# AIR QUALITY MANAGEMENT PLAN FOR THE NORTHERN CAPE

## MODEL PLAN OF STUDY

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## *1. INTRODUCTION*

In accordance with Section 15(2) of the National Environmental Management: Air Quality Act (NEM: AQA) (Act No. 39 of 2004), the Northern Cape Department of Environment and Nature Conservation (NC-DENC) is required to develop an Air Quality Management Plan (AQMP). With the assistance of co-funding from Kumba Iron Ore, the Department of Environment and Nature Conservation are able to develop their first AQMP in 2017.

A baseline assessment is the first step in the development or review of an AQMP and includes an assessment of the status of the air quality management tools and systems, including dispersion modelling. The focus of this report is the dispersion modelling plan of study according to the requirements of the DEA regulation for dispersion modelling, documented in the Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (DEA, 2014).

## *2. OBJECTIVE*

Most mining and industrial activity in the Northern Cape take place in the John Taolo Gaetsewe and ZF Mgcawu District Municipalities. Ambient monitoring is done by the NC-DENC for $SO_2$, $NO_2$ and $O_3$ in both municipalities and particulate monitoring is done by some mines. Considering the mining and the arid nature of the environment, particulates are a pollutant of concern, particularly in these two municipalities.

The objective of the dispersion modelling is to develop an understanding of the spatial extent of the impact of emissions from mining and industrial activities on ambient air quality, particularly in the John Taolo Gaetsewe and ZF Mgcawu District Municipalities.

## *3. PROJECT LOCATION*

The Northern Cape has a shoreline in the west with the Atlantic Ocean and has international borders with Namibia in the northwest and Botswana in the north (Figure 3-1), with the Orange River forming the border with Namibia and the Molopo River forming the border with Botswana. It borders four provinces, namely North West Province to the northeast, the Free State to the east, the Eastern Cape to the southeast and the Western Cape to the south and southwest. (Figure 3-1). The Northern Cape has five district municipalities, namely Francis Baard, John Taolo Gaetsewe, Namakwa, Pixley ka Seme and ZF Mgcawu. Kimberley is the administrative capital of the province. The main regional settlements are Springbok, Upington, De Aar, Kuruman, Calvinia and Colesberg

