METHOD STATEMENT

AIR QUALITY BENEFIT OF THE ESKOM UNPAVED ROADS OFFSET INTERVENTIONS IN SHARPEVILLE

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AIR RESOURCE MANAGEMENT

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1. INTRODUCTION

1.1 BACKGROUND

UNPAVED ROADS

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

Most of the roads in South Africa are classified as gravel roads. A gravel road is a type of unpaved road surfaced with gravel that has been brought to the site from a quarry or stream bed. In many cases, replacement of gravel on these roads may not always be available or feasible. In 2016, SANRAL estimated between 74-79% of South African roads are gravel (https://www.arrivealive.co.za/The-South-African-National-Roads-Agency-LTD). Most of these roads are found within rural areas but a large percentage of these gravel roads are also found in urban areas. According to the Cornerstone Economic Research (2018), over 80% of Gauteng's road network is considered gravel with more than two thirds of these gravel roads being in poor condition. A larger portion of the unpaved road network in Gauteng is found in outer lying urban areas and within townships (Naidoo et al., 2022).

The Gauteng Province receives on average approximately 721 mm of rainfall per year (South African Weather Service, 2021), with the Köppen-Gieger classification scheme (Peel et al., 2007) describing the province as temperate with dry winters and hot/warm summers. Although the annual rainfall in the province may be seen as moderate, much of the rainfall occurs in heavy events during a short period. There are distinctly dry seasons. This combined with potentially intense traffic in the urban areas, unpaved roads may present a significant local source of particulate matter (Naidoo et al., 2022).

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

Health and Nuisance Impacts

In the past, road dust has only been considered as a nuisance factor. However, there is a growing awareness that dust generated by vehicles on unpaved roads has significant environmental and social impacts in terms of health, safety and visual impacts, as well as considerable economic impacts relating to the loss of road construction material, higher vehicle operating costs, lower agricultural yields and higher building maintenance (Jones, 2000).

It is well documented that many respiratory diseases are attributed to high levels of fugitive dust. The potential health impacts of fine particulate matter (PM_{10} and particularly $PM_{2.5}$) pollution is well documented by the World Health Organisation (WHO, 2013), especially in dry regions where emission of dust from exposed surfaces contribute significantly to total PM concentrations (Garland et al., 2021; Hassan et al., 2022).

The prolonged inhalation of road dust can result in respiratory ailments and the aggravation of existing health problems, especially if the dust particles are combined with contaminants. In South Africa, dust from unpaved roads in developing communities contributes to as much as 16% of the airborne particulate matter in those areas. The high incidence of respiratory disease, especially amongst children is also linked to the higher ambient air pollution levels (Annegarn and Kneen (1995).

Residents living in properties close to the unpaved roads, pedestrians and commuters travelling in vehicles face a huge amount of discomfort. Residents also have to deal with the accumulation of dust inside dwellings and the soiling of curtains and washing.

Need for the study

Results from the Second Generation Air Quality Management Plans (AQMPs) for the Vaal Triangle Airshed Priority Area (VTAPA Study) (DEA, 2020) and the Highveld Priority Area (HPA Study) (DEA, 2022) have recognized that unpaved road surfaces play an important contributing factor to the particulate loading in the region.

According to Goal 8 in the VTAPA Study (DEA, 2020), and in terms of the Implementation Plan for Vehicle Emissions, the overall goal is to reduce emissions from vehicles to ensure compliance with National Ambient Air Quality Standards (NAAQS) near roads by 2025. Furthermore, in terms of unpaved roads, two important activities under this implementation plan (both which are rated as high priority) are:

(i) To identify unpaved roads generating dust and prioritise high risk roads

- This activity is assumed to come at a low cost as it can be done by existing personnel. Enabling factors include community awareness campaigns and cooperation with NGO's and CBO's; and Air Quality personnel to visually inspect areas and identify busy unpaved roads.

(ii) To implement management measures for identified high risk dust generating roads.

- This activity is assumed to come at a medium cost as it is once off with maintenance. Enabling factors include costing, which will depend on the length of the road and can be done by industry as part of Offset Projects.

Air Quality Offset Guideline

The Department of Environment, Forestry, Fisheries and Environment (DFFE) Air Quality Offset Guideline has shaped and informed Eskom's Air Quality Offsets Implementation Plan. This Plan has been based on a scientific process of feasibility studies, testing and demonstration, and on consultation with key stakeholders. Thus, Eskom's air quality offsets programme is designed to reduce human exposure to harmful levels of air pollution by reducing emissions from local sources, like domestic coal burning and waste burning.

