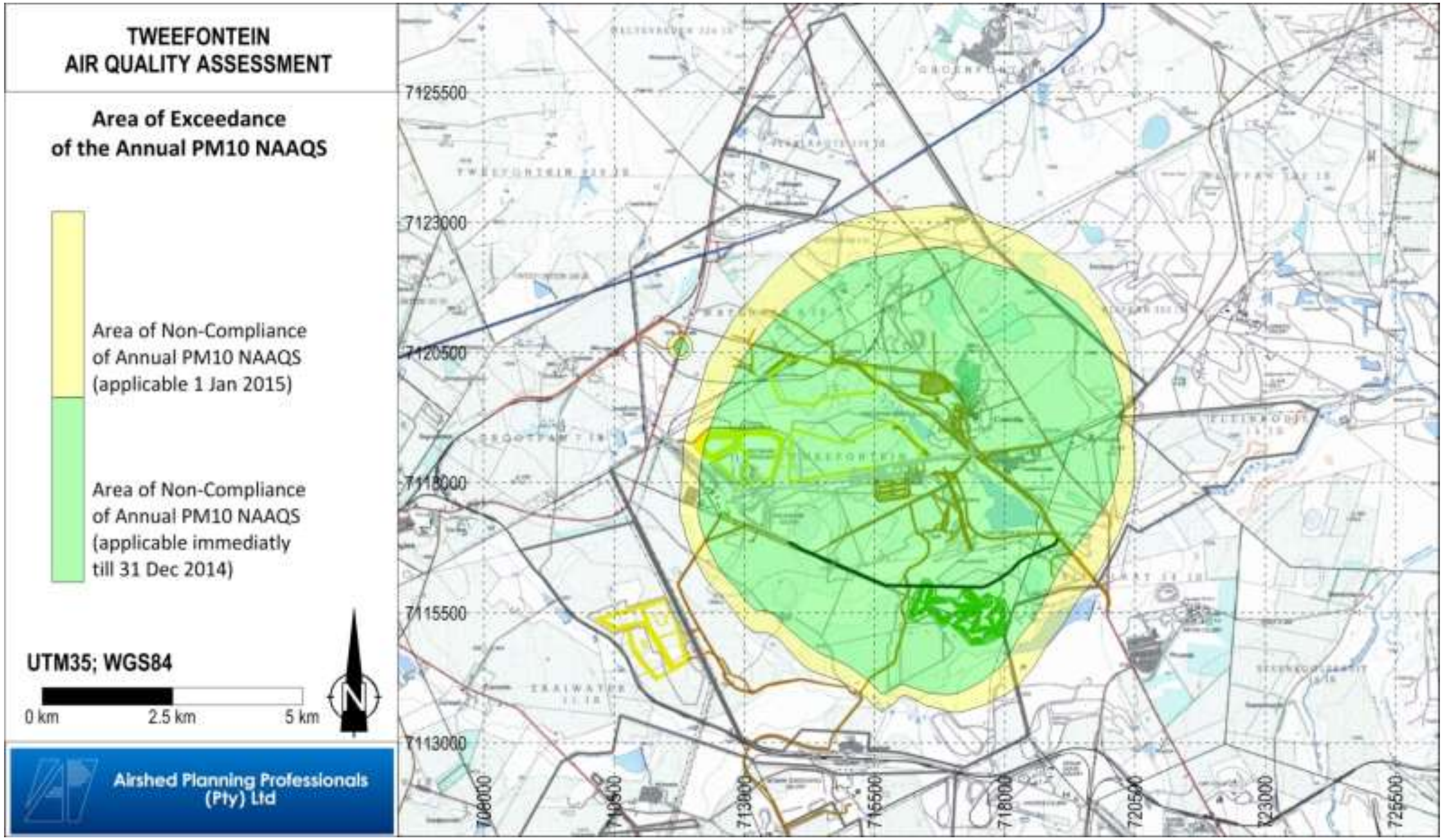


**Figure 4-33: Area of exceedance of annual $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

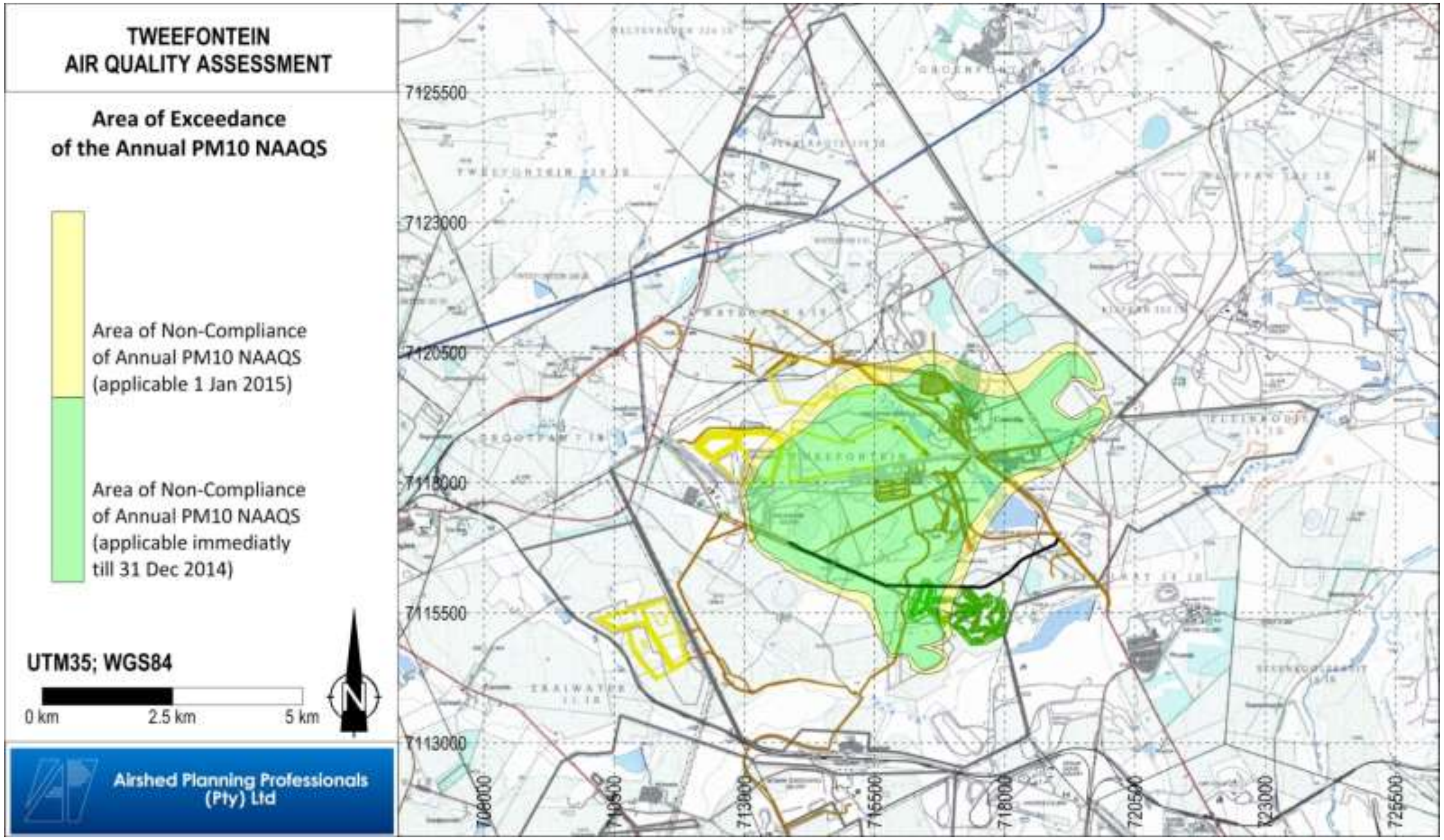


**Figure 4-34: Area of exceedance of annual $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

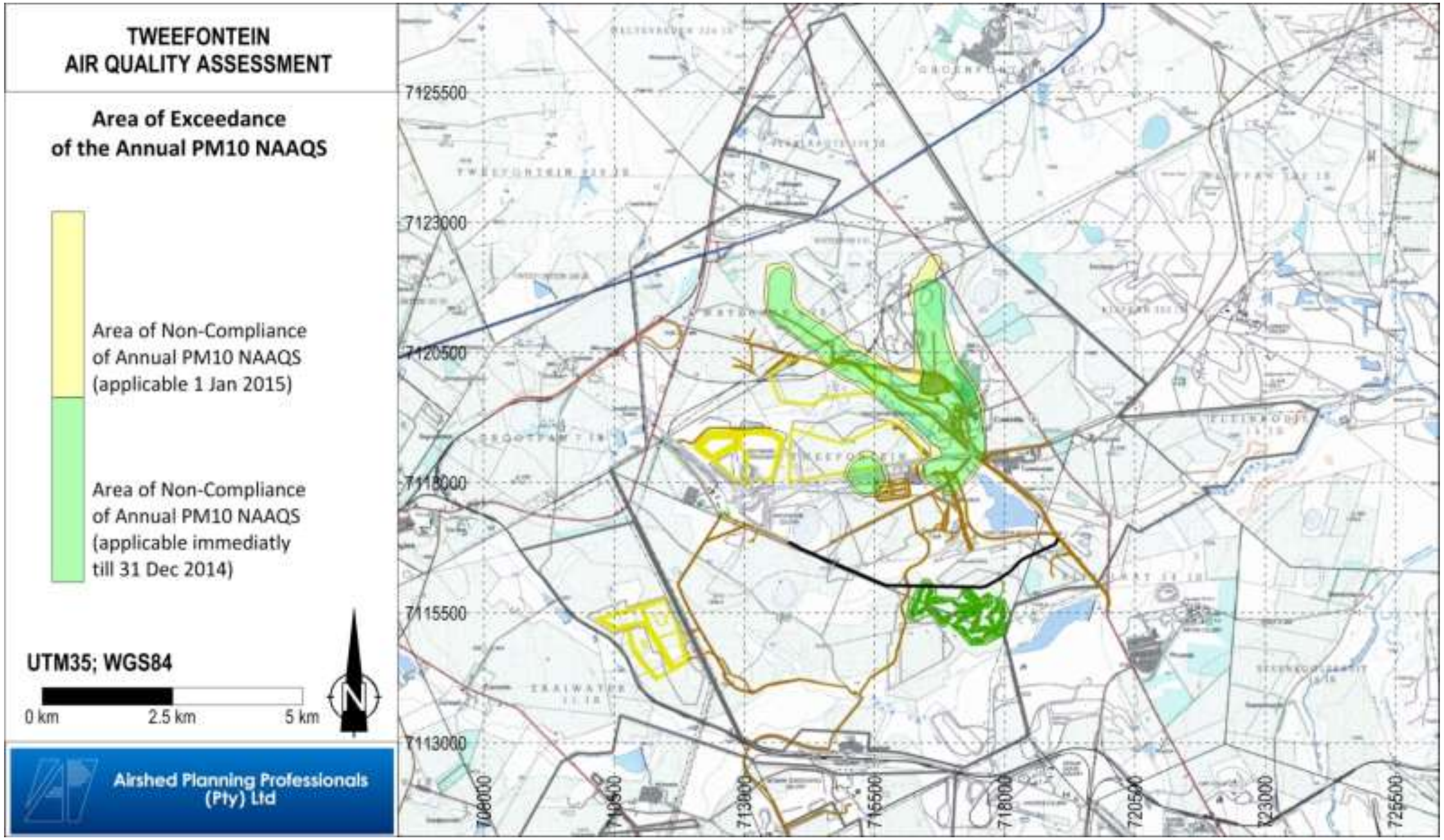


**Figure 4-35: Area of exceedance of annual $PM_{10}$ NAAQS due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

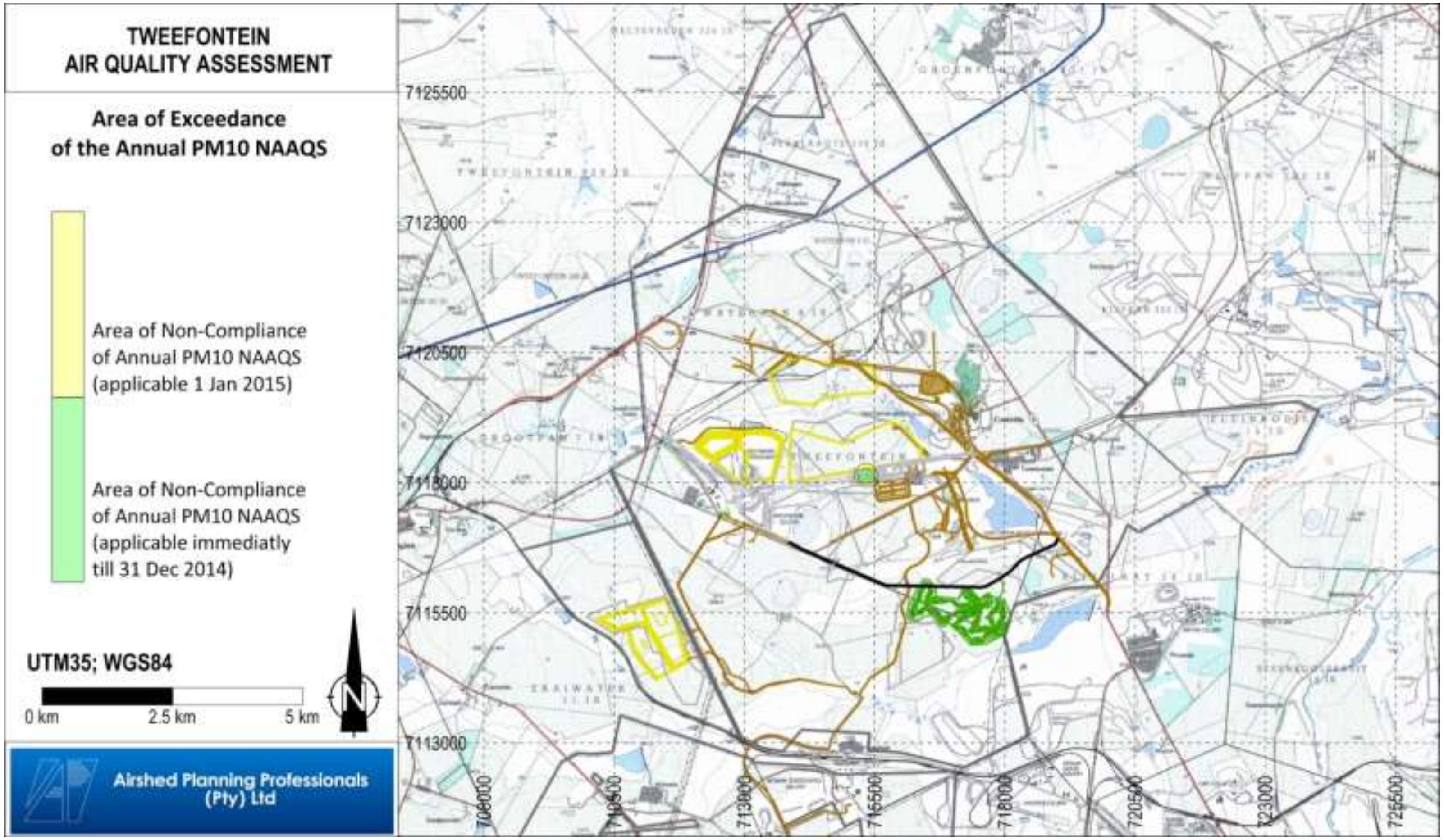


**Figure 4-36: Area of exceedance of annual $PM_{10}$ NAAQS due to mitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