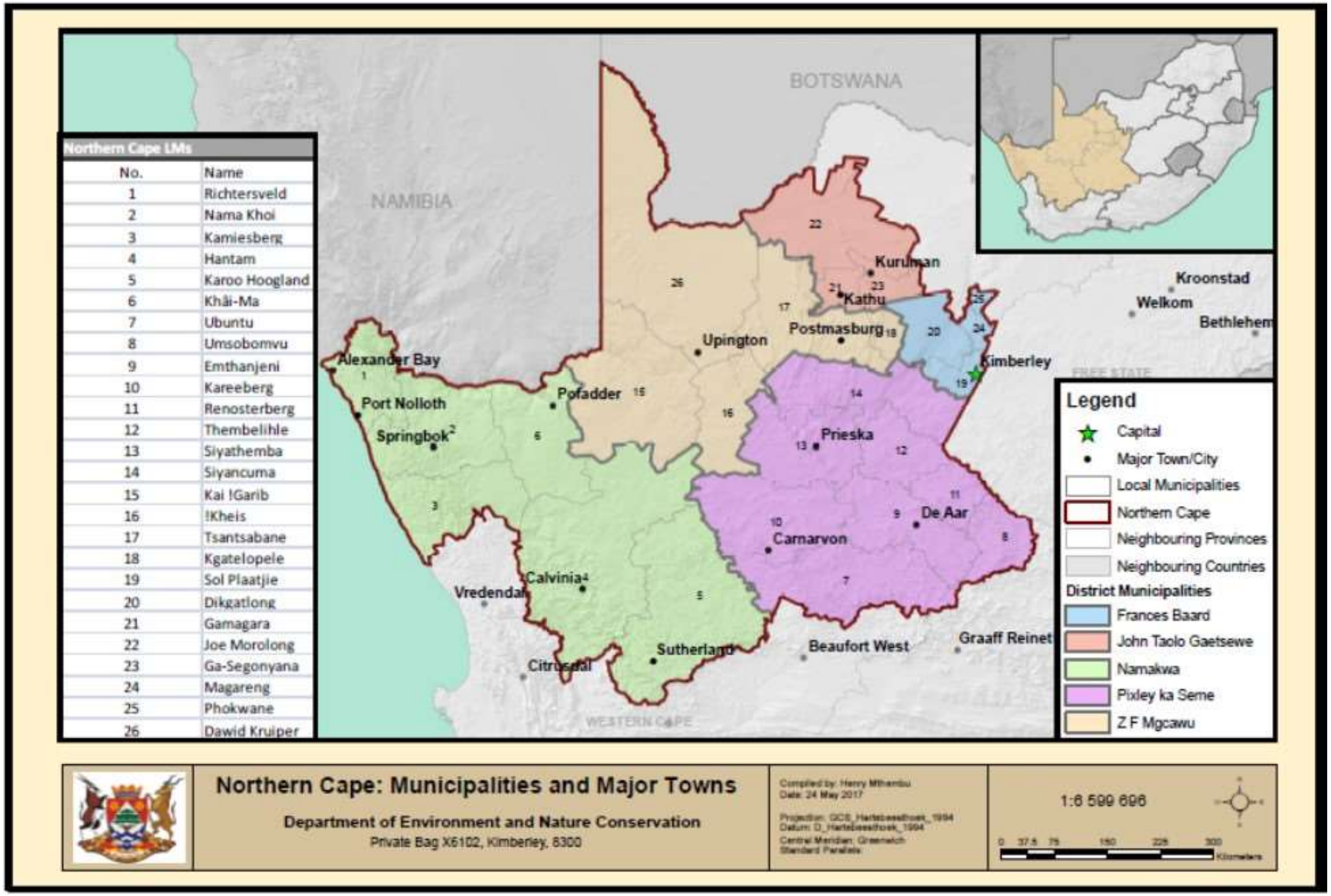


*Figure 3-1: Location map showing the Northern Cape with the municipal boundaries*

## *4. LAND USE DETERMINATION IN THE MODELLING DOMAIN*

The Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (DEA, 2014) recommends the Land Use Procedure as sufficient for determining the urban/rural status of a modelling domain. The classification of the study area as urban or rural is based on the Auer method specified in the US EPA guideline on air dispersion models (US EPA, 2005). From the Auer's method, areas typically defined as rural include residences with grass lawns and trees, large estates, metropolitan parks and golf courses, agricultural areas, undeveloped land and water surfaces. An area is defined as urban if it has less than 35% vegetation coverage or the area falls into one of the use types in Table 4-1. The Land cover Map of the Northern Cape is shown in Figure 4-1.