1.2 Unpaved Roads in Sharpeville

In 2024, a dispersion modelling study of the Sharpeville Airshed (Figure 1) conducted by Air Resource Management (ARM, 2024) revealed that unpaved roads is having a detrimental effect on air quality in the area. As discussed in the sections above, particulate emissions from unpaved roads results in harmful and visible emissions. This is a significant contributor to air quality challenges in Sharpeville. As part of Eskom's Air Quality Offset (AQO) programme for the Lethabo Power Station, Eskom is currently investigating whether the paving of unpaved roads in Sharpeville would have a positive impact on air quality in the area.

Figure 1: Map showing the location of Sharpeville

2. STUDY PROPOSED

A DFFE approved AQO project must have measurable air quality outcomes. Thus, a study is proposed to theoretically quantify both the:

1) Net PM_{10}, PM_{10} and dustfall emissions avoided from unpaved roads
2) The potential net ambient air quality benefit of Eskom's Sharpeville AQO Project.

2.1 METHODOLOGY

The study will be conducted over 3 Phases (Figure 2). This entails the following:

Phase 1: Understanding the vast network of unpaved roads in Sharpeville

Phase 2: Determining the net emissions avoided for Eskom's Sharpeville AQO Project

Phase 3: Quantification of the net ambient air quality for Eskom's Sharpeville AQO Project

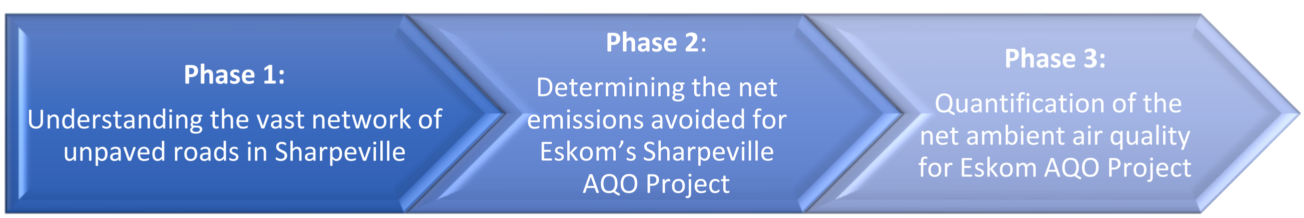

Figure 2: Approach to Study

3.1.1 PHASE 1: UNDERSTANDING THE VAST NETWORK OF UNPAVED ROADS IN SHARPEVILLE

LOCATION OF UNPAVED ROADS

Based on satellite imagery from the previous modelling exercise undertaken for Sharpeville (ARM, 2024), it was noted that there are a few main roads and access roads within Sharpeville that are paved. Whilst these roads may be paved, it is noted that most of them are in poor condition.

In this study, Google Earth satellite imagery will be used to map out the distance and location of each road segment for all unpaved roads in Sharpeville. From a modelling perspective, a modelling exercise to include all unpaved road segments would be an exceptionally time-consuming exercise and would require exceptionally long model run-times. This study therefore builds on the previous modelling study where all unpaved roads in Sharpeville were combined into a few area sources, but in this study, they will be modelled in much greater detail (i.e. each unpaved road segment will be modelled as individual area sources). This will enable a more accurate application and emission estimation using the relevant emission factors.

The re-modelling of unpaved roads in Sharpeville at a very high resolution will have many added benefits such as:

- It will provide a more accurate representation of the resultant ambient PM_{10} and $PM_{2.5}$ concentrations and dustfall in the airshed
- It will allow Eskom to identify problem areas in terms of high-risk areas or locations of highest concentrations, which in turn can enable Eskom to prioritise these areas for the paving of roads
- It will allow Eskom to see how this particular intervention would reduce air quality impacts in terms of particulates

3.1.2 Phase 2: Determining the net emissions avoided for Eskom's Sharpeville AQO Project

Methodology – Particulate Emissions from Unpaved Road Surfaces

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

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

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

Where:

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

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

TOTAL VEHICLE KILOMETRES TRAVELLED (VKT)

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

No such data is currently available for this study area. VKT will therefore be calculated using assumptions outlined below.