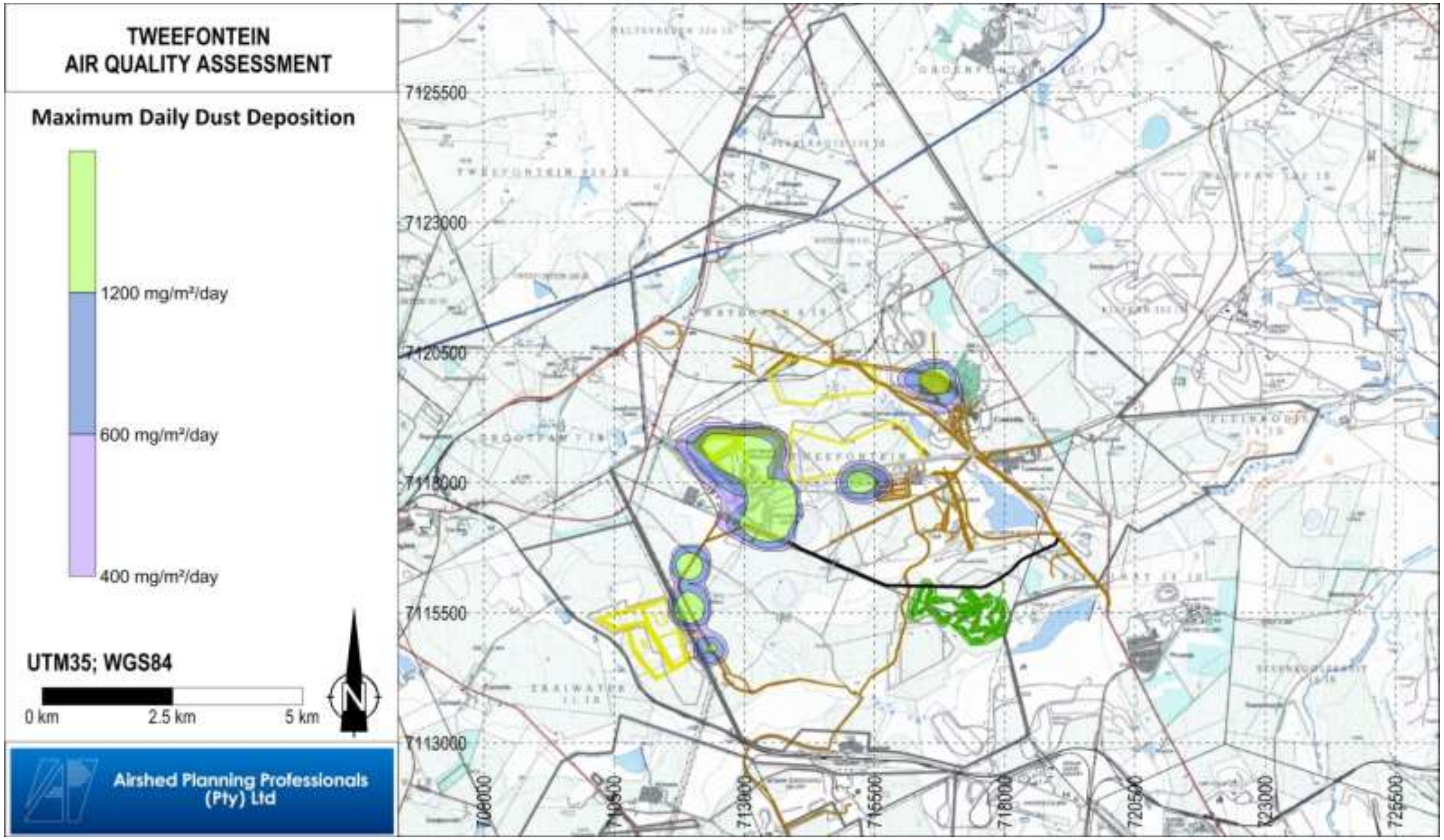


**Figure 4-37: Maximum daily dust deposition due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

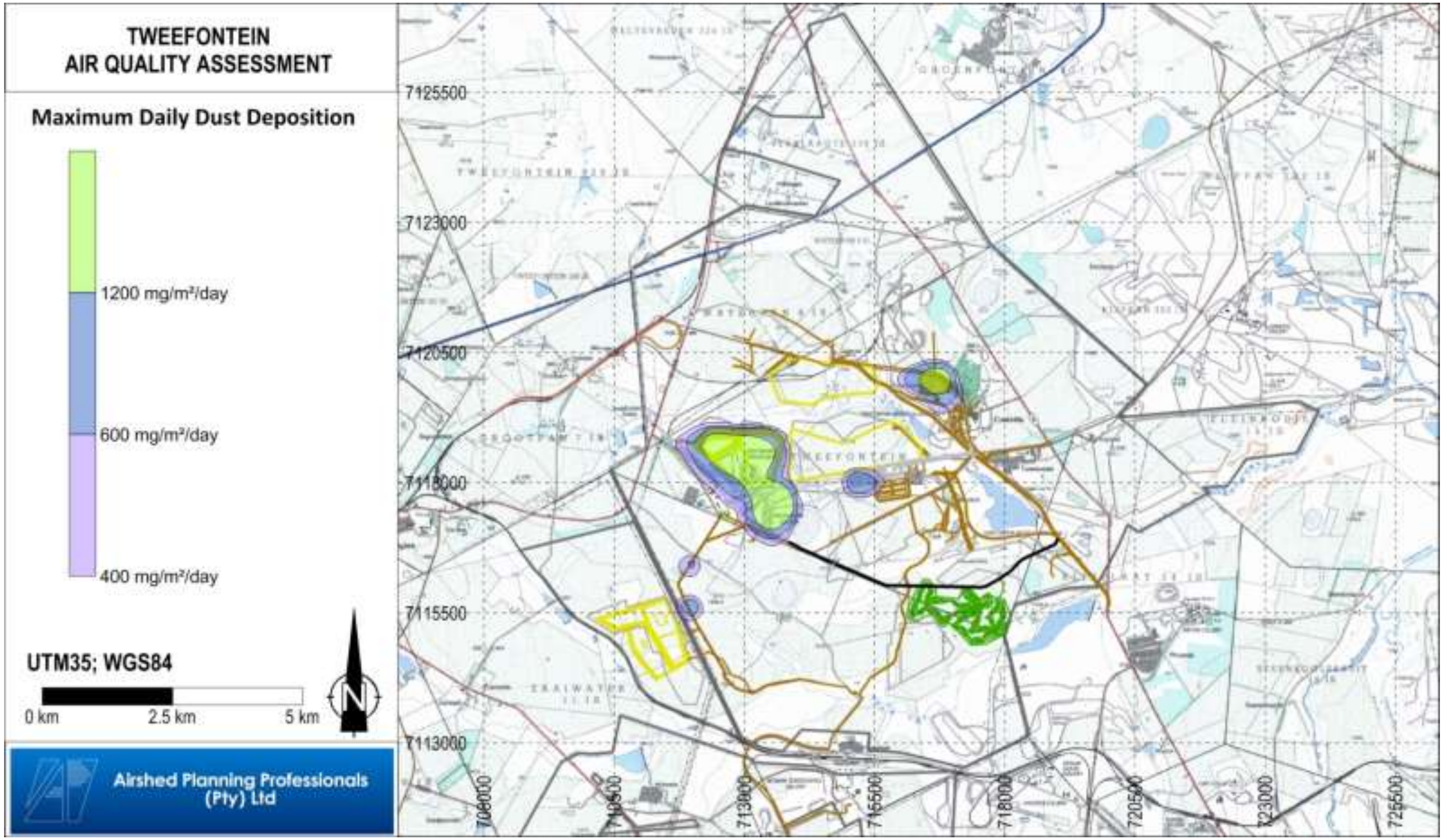


**Figure 4-38: Maximum daily dust deposition due to mitigated Tweefontein Optimisation Project Amendment operations (year 2013)**

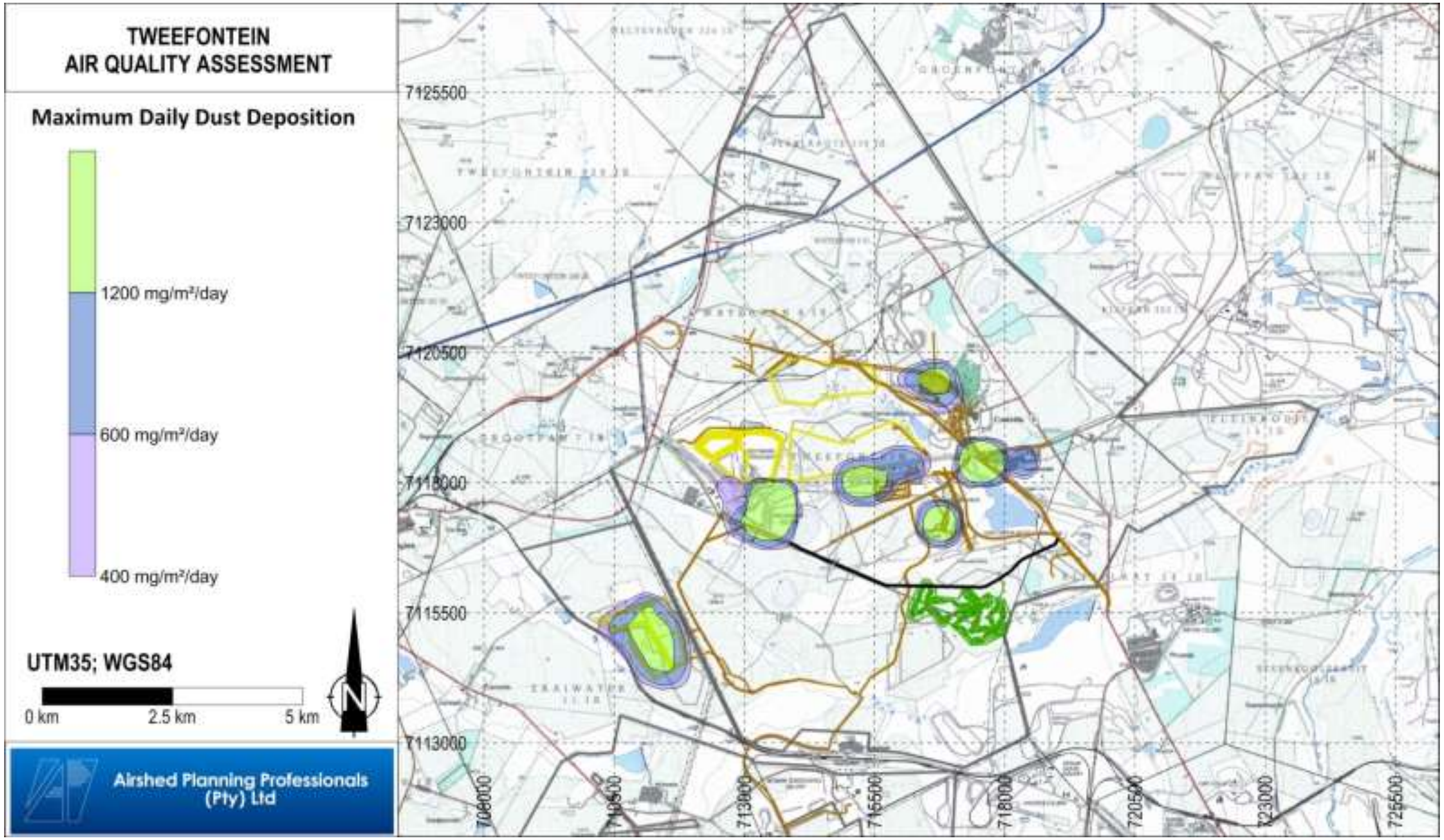


**Figure 4-39: Maximum daily dust deposition due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

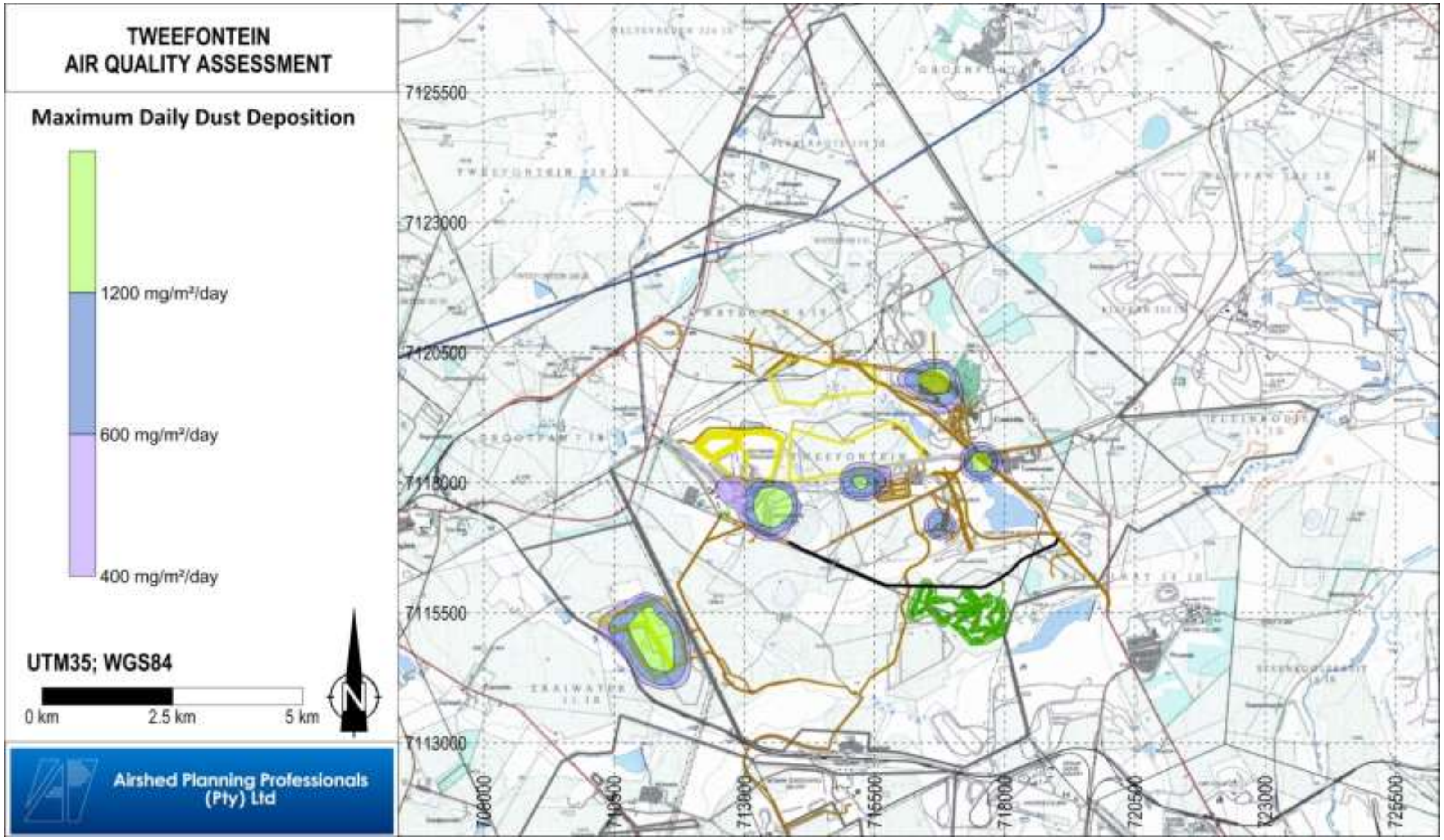


**Figure 4-40: Maximum daily dust deposition due to mitigated Tweefontein Optimisation Project Amendment operations (year 2018)**