***Table 4-1: Land types, use and structures and vegetation cover***

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

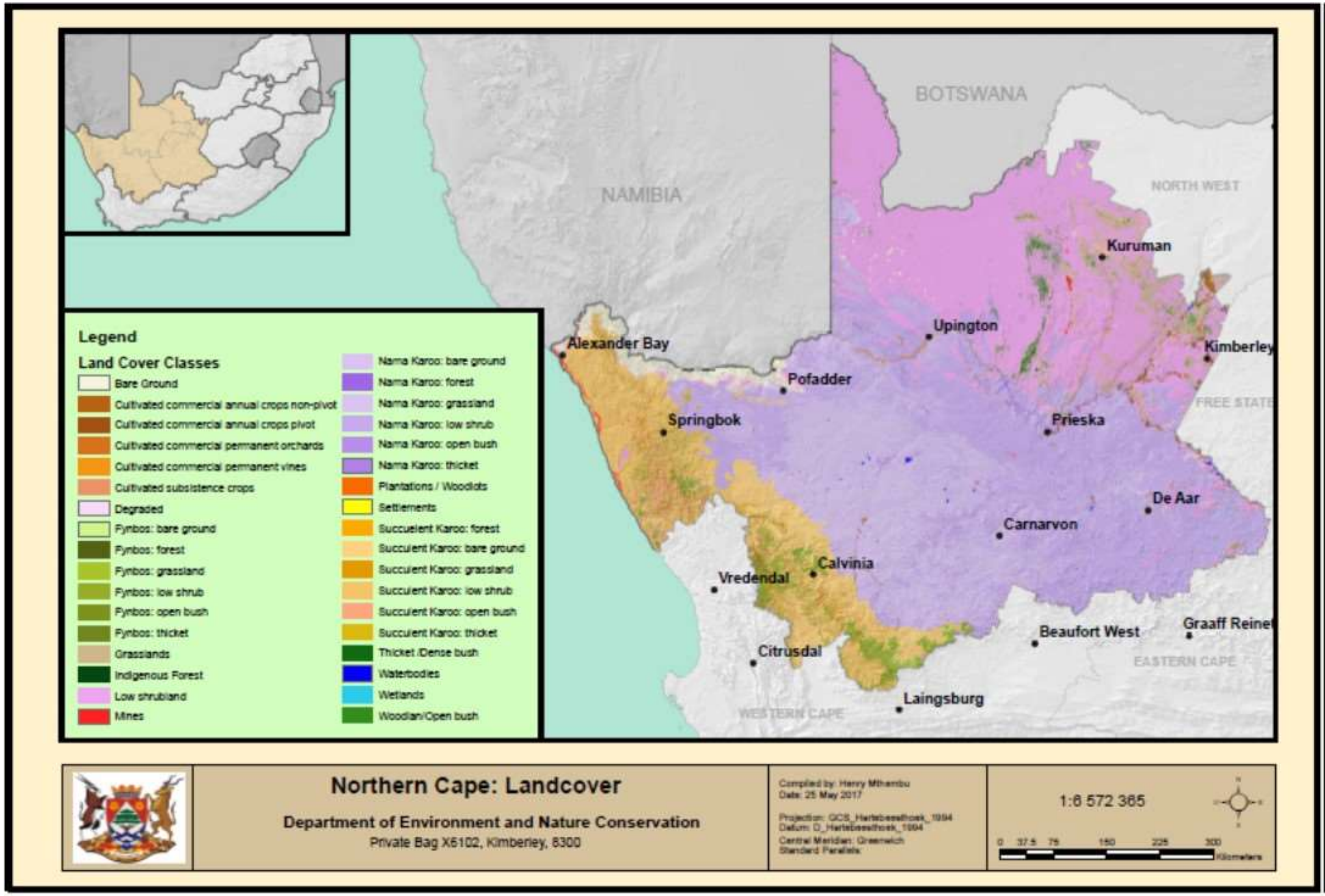


***Figure 4-1: Land cover Map of the Northern Cape***

# 5. ELEVATION DATA (DEM) AND RESOLUTION

The topographical and land use for the respective modelling domains is obtained from the dataset accompanying the CSIRO's The Air Pollution Model (TAPM) modelling package. This dataset includes global terrain elevation and land use classification data on a longitude/latitude grid at 30-second grid spacing from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center.

# 6. EMISSIONS CHARACTERISATION AND MODEL SCENARIOS

## 6.1 Emission sources

Emissions of air pollutants result from a number of source sectors in the Northern Cape, including:

- Industrial facilities (listed activities and controlled emitters);
- Transport (motor vehicles, airports);
- Waste management (landfill sites and wastewater treatment works);
- Residential fuel burning;
- Mining and quarries, including mine dumps;
- Biomass burning; and
- Biogenic emissions.

An emissions inventory is being developed as part of the baseline assessment. The emission inventory will quantify the emissions from industrial sources, transport, residential fuel burning and biomass burning. Emissions from waste management, mining and mine dumps, and biogenic sources will be described qualitatively in the emission inventory.

For modelling purposes, the emission inventory includes details of source parameters for industrial and mining sources only. This means that only industrial and mining sources will be modelled.

## 6.2 Baseline modelling

Industrial sources are modelled in the baseline assessment to augment ambient monitoring data.

Industrial sources are categorised and modelled according to the Section 21 categories in order to assess the relative contribution of different categories to ambient concentrations.

## 6.3 Background concentrations

In this study, ambient monitoring data will be assessed to determine representative background concentrations. These will not be included in the model runs, but will be used to assess the relative contribution of industrial and mining sources.

## *7. METEOROLOGICAL DATA*

The South African Weather Service (SAWS) operate meteorological monitoring stations within the Northern Cape. These do not provide comprehensive data coverage across the province. To address this issue the TAPM meteorological data will be used to supplement the meteorology in the modelling domain (CSIRO, 2008).

Three years of hourly observed meteorological data for the period 2014-2016 from selected SAWS meteorological stations will be input to TAPM to 'nudge' the modelled meteorology towards the observations and to create a continuous meteorological input file for the domain. The datasets will be chosen based on the completeness of the data record and the representativeness of the surrounding areas.