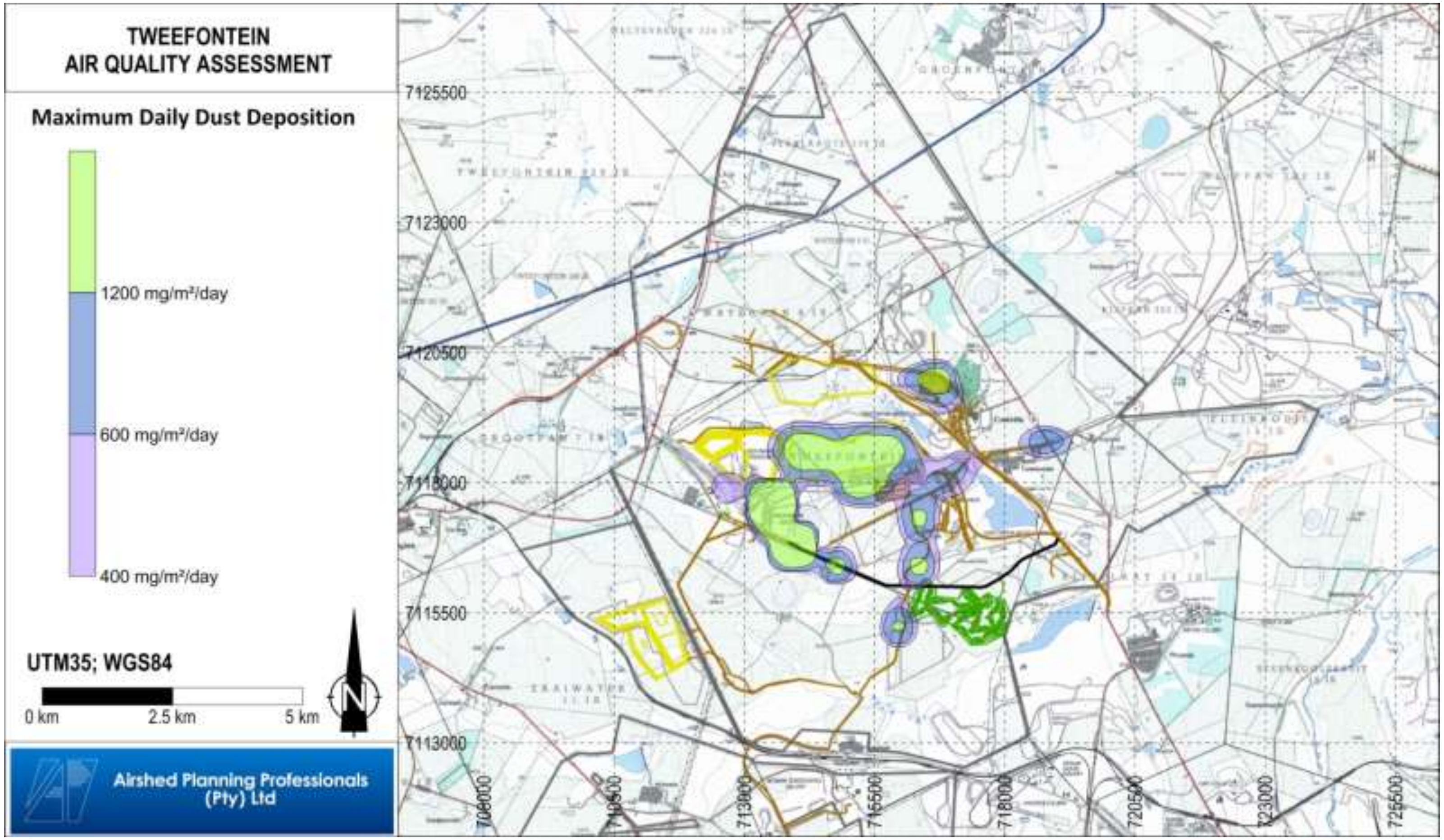


**Figure 4-41: Maximum daily dust deposition due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

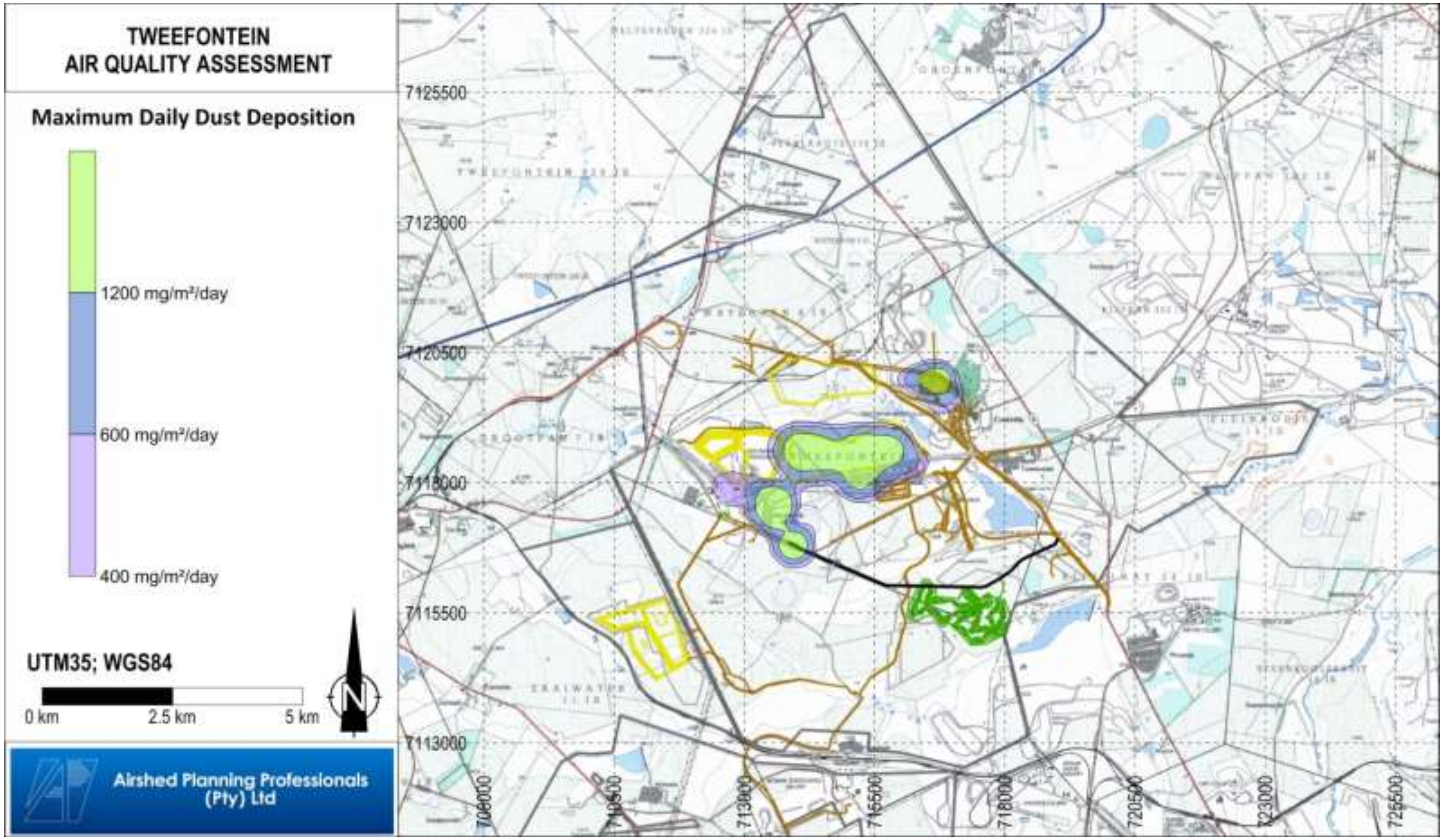


**Figure 4-42: Maximum daily dust deposition due to mitigated Tweefontein Optimisation Project Amendment operations (year 2029)**