TAPM is set-up in a nested configuration of two domains. The outer domain is 400 km by 400 km at a 20 km grid resolution and the inner domain is 200 km by 200 km at a 10 km grid resolution. The subset of the entire TAPM model output in the form of pre-processed gridded surface meteorological data fields will be input into CALMET. This approach eliminates potential issues associated with missing observational data. Upper air data is included in the pre-processed TAPM meteorological fields.

## *8. MODELLING PROCEDURES*

### 8.1 Proposed Model

A Level 3 air quality assessment is conducted in situations where the purpose of the assessment requires a detailed understanding of the air quality impacts (time and space variation of the concentrations) and when it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types and chemical transformations (DEA, 2014). A Level 3 assessment may be used in situations where there is a need to evaluate air quality consequences under a permitting or environmental assessment process for large industrial developments that have considerable social, economic and potential environmental consequences. Under these circumstances, this study clearly demonstrates the need for a Level 3 assessment.

CALPUFF is a US EPA approved air dispersion model (http://www.src.com/calpuff/calpuff1.htm) and is recommended by the DEA for Level 3 assessments (DEA, 2014). CALPUFF is considered to be an appropriate air dispersion model for the purpose of this assessment as it is well suited to simulate dispersion from the large array of sources and source types. More information about the model can be found in the User's Guide for the CALPUFF Dispersion Model (US EPA, 1995).

### 8.2 Grid receptors

Three modelling domains (Figure 8-1) will be used for the CALMET and CALPUFF model runs. These focus on the concentration of emission sources and current or future air pollution hotspots. Modelling grid specifications are given in Table 8-1.

### *John Taolo Gaetsewe and* ZF Mgcawu Districts (Modelling domain 1)

A CALPUFF modelling domain of 40 000 km$^2$ which covers both municipalities, where the domain extends 200 km (west-east) by 200 km (north-south). It will consist of a uniformly spaced receptor grid with 5 km spacing, giving 1 600 grid cells (40x40 grid cells). The modelling domain caters for a buffer zone around the boundaries of the province.

### John Taolo Gaetsewe District (Modelling domain 2)

A CALPUFF modelling domain of 12 000 km$^2$, where the domain extends 100 km (west-east) by 120 km (north-south). It will consist of a uniformly spaced receptor grid with 2 km spacing, giving 3 000 grid cells (50x60 grid cells).

### ZF Mgcawu District (Modelling domain 3)

A CALPUFF modelling domain of 14 000 km$^2$, where the domain extends 140 km (west-east) by 100 km (north-south). It will consist of a uniformly spaced receptor grid with 2 km spacing, giving 3 500 grid cells (70x50 grid cells).

***Table 8-1: Modelling domain specifications***

| | | Modelling Domains | | |
|---|---|---|---|---|
| | | ***John Taolo Gaetsewe and* ZF Mgcawu Districts** | **John Taolo Gaetsewe District** | **ZF Mgcawu District** |
| Modelling grid specifications | Area (km$^2$) | 40 000 | 12 000 | 14 000 |
| | Distance (km) in west-east and north-south direction | 200x200 | 100x120 | 140x100 |
| | Grid resolution (km) | 5 | 2 | 2 |
| | Number of grid cells in west-east and north-south direction | 40x40 | 50x60 | 70x50 |
| | Total number of grid cells in modelling domain | 1 600 | 3 000 | 3 500 |