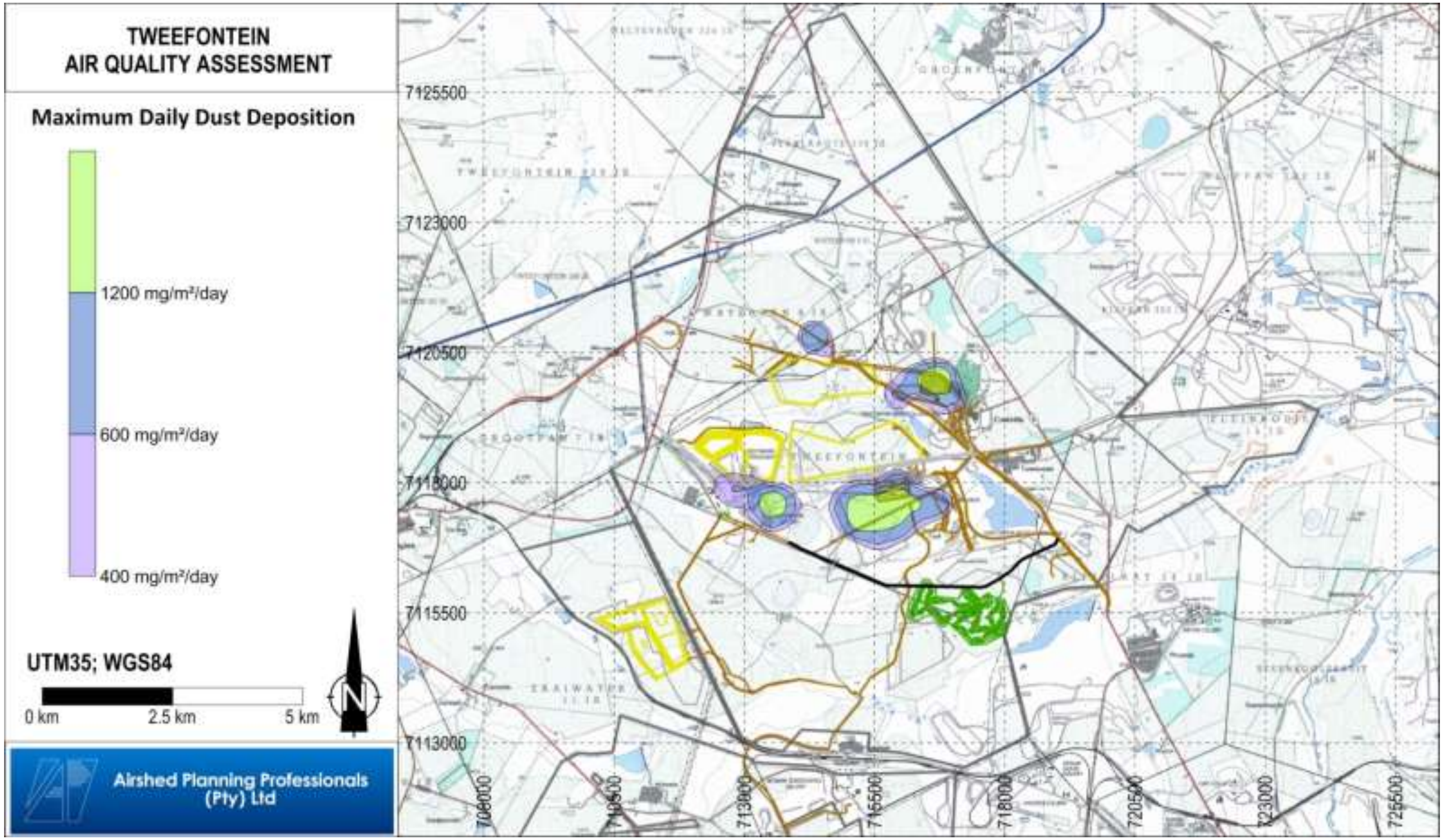


**Figure 4-43: Maximum daily dust deposition due to unmitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

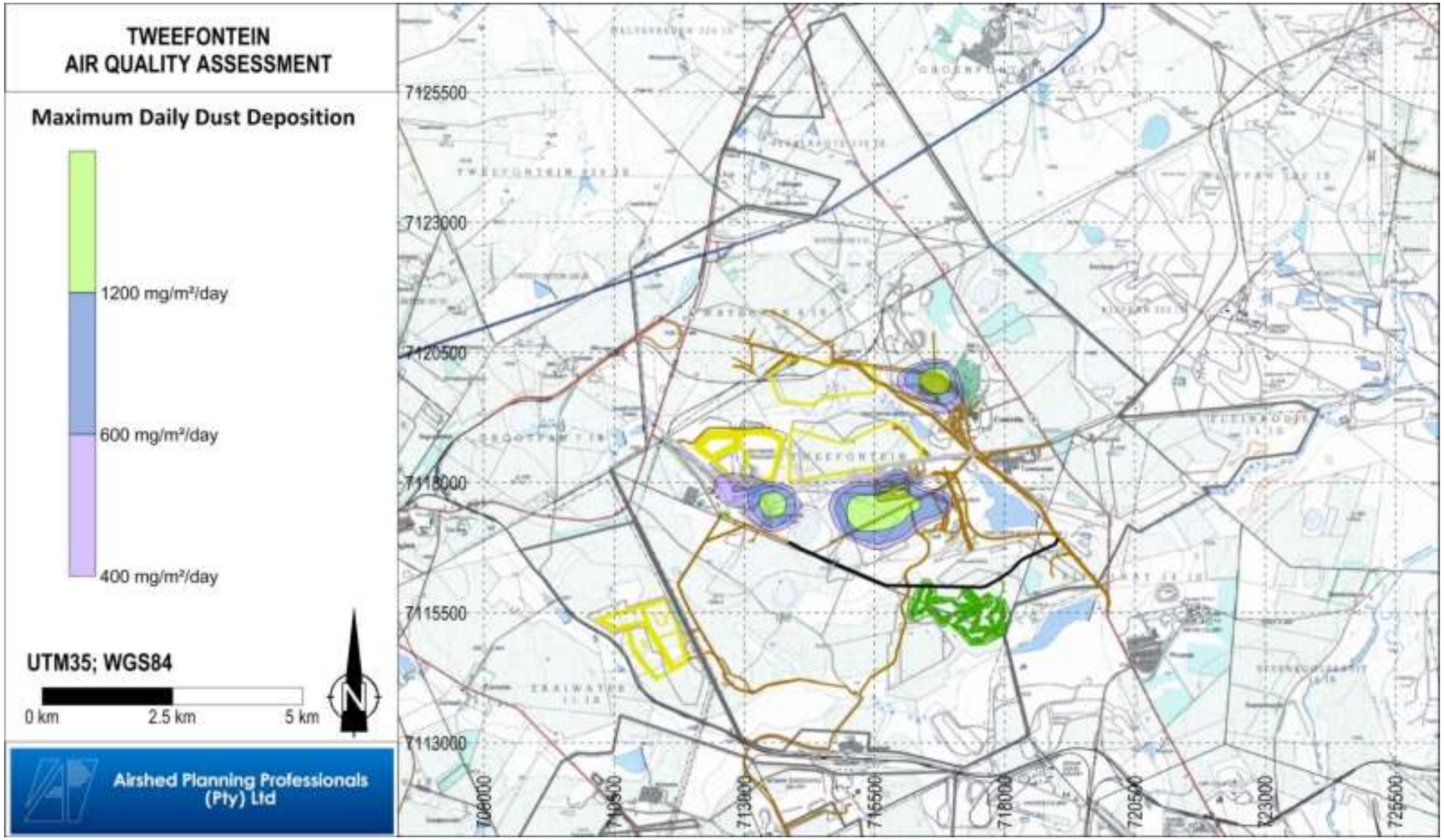


**Figure 4-44: Maximum daily dust deposition due to mitigated Tweefontein Optimisation Project Amendment operations (year 2036)**

### 4.2.3 Predicted Impacts

#### *4.2.3.1 Inhalable Particulate Matter of less than 2.5 µm ($PM_{2.5}$)*

Predicted area of exceedance of the $PM_{2.5}$ NAAQS is provided in Figure 4-5 to Figure 4-20. The predicted $PM_{2.5}$ impacts at the closest sensitive receptors of Makoupan, Vlaklaagte, Saaiwater and Ogies are provided in Table 4-11.

For unmitigated and mitigated operations predicted $PM_{2.5}$ impacts at Vlaklaagte (and individual farmsteads in the area), Saaiwater and Ogies are within NAAQS. At the sensitive receptor of Makoupan, as the mining throughput increases (as is the case for the modelling period 2018 and 2029), the predicted $PM_{2.5}$ impacts due to unmitigated and mitigated operations exceed daily NAAQS.

**Table 4-11: Predicted $PM_{2.5}$ ground level concentrations at the nearest sensitive receptors due to Tweefontein Optimisation Project Amendment operations**

| Unmitigated/ mitigated[a] (U/M) | Sensitive Receptor | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable till 31 Dec 2015 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable 1 Jan 2016 till 31 Dec 2029 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable from 1 Jan 2030 | Annual Average Concentration (µg/m³) | Within $PM_{2.5}$ NAAQS applicable till 31 Dec 2015 | Within $PM_{2.5}$ NAAQS applicable 1 Jan 2016 till 31 Dec 2029 | Within $PM_{2.5}$ NAAQS applicable from 1 Jan 2030 |
|---|---|---|---|---|---|---|---|---|
| **2013** | | | | | | | | |
| U | Makoupan | 1 | NA | NA | <15 | Y | NA | NA |
| | Vlaklaagte/ individual farmsteads in area | 1 | NA | NA | <15 | Y | NA | NA |
| | Saaiwater | 0 | NA | NA | <15 | Y | NA | NA |
| | Ogies | 0 | NA | NA | <15 | Y | NA | NA |
| M | Makoupan | 0 | NA | NA | <15 | Y | NA | NA |
| | Vlaklaagte/ individual farmsteads in area | 1 | NA | NA | <15 | Y | NA | NA |
| | Saaiwater | 0 | NA | NA | <15 | Y | NA | NA |
| | Ogies | 0 | NA | NA | <15 | Y | NA | NA |
| **2018** | | | | | | | | |

| Unmitigated/ mitigated[a] (U/M) | Sensitive Receptor | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable till 31 Dec 2015 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable 1 Jan 2016 till 31 Dec 2029 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable from 1 Jan 2030 | Annual Average Concentration (µg/m³) | Within $PM_{2.5}$ NAAQS applicable till 31 Dec 2015 | Within $PM_{2.5}$ NAAQS applicable 1 Jan 2016 till 31 Dec 2029 | Within $PM_{2.5}$ NAAQS applicable from 1 Jan 2030 |
|---|---|---|---|---|---|---|---|---|
| U | Makoupan | NA | 105 | NA | 34 | NA | N | NA |
| | Vlaklaagte/ individual farmsteads in area | NA | 2 | NA | <15 | NA | Y | NA |
| | Saaiwater | NA | 0 | NA | <15 | NA | Y | NA |
| | Ogies | NA | 0 | NA | <15 | NA | Y | NA |
| M | Makoupan | NA | 9 | NA | 15 | NA | N | NA |
| | Vlaklaagte/ individual farmsteads in area | NA | 2 | NA | <15 | NA | Y | NA |
| | Saaiwater | NA | 0 | NA | <15 | NA | Y | NA |
| | Ogies | NA | 0 | NA | <15 | NA | Y | NA |
| **2029** | | | | | | | | |
| U | Makoupan | NA | 120 | NA | 38 | NA | N | NA |
| | Vlaklaagte/ individual farmsteads in area | NA | 2 | NA | <15 | NA | Y | NA |
| | Saaiwater | NA | 0 | NA | <15 | NA | Y | NA |
| | Ogies | NA | 0 | NA | <15 | NA | Y | NA |
| M | Makoupan | NA | 12 | NA | 15 | NA | N | NA |
| | Vlaklaagte/ individual farmsteads in area | NA | 2 | NA | <15 | NA | Y | NA |
| | Saaiwater | NA | 0 | NA | <15 | NA | Y | NA |
| | Ogies | NA | 0 | NA | <15 | NA | Y | NA |
| **2036** | | | | | | | | |
| U | Makoupan | NA | NA | 4 | <15 | NA | NA | Y |
| | Vlaklaagte/ individual farmsteads in area | NA | NA | 4 | <15 | NA | NA | Y |
| | Saaiwater | NA | NA | 0 | <15 | NA | NA | Y |
| | Ogies | NA | NA | 0 | <15 | NA | NA | Y |

| Unmitigated/ mitigated[a] (U/M) | Sensitive Receptor | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable till 31 Dec 2015 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable 1 Jan 2016 till 31 Dec 2029 | No. of exceedances of daily $PM_{2.5}$ NAAQ limits applicable from 1 Jan 2030 | Annual Average Concentration (µg/m³) | Within $PM_{2.5}$ NAAQS applicable till 31 Dec 2015 | Within $PM_{2.5}$ NAAQS applicable 1 Jan 2016 till 31 Dec 2029 | Within $PM_{2.5}$ NAAQS applicable from 1 Jan 2030 |
|---|---|---|---|---|---|---|---|---|
| M | Makoupan | NA | NA | 0 | <15 | NA | NA | Y |
| | Vlaklaagte/ individual farmsteads in area | NA | NA | 4 | <15 | NA | NA | Y |
| | Saaiwater | NA | NA | 0 | <15 | NA | NA | Y |
| | Ogies | NA | NA | 0 | <15 | NA | NA | Y |

(a) 75% control efficiency on unpaved roads and 50% control efficiency on crushing activities

NA: not applicable as NAAQS not applicable during the operational year

#### *4.2.3.2 Inhalable Particulate Matter of less than 10 µm ($PM_{10}$)*

Predicted area of exceedance of the $PM_{10}$ NAAQS is provided in Figure 4-21 to Figure 4-36. The predicted $PM_{10}$ impacts at the closest sensitive receptors of Makoupan, Vlaklaagte, Saaiwater and Ogies are provided in Table 4-12.

For unmitigated and mitigated operations predicted $PM_{10}$ impacts at Saaiwater and Ogies are within NAAQS. At the sensitive receptor of Vlaklaagte (and individual farmsteads in the area), as the mining throughput increases (as is the case for the modelling period 2018 and 2029), the predicted $PM_{10}$ impacts due to unmitigated operations exceed daily NAAQS but are within standards for mitigated operations. At the sensitive receptor of Makoupan the predicted $PM_{10}$ impacts due to unmitigated operations exceed daily NAAQS. As the mining throughput increases (as is the case for the modelling period 2018 and 2029), predicted $PM_{10}$ concentrations at Makoupan still exceed NAAQS during mitigated operations.

**Table 4-12: Predicted $PM_{10}$ ground level concentrations at the nearest sensitive receptors due to Tweefontein Optimisation Project Amendment operations**

| Unmitigated/ mitigated[(a)] (U/M) | Sensitive Receptor | No. of exceedances of daily $PM_{10}$ NAAQ limits applicable till 31 Dec 2014 | No. of exceedances of daily $PM_{10}$ NAAQ limits applicable 1 Jan 2015 | Annual Average Concentration (µg/m³) | Within $PM_{10}$ NAAQS applicable till 31 Dec 2014 | Within $PM_{10}$ NAAQS applicable 1 Jan 2015 |
|---|---|---|---|---|---|---|
| **2013** | | | | | | |
| U | Makoupan | 25 | NA | 40 | N | NA |
| | Vlaklaagte/ individual farmsteads in area | 4 | NA | <40 | Y | NA |
| | Saaiwater | 3 | NA | <40 | Y | NA |
| | Ogies | 0 | NA | <40 | Y | NA |
| M | Makoupan | 4 | NA | <40 | Y | NA |
| | Vlaklaagte/ individual farmsteads in area | 1 | NA | <40 | Y | NA |
| | Saaiwater | 0 | NA | <40 | Y | NA |
| | Ogies | 0 | NA | <40 | Y | NA |
| **2018** | | | | | | |
| U | Makoupan | NA | 260 | 300 | NA | N |
| | Vlaklaagte /individual farmsteads in area | NA | 25 | <40 | NA | N |
| | Saaiwater | NA | 7 | <40 | NA | N |
| | Ogies | NA | 3 | <40 | NA | Y |
| M | Makoupan | NA | 150 | 90 | NA | N |
| | Vlaklaagte/individual farmsteads in area | NA | 4 | <40 | NA | Y |
| | Saaiwater | NA | 0 | <40 | NA | Y |
| | Ogies | NA | 0 | <40 | NA | Y |
| **2029** | | | | | | |
| U | Makoupan | NA | 290 | 320 | NA | N |
| | Vlaklaagte/ individual farmsteads in area | NA | 50 | <40 | NA | N |
| | Saaiwater | NA | 34 | <40 | NA | N |
| | Ogies | NA | 5 | <40 | NA | N |
| M | Makoupan | NA | 160 | 100 | NA | N |
| | Vlaklaagte/ individual farmsteads in area | NA | 4 | <40 | NA | Y |

| Unmitigated/ mitigated[(a)] (U/M) | Sensitive Receptor | No. of exceedances of daily $PM_{10}$ NAAQ limits applicable till 31 Dec 2014 | No. of exceedances of daily $PM_{10}$ NAAQ limits applicable 1 Jan 2015 | Annual Average Concentration (µg/m³) | Within $PM_{10}$ NAAQS applicable till 31 Dec 2014 | Within $PM_{10}$ NAAQS applicable 1 Jan 2015 |
|---|---|---|---|---|---|---|
| | Saaiwater | NA | 3 | <40 | NA | Y |
| | Ogies | NA | 0 | <40 | NA | Y |
| **2036** | | | | | | |
| U | Makoupan | NA | 35 | <40 | NA | N |
| | Vlaklaagte/ individual farmsteads in area | NA | 8 | <40 | NA | N |
| | Saaiwater | NA | 0 | <40 | NA | Y |
| | Ogies | NA | 0 | <40 | NA | Y |
| M | Makoupan | NA | 1 | <40 | NA | Y |
| | Vlaklaagte/ individual farmsteads in area | NA | 4 | <40 | NA | Y |
| | Saaiwater | NA | 0 | <40 | NA | Y |
| | Ogies | NA | 0 | <40 | NA | Y |

(a) 75% control efficiency on unpaved roads and 50% control efficiency on crushing activities

NA: not applicable as NAAQS not applicable during the operational year

#### *4.2.3.3 Predicted Dustfall Rates*

The predicted area of exceedance of the draft National Dust Control Regulation for residential areas is provided in Figure 4-37 to Figure 4-44. Table 4-13 provides predicted dust fallout due to Tweefontein Optimisation Project Amendment operations at the closest sensitive receptors. Predicted dustfall at all sensitive receptors are within the draft dust fallout regulations of 600 mg/m²/day (with the exception of Makoupan due to unmitigated operations during the period 2018) considered acceptable for residential areas.

**Table 4-13: Predicted dustfall rates during the operation phase at the closest sensitive receptor**

| Sensitive Receptor | Highest Daily Dustfall (mg/m²/day) | |
|---|---|---|
| | Unmitigated operations | Mitigated operations [(a)] |
| **2013** | | |
| Makoupan | <400 | <400 |
| Vlaklaagte/ individual farmsteads in area | <400 | <400 |
| Saaiwater | <400 | <400 |
| Ogies | <400 | <400 |
| **2018** | | |
| Makoupan | 1200 | 600 |
| Vlaklaagte/ individual farmsteads in area | <400 | <400 |
| Saaiwater | <400 | <400 |
| Ogies | <400 | <400 |
| **2029** | | |
| Makoupan | 400 | <400 |
| Vlaklaagte/ individual farmsteads in area | <400 | <400 |
| Saaiwater | <400 | <400 |
| Ogies | <400 | <400 |
| **2036** | | |
| Makoupan | <400 | <400 |
| Vlaklaagte/ individual farmsteads in area | <400 | <400 |
| Saaiwater | <400 | <400 |
| Ogies | <400 | <400 |

(a) 75% control efficiency on unpaved roads and 50% control efficiency on crushing activities

#### *4.2.3.4 Predicted Impacts on Vegetation and Animals*

No national ambient air quality standards or guidelines are available for the protection of animals and vegetation. In the absence of national ambient standards for animals, the standards used for the protection of human beings may be used to assess the impacts on animals. Areas of non-compliance of $PM_{10}$ and $PM_{2.5}$ NAAQS due to Tweefontein Optimisation Project Amendment operations are illustrated in Figure 4-5 to Figure 4-36.

While there is little direct evidence of what the impact of dust fall on vegetation is under a South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in Sunflower and Cotton plants exposed to dust fall rates greater than 400 mg/m²/day (Farmer 1991). The predicted dust deposition due to Tweefontein Optimisation Project Amendment operations is provided in Figure 4-37 to Figure 4-44.

If more detailed information is required on the impact of particulate matter on vegetation and animals, it is recommended that the predicted PM concentrations and dust depositions be used in a more detailed biodiversity and/or health risk assessment study.

### 4.2.4 Mitigation Measures Recommended

Air quality management measures should be implemented to ensure the lowest possible impacts on the surrounding environment from operations. This can be achieved through a combination of mitigation measures and ambient monitoring.

Proposed target controls on the various sources are provided below:

- Vehicle entrainment on haul roads – 75% control efficiency through effective water sprays on unpaved road surfaces.
- Crushing and screening activities – 50% control efficiency through effective water sprays.

#### *4.2.4.1 Materials Handling Dust Control Options*

Although these activities did not represent the largest source of particulate emissions, various mitigation measures (as discussed in this section) are available to minimise the emissions.

Control techniques applicable to materials handling are generally classifiable as comprising (i) source extent reduction, (ii) source improvement related to work practices and transfer equipment, and (iii) surface treatment. These control options may be summarised as follows:

(i) Source extent reduction:
  - Mass transfer reduction

(ii) Source improvement:

- Drop height reduction
- Wind sheltering
- Moisture retention

(iii) Surface treatment:

- Wet suppression
- Air atomising suppression

The efficiency of these controls may be estimated through the relationships between climatic parameters, material properties and quantities of material transferred demonstrated in the predictive emission factor equation.

**(a) Good Operating Practices: Mass Transfer Reduction**

*Good operational practices* frequently represent the **most cost effective and efficient means** of reducing emissions. The variation of the height from which stacking occurs to suit the height of the storage pile would limit drop heights and therefore reduce the potential for the entrainment of fines by the wind.

**(b) Wet Suppression: Liquid and Foam Spray Systems**

Wet suppression systems use either liquid sprays or foam to suppress the formation of airborne dust. Emissions are prevented through agglomerate formation by combining fine particulates with larger aggregate or with liquid droplets. The key factors which affect the extent of agglomeration and therefore the efficiency of the system are the coverage of the material by the liquid and the ability of the liquid to "wet' small particles. The only wet suppression systems considered in this section is liquid sprays.

Liquid spray suppression systems may use only water or a combination of water and a chemical surfactant as the wetting agent. Surfactants reduce the surface tension of the water thus allowing particles to more easily penetrate the water particle and reducing the quantity of water needed to achieve the control efficiency required. General engineering guidelines which have been shown to be effective in improving the control efficiency of liquid spray systems are as follows:

- of the various nozzle types, the use of hollow cone nozzles tend to afford the greatest control for bulk materials handling applications whilst minimising clogging;
- optimal droplet size for surface impaction and fine particle agglomeration is about 500 µm; finer droplets are affected by drift and surface tension and appear to be less effective; and,
- application of water sprays to the underside of conveyor belts have been noted by various studies to improve the efficiency of water suppression systems and belt-to-belt transfer points.

The control efficiency of pure water suppression can be estimated based on the US-EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 4-45 and was used as the basis for assumptions made with regard to the control efficiency of wet suppression systems currently being utilised at the facility.

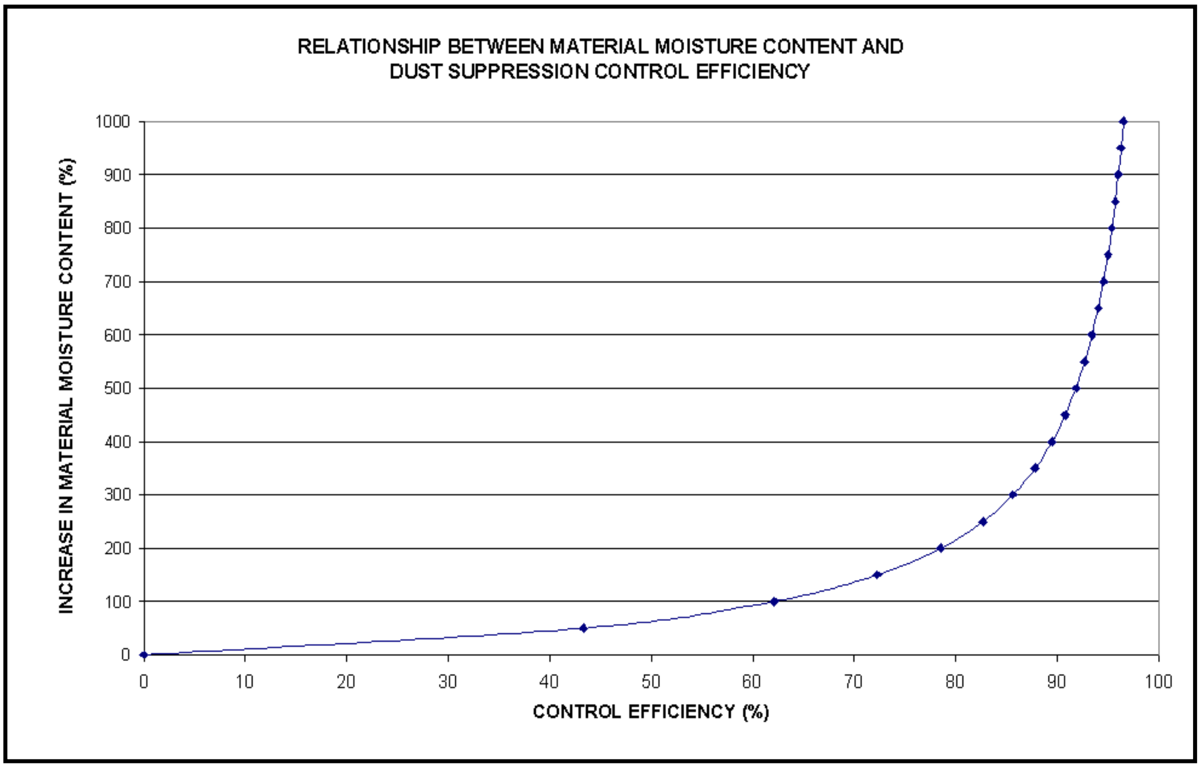


**Figure 4-45: Relationship between the moisture content of the material being handled and the dust control efficiency provided for, calculated based on the US-EPA predictive emission factor equation for continuous and batch drop operations**

It is important to note that the improvements in dust control efficiencies are marginal following increases in material moisture contents by 400%. To obtain control efficiencies of greater than 90%, it would be more feasible and cost effective to consider either alternative systems (e.g. foam suppression) or supplementary methods (e.g. addition of chemical surfactants to water).

**(c) Wind Sheltering**

Wind sheltering techniques are widely applied for dust minimization during stacking and loading operations, particularly in cases where the application of wet suppression is not a viable alternative. The application of transfer chutes represents one of the most common of such wind sheltering methods.

Transfer chutes can be used at belt-to-belt transfer points. Chutes provide the potential for dust control due to (i) wind sheltering, and (ii) prevention of spillages, which could give rise to dust emissions through wind or vehicle entrainment. Spillage, material degradation, conveyor belt damage, blockage and high maintenance costs have been noted as commonly re-occurring problems at transfer chute operating sites. Considerable improvements on conventional transfer chute design over the past few years have, however, resulting in solutions to many of these problems.

The South African developed Weba Chute is reported by its developer, M & J Engineering (Pty) Ltd, to have been installed in dolomite, iron ore, coal, manganese, kimberlite, phosphate and agricultural product operations. This transfer chute technology is described as being able to be applied in transfer of lumpy, sticky, and slightly wet materials. Spillage avoidance, dust minimization and noise abatement represent the main environmental benefits of the Weba Chute. Examples of Weba chutes are given in Figure 4-46.

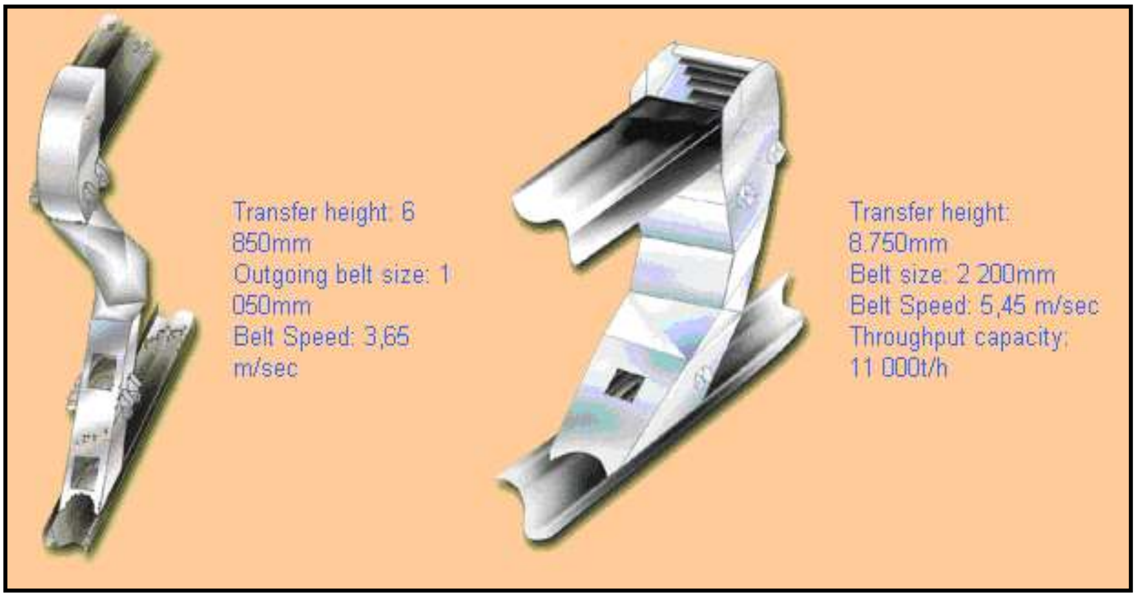


**Figure 4-46: Examples of Weba chutes, developed by M & J Engineering (after www.mjeng.co.za)**

### (d) Air Atomising Spray Systems

Significant developments have been made in the field of air atomising spray systems. These systems use water and compressed air to produce micron sized droplets that are able to suppress respirable dust without adding any detectable moisture to the process. As such, such systems may be suitable for implementation at transfer points beyond the sampling plant. No information could be obtained on the control efficiency of such spray systems.

### (e) Conveyor

A conveyor belt can generate large amounts of respirable dust on-site from several sources. If the belt is not clean, dust is knocked from the belt as it passes over the idlers. Belt scraping and washing will reduce this dust source, and if the belt is dry, just wetting it can help. Also, much respirable dust originates at belt transfer points (Kissel & Stachulak, 2003).

Belt cleaning by scraping and washing. Conveyor belts are usually equipped with belt scrapers; some have belt washers as well. Several manufacturers sell scrapers and washers; these play an important role in reducing the amount of dust generated by conveyor belt carryback. Carryback is that portion of the carried material that sticks to the belt instead of falling off at the head pulley. It becomes airborne dust as the belt dries and passes over the return idlers. When dust levels are high, the usual approach is to add a second or even third scraper rather than trying to get a single scraper to work better. While multiple scrapers will reduce dust, they may be more efficient at spillage control than respirable dust control. Roberts et al. (1987) have shown that with each successive scraping, both the percentage of fines and the moisture level of the carryback substantially increase. This shows that the larger material is preferentially removed by scraping and the smallest fines (which generate respirable dust) tend to stay stuck to the belt. If multiple scrapers do not remove enough carryback to cut the respirable dust sufficiently, a water wash system may be necessary. These systems spray the belt with water in addition to scraping it.

Planner (1990) has reported on the average belt-cleaning efficiency of water sprays when used with primary and secondary scrapers. In the Planner study, water sprays placed between the primary and secondary scrapers reduced carryback from 11.1% to 3.4%. In another test, water sprays added to a secondary scraper reduced carryback from 13.9% to 1.1%. Belt sprays also reduce airborne dust. Rodgers et al. (1978) added a 150-gpm water spray system to dry scrapers on a 54-in belt at a taconite processing plant. The sprays reduced respirable dust by 48% and total dust by 78% compared to dry scrapers alone.

More recently, Baig et al. (1994) reported that airborne (respirable and float) coal dust levels were reduced 80%-90% when their belt scrapers were augmented with spray wash boxes.

Wetting of dry belts. Several studies have shown that wetting the bottom (return) belt can reduce dust from a dry belt. For example, Courtney (1983) measured the respirable dust reduction from a single 0.33-gpm spray onto the top surface (the non-carrying surface) of the bottom belt. The goal was to prevent dust from being knocked loose by the tail pulley and upper idlers. The spray was followed by a piece of ordinary floor carpet that wiped the belt to prevent channelling of the water. The spray and carpet were mounted close to the tail pulley so that the belt was wet as it passed around the tail pulley and moved out by over the upper idlers (Figure 4-47).

Respirable dust reduction from installation of the spray and carpet averaged 75%. A 2-gpm spray without the carpet worked about as well. Slippage from excessive wetting was not a problem, as water usage was low (only 2 gpm) and the belt then travelled for 5,000 ft before passing over the drive at the head end.