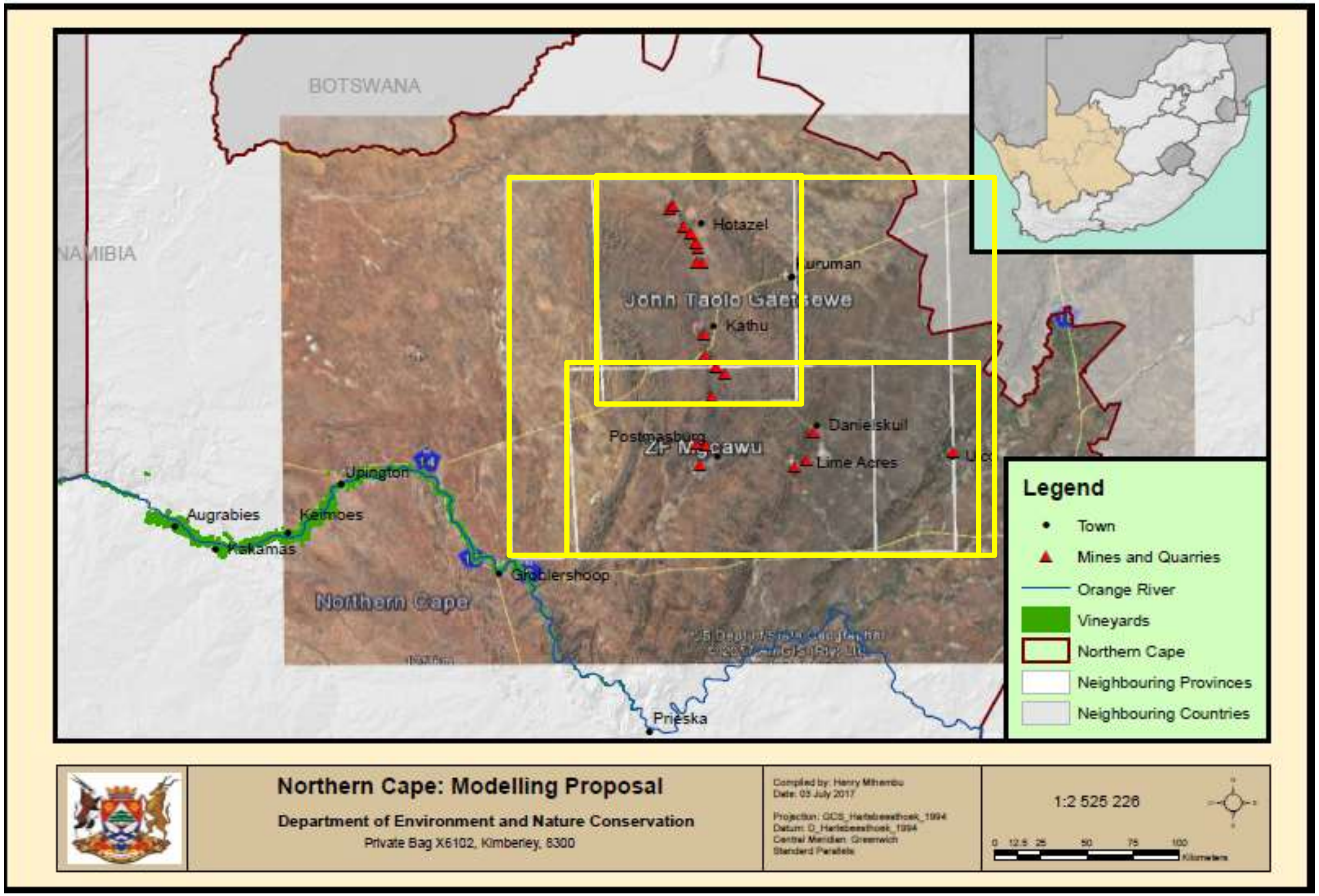


***Figure 8-1: Relative location of the three modelling domains that will be used for the CALMET and CALPUFF model runs. The modelling domains are represented by the white lines***

## 8.3 Model settings

The parameterisation of key variables that will apply in CALMET and CALPUFF are indicated in Table 8-2 and Table 8-3 respectively.

***Table 8-2: Parameterisation of key variables for CALMET***

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

***Table 8-3: Parameterisation of key variables for CALPUFF***

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

## 8.4 Model accuracy

Air quality models attempt to predict ambient concentrations based on "known" or measured parameters, such as wind speed, temperature profiles, solar radiation and emissions. There are however, variations in the parameters that are not measured, the so-called "unknown" parameters as well as unresolved details of atmospheric turbulent flow. Variations in these "unknown" parameters can result in deviations of the predicted concentrations of the same event, even though the "known" parameters are fixed.

There are also "reducible" uncertainties that result from inaccuracies in the model, errors in input values and errors in the measured concentrations. These might include poor quality or unrepresentative meteorological, geophysical and source emission data, errors in the measured concentrations that are used to compare with model predictions and inadequate model physics and formulation used to predict the concentrations. "Reducible" uncertainties can be controlled or minimised. This is done by using accurate input data, preparing the input files correctly, checking and re-checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics.

Models recommended in the DEA dispersion modelling guideline (DEA, 2014) have been evaluated using a range of modelling test kits (http://www.epa.gov./scram001). CALPUFF is one of the models that have been evaluated and it is therefore not mandatory to perform any modelling evaluations. Rather the accuracy of the modelling in this assessment is enhanced by every effort to minimise the "reducible" uncertainties in input data and model parameterisation.

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