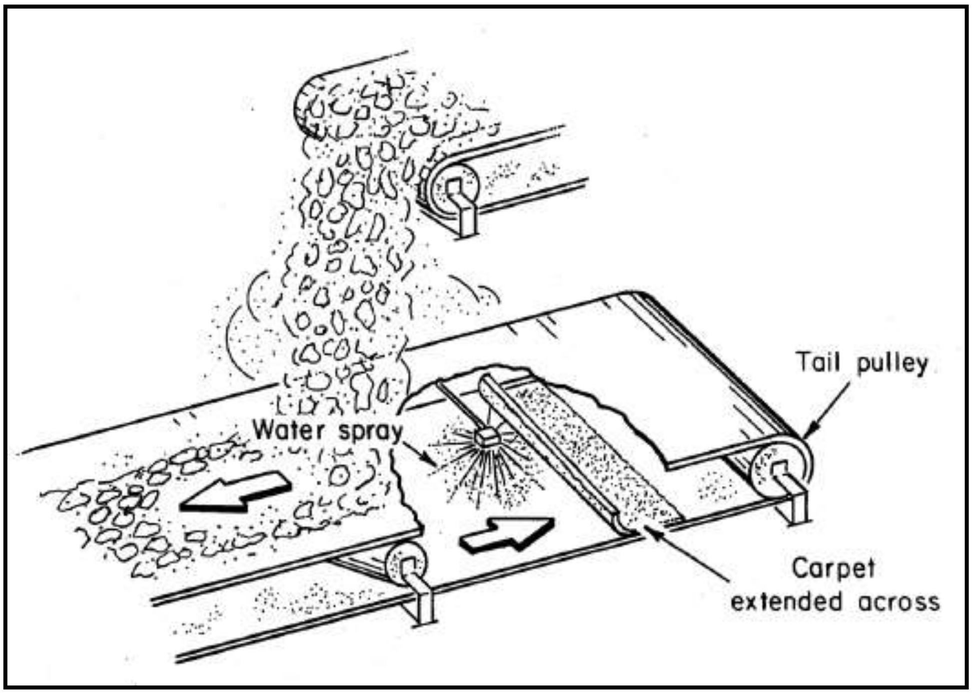


**Figure 4-47: Wetting the top surface of the bottom belt**

A decade earlier than Courtney, Ford (1973) tested a system that wetted both surfaces of the bottom belt (Figure 4-48). A spray in the loop take-up near the belt head wetted the carrying surface so that dust was not knocked loose by the ingoing trip over the lower idlers. Then, near the tail pulley, the non-carrying surface of the bottom belt was wetted by a second spray for the trip around the tail pulley and across the upper idlers, similar to the system described by Courtney. Sprays were mounted so as to wet the entire width of the belt, and they were controlled automatically to operate only when the belt ran. A belt plow was used in place of the carpet. Respirable dust was reduced by 67% with a total (all sprays) water flow of 0.53 gpm[1].

Closed conveyor belts. Another technique used to control dust from conveyor belts is to close the conveyor belt system. The Australia NPi provides control efficiencies of 70% on closed conveyor systems.

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[1] Low-flow spray nozzles are prone to clogging because of their small orifice size. To avoid nozzle clogging while reducing water use, control timers have been developed to cycle belt sprays on and off (BWI Eagle, Inc.). Timers also allow better control over the degree of belt wetting.

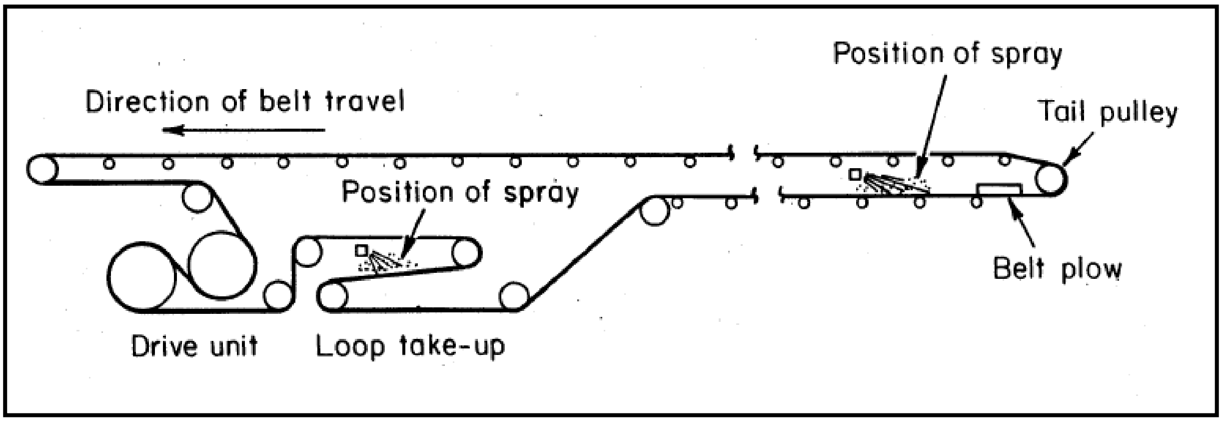


**Figure 4-48: Wetting both surfaces of the bottom belt**

### *4.2.4.2 Dust Control Options for Unpaved Roads*

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowhert et al., 1988; APCD, 1995).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds
- Number of wheels per vehicle
- Traffic volumes
- Particle size distribution of the aggregate
- Compaction of the surface material
- Surface moisture
- Climate

According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 10 miles per hour resulted in an increase in $PM_{10}$ emissions of between 1.5 and 3 times. A similar study conducted by Flocchini et.al. (1994) found a decrease in $PM_{10}$ emissions of 42±35% with a speed reduction from 40 km/hr to

24 km/hr (Stevenson, 2004). The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads.

Water sprays on unpaved roads is the most common means of suppressing fugitive dust due to vehicle entrainment at mines, but it is not necessarily the most efficient means (Thompson and Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs. The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson and Visser, 2000).

An empirical model, developed by the US EPA (EPA, 1996), can be used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic.

Chemical suppressant has been proven to be affective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative include numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of each own. In general, chemical suppressants are given to achieve a $PM_{10}$ control efficiency of 80% to 90% when applied regularly on the road surfaces (Stevenson, 2004).

There is however no cure-all solution but rather a combination of solutions. A cost-effective chemical control programme may be developed through establishing the minimum control efficiency required on a particular roadway, and evaluating the costs and benefits arising from various chemical stabilization practices. Appropriate chemicals and the most effective relationships between application intensities, reapplication frequencies, and dilution ratios may be taken into account in the evaluation of such practices.

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic “housekeeping” activities (Cowherd et al., 1988; EPA, 1996). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded. The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping for cross sectional crowing to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources (MFE, 2001).

#### *4.2.4.3 Crushing and Screening Operations*

Enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts. According to the Australian NPi, water sprays can have up to 50% control efficiency and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed; up to 100% control efficiency can be achieved. Hooding with fabric filters can result in control efficiencies of 83%. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

## 4.3 Demolition and Closure Phase

It is assumed that all the operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure.

Aspects and activities associated with the demolition and closure phase of the proposed operations are listed in Table 4-14.

**Table 4-14: Activities and aspects identified for the demolition and closure phase**

| Impact | Source | Activity |
|---|---|---|
| Generation of TSP, $PM_{2.5}$ and $PM_{10}$ | Topsoil stockpiles | Topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings |
| | Plant site | Infrastructure removal at plant site |
| | Unpaved roads | Vehicle entrainment on unpaved road surfaces |
| Gas emissions | Vehicles | Tailpipe emissions from vehicles utilised during the closure phase. |

Simulations of the closure phase were not included in the current study due to its temporary impacting nature.

### 4.3.1 Overview of Dust Control Measures for Exposed Surfaces

Dust control measures for open areas can consist of wet suppression, chemical suppressants, vegetation, wind breaks, etc. Wet suppressants and chemical suppressants are generally applied for short storage pile durations. For long-term control measures vegetation frequently represents the most cost-effective and efficient control.

### *Long-term Control Measures*

Vegetation cover retards erosion by binding the soil with a root network, by sheltering the soil surface and by trapping material already eroded. Sheltering occurs by reducing the wind velocity close to the surface, thus reducing the erosion potential and volume of material removed. The trapping of the material already removed by wind and in suspension in the air is an important secondary effect. Vegetation is also considered the most effective control measure in terms of its ability to also control water erosion. In investigating the feasibility of vegetation types the following properties are normally taken into account: indigenous plants; ability to establish and regenerate quickly; proven effective for reclamation elsewhere; tolerant to the climatic conditions of the area; high rate of root production; easily propagated by seed or cuttings; and nitrogen-fixing ability. The long-term effectiveness of suitable vegetation selected for the site will be dependent on the nature of the cover.

# 5 SIGNIFICANCE RATING

The significance rating for the Tweefontein Optimisation Project Amendment is provided in Table 5-1.

**Table 5-1: Significance rating for air quality due to Tweefontein Optimisation Project Amendment operations**

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation – Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| **1. CONSTRUCTION PHASE (approx. 6 months - 1 year)** | | | | | | | | | | | | | | | | | | | | | | | |
| **1.1 Opening of Initial Boxcuts for Coal Mining** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.2 Preparation for the Underground Mining of Coal** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.2.1 | **Air** | It is noted that all new underground mining areas associated with this project will be accessed via existing shafts, and therefore no construction activities will be applicable. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **1.3 Opening of Initial Boxcuts for Sand and Gravel Mining (Borrow Pits) for Construction Purposes** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs Yes / No | Rating: Status | Rating: Magnitude | Rating: Extent | Rating: Duration | Rating: Probability | Rating: Significance | Rating: Reversibility | Rating: Irreplaceable loss of resources | Rating: Potential of impacts to be mitigated | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan: Concurrent (Annual Cost) | Financial Plan: Final (Rehabilitation) | Residual Impacts after mitigation Rating: Magnitude | Residual Rating: Extent | Residual Rating: Duration | Residual Rating: Probability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.3.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities. Wet suppression or chemical stabilization of unpaved roads. Haul trucks to be restricted to specified haul roads. Reduction of unnecessary traffic. Strict speed control. Minimise extent of disturbed areas. Reduction of frequency of disturbance. Early re-vegetation. Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.4 Construction of Water Management Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.4.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.Wet suppression or chemical stabilization of unpaved roads.Haul trucks to be restricted to specified haul roads.Reduction of unnecessary traffic.Strict speed control.Minimise extent of disturbed areas.Reduction of frequency of disturbance.Early re-vegetation.Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental ManagerContractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.5 Construction of Diesel Storage Tanks** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 1.5.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.Wet suppression or chemical stabilization of unpaved roads.Haul trucks to be restricted to specified haul roads.Reduction of unnecessary traffic.Strict speed control.Minimise extent of disturbed areas.Reduction of frequency of disturbance.Early re-vegetation.Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental ManagerContractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.6 Construction of Waste Management Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.6.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.7 Construction of Temporary Coal Stockpile** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 1.7.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.8 Construction of Explosives Magazine** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.8.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Medium** |
| **1.9 Construction of General Fencing on Site** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 1.9.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.Wet suppression or chemical stabilization of unpaved roads.Haul trucks to be restricted to specified haul roads.Reduction of unnecessary traffic.Strict speed control.Minimise extent of disturbed areas.Reduction of frequency of disturbance.Early re-vegetation.Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental ManagerContractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Low** |
| **1.10 Construction of Roads** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.10.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Water sprays at area to be graded.<br>Freshly graded areas to be kept to a minimum. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Mediu m** |
| **1.11 Construction of ROM Tip** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs Yes / No | Rating: Status | Rating: Magnitude | Rating: Extent | Rating: Duration | Rating: Probability | Rating: Significance | Rating: Reversibility | Rating: Irreplaceable loss of resources | Rating: Potential of impacts to be mitigated | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan: Concurrent (Annual Cost) | Financial Plan: Final (Rehabilitation) | Residual Impacts after mitigation Rating: Magnitude | Residual Impacts after mitigation Rating: Extent | Residual Impacts after mitigation Rating: Duration | Residual Impacts after mitigation Rating: Probability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.11.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Mediu m** |
| **1.12 Construction of Raw Coal Stockpile** | | | | | | | | | | | | | | | | | | | | | | | |
| 1.12.1 | **Air** | Dust will be generated by construction activities. Exposed surfaces from the removal of vegetation are susceptible to erosional forces including wind. Construction vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | **36** | **1** | **1** | **2** | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction Phase | | | **Low** | **Local** | **Short term** | **Mediu m** |
| **2. OPERATIONAL PHASE** | | | | | | | | | | | | | | | | | | | | | | | |
| **2.1 Opencast Mining of Coal** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 2.1.1 | **Air** | Dust will be generated by materials handling activities. | | **-** | **6** | **2** | **4** | **4** | **48** | **1** | **1** | **2** | Conserve air quality | N/A | Drop height from excavator into haul trucks to be kept at a minimum for ore and waste rock. | Environmental Manager | Operation Phase | | | **Low** | **Local** | **Long term** | **Medium** |
| 2.1.2 | **Air** | Dust will be generated by drilling and blasting activities. | | **-** | **6** | **2** | **4** | **4** | **48** | **1** | **1** | **2** | Conserve air quality | N/A | Controlled blasting techniques to be used to ensure minimal dust generation. | Environmental Manager | Operation Phase | | | **Low** | **Local** | **Long term** | **Medium** |
| 2.1.3 | **Air** | Dust will be generated by vehicle entrainment for the removal of coal to crusher plant. | | **-** | **8** | **3** | **4** | **4** | **60** | **1** | **1** | **2** | Conserve air quality | N/A | Regular water sprays preferably combined with chemicals on unpaved haul roads to ensure at least 75% control efficiency.<br>Speed limit on haul roads not to exceed 40 km/hr. | Environmental Manager | Operation Phase | | | **Low** | **Local** | **Long term** | **Medium** |
| **2.2 Concurrent Rehabilitation of Opencast Voids** | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2.1 | **Air** | Dust will be generated by materials handling activities. | | **-** | **6** | **2** | **4** | **4** | **48** | **1** | **1** | **2** | Conserve air quality | N/A | Minimise drop height for backfilling activities.<br>Reduction of unnecessary traffic.<br>Minimise extent of disturbed areas.<br>Early re-vegetation. | Environmental Manager | Operation Phase | | | **Low** | **Local** | **Long term** | **Medium** |
| **2.3 Underground Mining of Coal** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 2.3.1 | **Air** | Dust and gaseous emissions from updraft vents and removal of ROM material to crusher plant. | | **-** | **8** | **3** | **4** | **4** | **60** | **1** | **1** | **2** | Conserve air quality | N/A | Regular water sprays preferably combined with chemicals on unpaved haul roads to ensure at least 75% control efficiency.<br>Speed limit on haul roads not to exceed 40 km/hr. | Environmental Manager | Operation Phase | | | **Mode-rate** | **Local** | **Long term** | **Mediu m** |
| **2.4 Opencast Mining of Sand and Gravel (Borrow Pits) for Construction Purposes** | | | | | | | | | | | | | | | | | | | | | | | |
| 2.4.1 | **Air** | Dust will be generated by materials handling activities. | | **-** | **6** | **2** | **4** | **4** | **48** | **1** | **1** | **2** | Conserve air quality | N/A | Drop height from excavator into haul trucks to be kept at a minimum for ore and waste rock.<br>Tipping onto ROM storage pile to be controlled through water sprays should significant amounts of dust be generated. | Environmental Manager | Operation Phase | | | **Low** | **Local** | **Long term** | **Mediu m** |
| 2.4.2 | **Air** | Dust will be generated by vehicle entrainment. | | **-** | **8** | **3** | **4** | **4** | **60** | **1** | **1** | **2** | Conserve air quality | N/A | Regular water sprays preferably combined with chemicals on unpaved haul roads to ensure at least 75% control efficiency.<br>Speed limit on haul roads not to exceed 40 km/hr. | Environmental Manager | Operation Phase | | | **Mode-rate** | **Local** | **Long term** | **Mediu m** |
| **2.5 Use and Maintenance of Water and Waste Management Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs Yes / No | Rating: Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan: Concurrent (Annual Cost) | Final (Rehabilitation) | Residual Impacts after mitigation Rating: Magnitude | Extent | Duration | Probability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5.1 | Air | Dust will be generated with the construction and operation of the Zaaiwater tailings dams over the Zaaiwater opencast pit area. | | - | 6 | 2 | 4 | 4 | 48 | 1 | 1 | 2 | Conserve air quality | N/A | Wet suppression where feasible on exposed surfaces and materials handling activities.<br>Wet suppression or chemical stabilization of unpaved roads.<br>Haul trucks to be restricted to specified haul roads.<br>Reduction of unnecessary traffic.<br>Strict speed control.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Construction and Operation Phase | | | Mode-rate | Local | Long term | Medium |
| **2.6 Use and Maintenance of Linear Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | |
| 2.6.1 | Air | Dust will be generated by vehicle entrainment and grading activities. | | - | 8 | 3 | 4 | 4 | 60 | 1 | 1 | 2 | Conserve air quality | N/A | Regular water sprays preferably combined with chemicals on unpaved haul roads to ensure at least 75% control efficiency.<br>Speed limit on haul roads not to exceed 40 km/hr. | Environmental Manager | Operation Phase | | | Mode-rate | Local | Long term | Medium |
| **2.7 Use and Maintenance of Other Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | |
| 2.7.1 | Air | Dust will be generated by materials handling activities at ROM tip and windblown from coal stockpiles. | | - | 6 | 2 | 4 | 4 | 48 | 1 | 1 | 2 | Conserve air quality | N/A | Tipping onto ROM storage pile to be controlled through water sprays should significant amounts of dust be generated. | Environmental Manager | Operation Phase | | | Low | Local | Long term | Medium |
| **3. Decommissioning Phase (after operational phase until closure goals are reached)** | | | | | | | | | | | | | | | | | | | | | | | |
| **3.1 Rehabilitation of Areas Impacted by the Mining and Related Activities within the Tweefontein Complex** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 3.1.1 | **Air** | Dust will be generated by rehabilitation activities. Exposed surfaces are susceptible to erosional forces including wind. Vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | 36 | 1 | 1 | 2 | Conserve air quality | N/A | Demolition of infrastructure to have water sprays where vehicle activity is high. Ensure site is restored to pre-mining conditions. | Environmental Manager Contractor(s) | Rehabilitation Phase | | | **Mode-rate** | **Local** | **Long term** | **Mediu m** |
| **3.2 Legacy Rehabilitation Project** | | | | | | | | | | | | | | | | | | | | | | | |
| 3.2.1 | **Air** | Dust will be generated by rehabilitation activities. Exposed surfaces are susceptible to erosional forces including wind. Vehicles and machinery moving along roads will generate dust. | | **-** | **6** | **1** | **2** | **4** | 36 | 1 | 1 | 2 | Conserve air quality | N/A | Water sprays where vehicle activity is high. Ensure site is restored to pre-mining conditions. | Environmental Manager Contractor(s) | Rehabilitation Phase | | | **Mode-rate** | **Local** | **Long term** | **Mediu m** |
| **3.3 Golf Course** | | | | | | | | | | | | | | | | | | | | | | | |
| 3.3.1 | **Air** | Dust will be generated by rehabilitation and construction activities. Exposed surfaces are susceptible to erosional forces including wind. Vehicles and machinery moving along roads will generate dust. As rehablitation progresses, less dust will be generated by the rehabilitation activities, and the air quality will improve. | | **-** | **6** | **1** | **2** | **4** | 36 | 1 | 1 | 2 | Conserve air quality | N/A | Wet suppression where feasible on stockpiles and materials handling activities. Wet suppression or chemical stabilization of unpaved roads. Haul trucks to be restricted to specified haul roads. Reduction of unnecessary traffic. Strict speed control. Minimise extent of disturbed areas. Reduction of frequency of disturbance. Stabilisation (vegetative) of disturbed soil. | Environmental Manager Contractor(s) | Rehabilitation and Construction Phase | | | **Mode-rate** | **Local** | **Long term** | **Mediu m** |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Rating: Magnitude | Extent | Duration | Probability |
| 3.3.2 | **Air** | Additional dust may be generated by the golf course if not managed correctly | | **-** | **6** | **1** | **4** | **4** | **44** | **1** | **1** | **2** | Conserve air quality | N/A | Manage the golf course correctly. | Environmental Manager Contractor(s) | Operation Phase | | | **Low** | **Local** | **Long term** | **Low** |
| **4.Cumulative Impacts** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | Rating | | | |
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Magnitude | Extent | Duration | Probability |
| 4.1 | **Air** | Dust will be generated by the proposed Tweefontein Optimisation Amendment Project as well as existing operations within the Tweefontein Complex and surrounding mining activities (Xstrata South Africa (Pty) Ltd; Anglo Operations Ltd).Should any other new mines open in the vicinity of the Tweefontein Complex, this will increase the cumulative impact on air quality.Dust will be generated by surrounding industries such as power stations.Dust will be generated by agricultural practices within the area.Exhaust fumes will be generated along all the roads in and around the site. Exhaust fumes will be generated as a result of the operation of the Tweefontein Complex, surrounding mine, industries, and agriculture as well as the day-to-day business of the residents in the region. This will impact on the air quality within the region.Air quality will be impacted on by biomass burning in the area (especially during dry, windy conditions). | | **-** | **8** | **3** | **4** | **5** | **75** | **1** | **1** | **2** | Conserve air quality | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **5. Post-Closure Phase** | | | | | | | | | | | | | | | | | | | | | | | |

| No. | Environmental Component | Potential Impact | Issue of Concern with I&APs | Rating | | | | | | | | | Mitigation management objectives and principles | Mitigation by design | Proposed Mitigation measures | Responsible person | Timeframe of mitigation | Financial Plan | | Residual Impacts after mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yes / No | Status | Magnitude | Extent | Duration | Probability | Significance | Reversibility | Irreplaceable loss of resources | Potential of impacts to be mitigated | | | | | | Concurrent (Annual Cost) | Final (Rehabilitation) | Rating: Magnitude | Extent | Duration | Probability |
| 5.1 | **Air** | It is not anticipated that there will be any post closure impacts on air quality as a result of the Tweefontein Optimisation Amendment Project, assuming that rehabilitation of used surface areas as cleared land is sufficient and effective. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

# 6 AIR QUALITY MANAGEMENT PLAN FOR THE TWEEFONTEIN OPTIMISATION PROJECT AMENDMENT

In the light of the potential for air quality impacts from the Tweefontein Optimisation Project Amendment, it is recommended that air quality management planning forms part of the construction, operational phase and decommissioning of the proposed Project. The air quality management plan provides options on the control of dust at the main sources with the monitoring network designed as such to track the effectiveness of the mitigation measures. The sources need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

## 6.1 Source Ranking

The ranking of sources serves to confirm or, where necessary revise, the current understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources of emissions during the operational phase of the Tweefontein Optimisation Project Amendment may be ranked based on emissions and impacts.

### 6.1.1 Emissions

The main sources of emissions are vehicle entrainment resulting in the main contributing sources to TSP and $PM_{10}$ unmitigated emissions. Emissions from crushing activities are also significant.

### 6.1.2 Impacts

The impacts show the main sources to be vehicle entrainment and crushing and screening activities.

Based on the qualitative evaluation of the proposed construction and decommissioning operations; and the quantitative assessment of the operational phase activities, management objectives that may be considered are summarised in Table 6-1 to Table 6-3.

**Table 6-1: Air Quality Management Plan - Construction Phase**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Land clearing activities such as bulldozing and scraping of golf course, open pit and plant areas | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Water sprays at areas to be cleared.<br>Moist topsoil will reduce the potential for dust generation when tipped onto stockpiles.<br>Ensure minimum travel distance between clearing area and storage piles. | Environmental Manager<br>Contractor(s) | Pre- and during construction |
| Road construction activities such as road grading and asphalt mixing and application | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout, sulphur dioxide and VOCs | Water sprays at area to be graded.<br>Freshly graded areas to be kept to a minimum. | | |
| Wind erosion from exposed areas | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Ensure exposed areas remain moist through regular water spraying during dry, windy periods. | | |
| Use of unpaved roads | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Water sprays on unpaved roads. | | |

**Table 6-2: Air Quality Management Plan – Operation Phase**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Dust generation from the open pit mining operations | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Controlled blasting techniques to be used to ensure minimal dust generation. | Environmental Manager | On-going during operational phase |
| Vehicle activity on unpaved haul roads | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Regular water sprays preferably combined with chemicals on unpaved haul roads to ensure at least 75% control efficiency.<br>Speed limit on haul roads not to exceed 40 km/hr. | | |
| Materials transfer points | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Drop height from excavator into haul trucks to be kept at a minimum for ore and waste rock.<br>Tipping of ROM at crusher plant to be controlled through water sprays (50% control efficiency) should significant amounts of dust be generated. | | |
| Material transfer points at conveyors | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Visual monthly inspections to ensure no significant visual dust generation from transfer points. | | |
| Crushing and screening operations | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Emissions from crushing activities can be controlled with water sprays to ensure 50% control efficiency. | Environmental Manager | On-going during operational phase |

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Wind erosion from tailings | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Ensure exposed areas remain moist through regular water spraying during dry, windy periods. | | |

**Table 6-3: Air Quality Management Plan - Rehabilitation activities**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Wind erosion from exposed areas | $PM_{2.5}$, $PM_{10}$ concentrations and dust fallout | Demolition of infrastructure to have water sprays where vehicle activity is high.<br>Ensure site is restored to pre-mining conditions. | Contractor(s)<br>Environmental Manager | Post-operational, can cease once rehabilitation is in place |

## 6.2 Monitoring

### 6.2.1 Air Quality Indicators

Increasingly environmental indicators are used in Environmental Land Use Planning and Management to simplify environmental assessments.

Indicators are defined as a single measure of a condition of an environmental element that represents the status or quality of that element. An index is a combination of a group of indicators to measure the overall status of an environmental element, and a threshold is the value of an indicator or index. For example, ambient $PM_{10}$ concentrations monitored within a specific area will be the indicator, with the National Ambient Air Quality Standard being the threshold.

### 6.2.2 Monitoring Network

Performance management is based on the understanding that you cannot manage that which you cannot measure. XCSA have recently re-looked at their ambient dust fallout network at their Witbank Group (consisting of Tweefontein, iMpunzi and Goedgevonden) to optimise their monitoring based on current operations at the mine. The ambient monitoring network has also been expanded to incorporate measurements of $PM_{10}$ and $PM_{2.5}$ concentrations. The focus of this section however will be on Tweefontein North monitoring network only (as the Tweefontein Optimisation Project Amendment is within this area) (Figure 6-1). The recommended monitoring management plan for Tweefontein North, as provided in the revised optimised monitoring network, is given in Table 6-4.

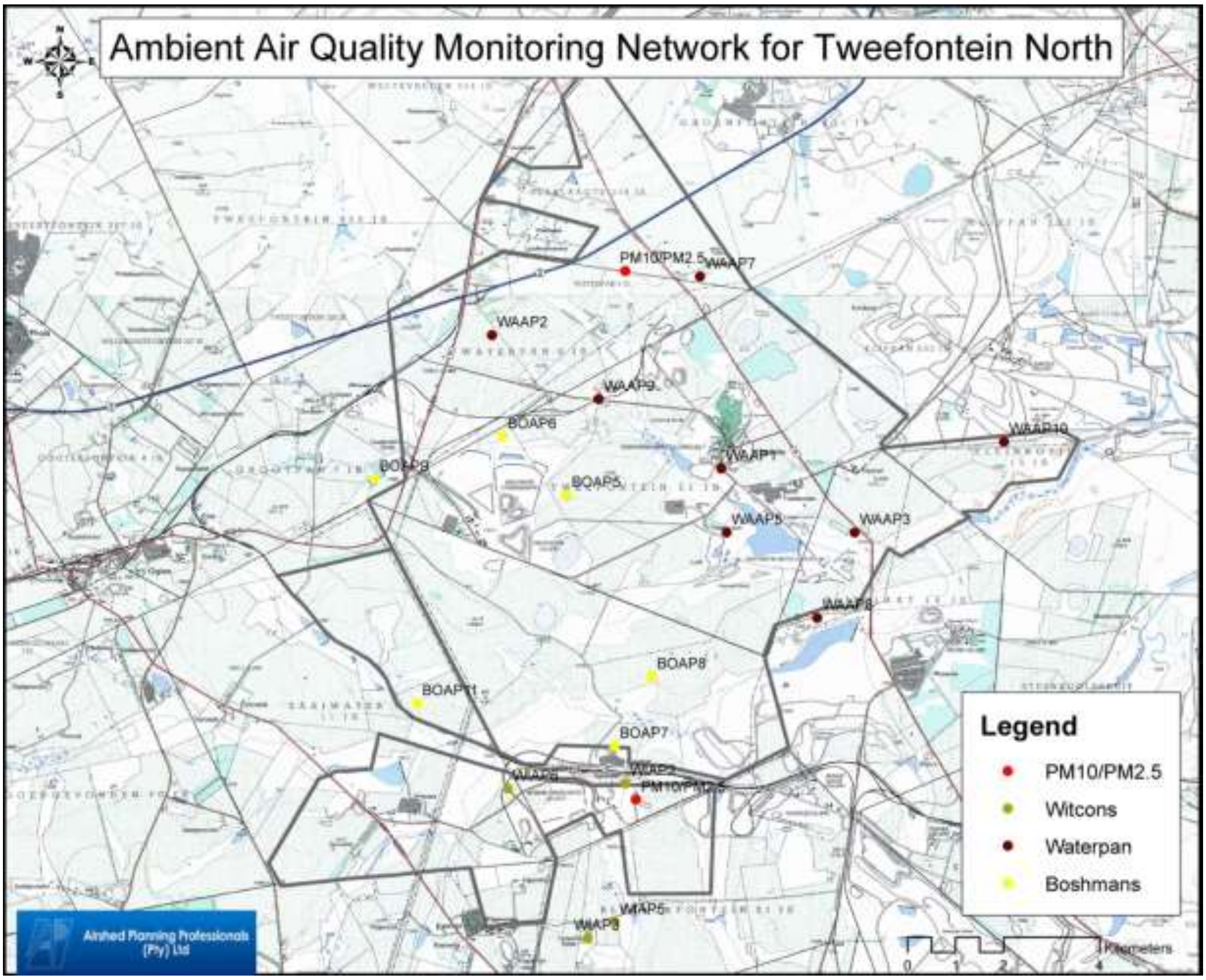


**Figure 6-1: Revised ambient air quality monitoring network for Tweefontein North**

**Table 6-4: Recommended monitoring management plan for Tweefontein North area only**

| Description | Bucket/ $PM_{10}$/ $PM_{2.5}$ sampler | Latitude | Longitude | Internal | Compliance | Regulation | Notes |
|---|---|---|---|---|---|---|---|
| Tweefontein North (Witcons) | WIAP2 | -26.092 | 29.152 | | x | With the draft dust fallout regulation of 600mg/m²/day for residential areas | Sampler near Saaiwater sensitive receptor |
| | WIAP3 | -26.121 | 29.145 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| | WIAP5 | -26.118 | 29.15 | x | | | Industrial site |
| | WIAP6 | -26.093 | 29.13 | x | | | Industrial site |
| Tweefontein North (Boshmans) | BOAP5 | -26.038 | 29.141 | x | | | Industrial site |
| | BOAP6 | -26.027 | 29.129 | x | | | Industrial site |
| | BOAP7 | -26.085 | 29.15 | | x | With the draft dust fallout regulation of 600mg/m²/day for residential areas | Sampler near Saaiwater sensitive receptor |
| | BOAP8 | -26.072 | 29.157 | x | | | Industrial site |
| | BOAP9 | -26.035 | 29.105 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| | BOAP11 | -26.077 | 29.113 | x | | | Industrial site |

| Description | Bucket/ $PM_{10}$/ $PM_{2.5}$ sampler | Latitude | Longitude | Internal | Compliance | Regulation | Notes |
|---|---|---|---|---|---|---|---|
| Tweefontein North (Waterpan) | WAAP1 | -26.033 | 29.17 | x | | | Industrial site |
| | WAAP2 | -26.008 | 29.127 | x | | | Industrial site |
| | WAAP3 | -26.045 | 29.195 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| | WAAP5 | -26.045 | 29.171 | x | | | Industrial site |
| | WAAP7 | -25.997 | 29.166 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| | WAAP8 | -26.061 | 29.188 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| | WAAP9 | -26.02 | 29.147 | x | | | Industrial site |
| | WAAP10 | -26.028 | 29.223 | | x | With the draft dust fallout regulation of 1200mg/m²/day for industrial areas | Boundary site |
| Tweefontein | $PM_{10}$/$PM_{2.5}$ (Center of XCSA operations) | -26.095 | 29.154 | | x | According to the national framework for the NEM: AQA (Act 39 of 2004), ambient air | Sampler near Saaiwater sensitive receptor |
| | $PM_{10}$/$PM_{2.5}$ (North | -25.996 | 29.152 | | x | | Boundary site |

| Description | Bucket/ $PM_{10}$/ $PM_{2.5}$ sampler | Latitude | Longitude | Internal | Compliance | Regulation | Notes |
|---|---|---|---|---|---|---|---|
| | of XCSA operations) | | | | | quality is to be monitored by provinces and municipalities and mines are to submit data on request. It is therefore not a requirement for measured ambient data to be reported on to authorities; however it may be required in future. | |

# 7 CONCLUSIONS AND RECOMMENDATIONS

An air quality impact assessment was conducted for the operations at the Tweefontein Optimisation Project Amendment. The main objective of this study was to determine the significance of the predicted impacts from proposed operations on the surrounding environment and on human health. Emission rates were quantified for the proposed activities and dispersion modelling executed.

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative $SO_2$, $NO_2$ and $PM_{10}$ impact are surrounding mining activities, power generation operations, farming, biomass burning, windblown dust from open areas and vehicle entrainment on unpaved road surfaces.

- The predominant wind direction within the study area is from the west-northwest. An increase in west-northwesterly winds occurs during day-time conditions with an increase in easterly winds during night-time.

- The nearest sensitive receptors (in terms of human settlements) to the Project are Vlaklaagte, Makoupan, Saaiwater, Klippoortjie, Tavlands Estate, Ogies and Phola.

- Measured annual average $PM_{10}$ concentrations from Emahaleni were 83 µg/m³ for the period 2008/2009.

The main findings from the impact assessment due to the Tweefontein Optimisation Project operations were as follows:

- For unmitigated and mitigated operations predicted $PM_{2.5}$ impacts at Vlaklaagte (and individual farmsteads in the area), Saaiwater and Ogies were within NAAQS. At the sensitive receptor of Makoupan, as the mining throughput increases, the predicted $PM_{2.5}$ impacts due to unmitigated and mitigated operations exceeded daily NAAQS.

- For unmitigated and mitigated operations predicted $PM_{10}$ impacts at Saaiwater and Ogies were predicted to be within NAAQS. At the sensitive receptor of Vlaklaagte (and individual farmsteads in the area), as the mining throughput increases, the predicted $PM_{10}$ impacts due to unmitigated operations exceeded daily NAAQS but were within standards for mitigated operations. At the sensitive receptor of Makoupan the predicted $PM_{10}$ impacts due to unmitigated operations exceeded daily NAAQS. As the mining throughput increases, predicted $PM_{10}$ concentrations at Makoupan still exceeded NAAQS during mitigated operations.

- Predicted dustfall at all identified sensitive receptors within the study area were within the draft dust fallout regulations of 600 mg/m²/day (with the exception of Makoupan due to unmitigated operations during the period 2018) considered acceptable for residential areas.

## 7.1 Recommendations

In light of the findings and the elevated particulate baseline ambient air quality levels, it was recommended that air quality management measures be implemented to ensure the lowest possible impacts on the surrounding environment from proposed operations.

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# APPENDIX A: EMISSION FACTORS AND EQUATIONS

## A.1 Vehicle-Entrained Emissions from Paved Roads

Particulate emissions will result from the entrainment of loose material from the paved road surface due to vehicle traffic (Cowhert and Engelhart, 1985). The extent of particulate emissions from paved roads is a function of the "silt loading" present on the road surface. In return, the silt loading is affected by the mean speed of vehicles on the road, the average daily traffic, the number of lanes and to a lesser extent of the average weight of vehicles travelling on the road (Cowhert and Engelhart, 1985; EPA, 2006). Silt loading (sL) refers to the mass of silt-size material (i.e. equal to or less than 75 microns in diameter) per unit area of the travel surface.

The quantity of dust emitted from vehicle traffic on paved roads was estimated based on the following equation (EPA, 2010):

$$E = k(sL)^{0.91}(W)^{1.02}$$

where,

***E*** = particulate emission factor in grams per vehicle km travelled (g/VKT)

***K*** = basic emission factor for particle size range and units of interest

***sL*** = road surface silt loadings (g/m$^2$)

***W*** = average weight (tons) of the vehicles travelling the road

The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$, 0.62 for $PM_{10}$, and as 3.23 for TSP.

## A.2 Vehicle-Entrained Emissions from Unpaved Roads

All road surfaces onsite were assumed to be unpaved as a conservative approach. Vehicle-entrained dust emissions from unpaved haul roads represent a potentially significant source of fugitive dust. The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic; including average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1998).

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

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

where,

***E*** = emissions in lb of particulates per vehicle mile travelled (lb/VMT) – 1 lb/VMT = 281.9 g/VKT (vehicle kilometres travelled)

***k*** = particle size multiplier (dimensionless)

***s*** = silt content of road surface material (%)

***W*** = mean vehicle weight (tonnes)

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 0.15 for $PM_{2.5}$, 1.5 for $PM_{10}$ and 4.9 for total suspended particulates (TSP). a and b are given as 0.9 and 0.45 respectively for $PM_{2.5}$ and $PM_{10}$ and as 0.7 and 0.45 respectively for TSP.

### *A.3 Fugitive Dust Emissions from Tipping Operations*

Materials handling operations include the transfer of material by means of tipping, loading and off-loading of trucks. The quantity of dust that will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

The following predictive US-EPA equation was used to estimate emissions from materials handling operations:

$$E_{TSP} = 0.0016 \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$$

where,

| | | |
|---|---|---|
| $E_{TSP}$ | = | Total Suspended Particulate emission factor (kg dust / t transferred) |
| $U$ | = | Mean wind speed (m/s) |
| $M$ | = | Material moisture content (%) |

## A.4 Wind Erosion

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

An hourly emissions file was created for the discard dump as well as various storage piles. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by

Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E(i) = G(i)10^{(0.134(\%clay)-6)}$$

for

$$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$

*and*

$$R = \frac{u_*^{\,t}}{u^*}$$

where,

| | | |
|---|---|---|
| $E_{(i)}$ | = | emission rate (g/m²/s) for particle size class i |
| $P_a$ | = | air density (g/cm³) |
| $g$ | = | gravitational acceleration (cm/s³) |
| $u_*^t$ | = | threshold friction velocity (m/s) for particle size i |
| $u^*$ | = | friction velocity (m/s) |

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure A-1.

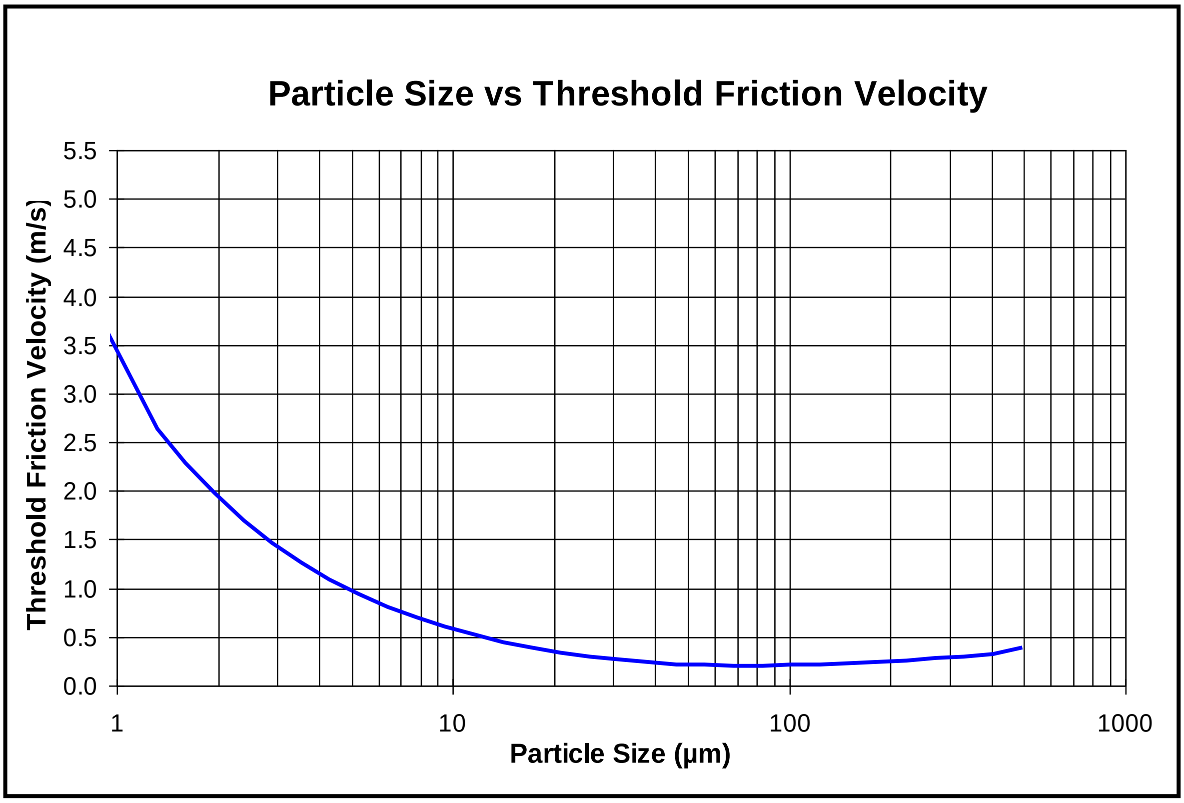


**Figure A-1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995)**

### *A.5 Crushing and Screening*

Fugitive dust emissions due to the crushing and screening operations were quantified using NPI single valued emission factors for such operations (Table A-1). These emission factors include emissions from the loading of crusher hoppers and screening.

**Table A-1: Emission factors for metallic minerals crushing and screening**

| Source | Emission Factor (kg/ton material processed) | | | |
|---|---|---|---|---|
| | Low Moisture Material[(a)] | | High Moisture Material (b) | |
| | $PM_{10}$ | TSP | $PM_{10}$ | TSP |
| Primary crushing | 0.02 | 0.2 | 0.004 | 0.01 |
| Secondary crushing | 0.04 | 0.6 | 0.012 | 0.03 |
| Tertiary Crushing | 0.08 | 1.4 | 0.01 | 0.03 |

Notes:

(a) Moisture content less than 4%

(b) Moisture content more than 4%

## *A.6 Drilling*

Fugitive dust emissions due to the in-pit drilling operations at the mine were quantified using the Australian NPI single valued emission factors for mining given in Table A-2.

**Table A-2: Australian NPI emission factors for drilling operations**

| Source | $PM_{10}$ (kg $PM_{10}$ / hole drilled) | TSP Emission (kg TSP / hole drilled) |
|---|---|---|
| Drilling | 0.31 | 0.59 |

## *A.7 Blasting*

Fugitive dust emissions due to blasting at the mine were quantified using the US-EPA predictive emission factor equation for mining:

$$EF = k \times 0.00022 \times A^{1.5}$$

where;

| | | |
|---|---|---|
| E | = | emission factor (kg dust / blast) |
| k | = | particle size multiplier ($kPM_{10}$ = 0.52; kTSP = 1) |
| A | = | blast area ($m^2$) |