ASSUMPTIONS

For development of the emission inventory, there is no available information for critical input data. A number of assumptions will be made based on best judgement. To streamline the modelling process, the following profile was created based on a 1 square kilometre of a high-density township, as was done in the previous modelling study (ARM, 2024):

- Approximately 1000 homes are located within 1 square kilometre of a township, representing 1000 families.
- 50% of these homes have a car, but only half of them are used on a regular basis for travelling to work, dropping off children at school or for shopping. It is therefore assumed that 250 cars travel on the unpaved roads on a daily basis. It is also assumed that each car travels on approximately 1 km of unpaved roads per day before getting to the main roads which are paved and vice versa.
- Many children and family members depend on public transport for travelling to school or work or to shopping centres. It is assumed that 1 minibus taxi and 1 bus is in operation on a daily basis. It is also assumed that each minbus taxi and bus travels on approximately 20 km of unpaved roads per day.
- Goods (for example building material, furniture, food supplies to spaza shops) also need to be transported to and/or from the townships. It is therefore assumed that 1 truck is in operation within the area on a daily basis, travelling 10 km per day.

The total VKT is presented in Table 1.

Table 1: Total VKT

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

EMISSION FACTORS

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

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

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

Where:

- EF: Size-specific emission factor (kg/VKT)
- s: Surface material silt content (%)
- W: Mean vehicle weight, tonnes (metric)
- k, a, b: Numerical constants for calculation (Table 2)

Table 2: Numerical constants used in the unpaved industrial road dust emission factor

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

The silt content (s) of an unpaved road may be obtained using the USEPA test method (Appendix C.1: Procedures for sampling surface/bulk dust loading, AP-42, USEPA, 2003). Site-specific values for silt content is not available for unpaved roads in the study area. As recommended by AP42, an appropriate mean value from Table AP-42 13.2.2-1 (USEPA, 2006) (reproduced below in Table 3), should be used as a default value, in the absence of measured values. It is understood that the use of default values may affect the quality of estimated values. In this study, a silt value of 8.3 (Stone quarrying and processing – haul road to/from pit) was chosen.

Table 3: Typical silt content values of surface material on industrial unpaved roads ((USEPA, 2006)

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

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

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

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

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

Where:

- ADJ: Adjustment factor for precipitation, snow cover and frozen days

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

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

Dust Control Methods (CE)

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

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

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

In this study, it is assumed that Eskom’s flyash dust reduction mechanisms are applied on unpaved roads. Its presumed that control efficiency of 80% will therefore be applied. However, a further literature scan and guidance from Eskom will be taken into account to revise this proposed presumed control efficiency for the flyash solution.

EMISSION RATES ON 1 SQUARE KILOMETRE BASIS

The emission rates for particulates from unpaved road surfaces will be based on a 1 square kilometre basis, taking account of VKT, emission factors and adjustment factors for natural mitigations.

3.1.3 PHASE 3: QUANTIFICATION OF THE NET AMBIENT AIR QUALITY FOR ESKOM'S SHARPEVILLE AQO PROJECT

Based on the emissions inventory (section 3.1.2), a dispersion modelling assessment aligned to the *Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa* (Gazette No 37804, 2014) will be utilised to determine the potential net ambient air quality benefit of Eskom's Sharpeville AQO Project. For this study, a level 3 tier modelling assessment, the US-EPA approved California Puff (CALPUFF) modelling suite will be utilised. The CALPUFF model is an integrated modelling system which can simulate the effects of time- and space-varying meteorological conditions for pollutant dispersion, transformation and deposition. The modelled predicted concentrations for PM_{10}, $PM_{2.5}$ and dustfall will be assessed against the NAAQS and National Dustfall Standard.

Two scenarios will be simulated, the first scenario will be a baseline scenario accounting for the unpaved whereas the second scenario will assume an Eskom flyash solution is applied to the roads to mitigate and reduce the impact of PM emissions from unpaved roads.

4. POTENTIAL BENEFITS

The results of this study will be able to demonstrate to both the local licensing authority and DFFE National (NAQO) that Eskom's Sharpeville AQO does theoretically deliver both a net emission avoided and an ambient air quality benefit as per the requirements of the *DFFE's Air Quality Offsets Regulation.*

5. ACTIVITY SCHEDULE

Table 5: Project schedule

Study Component	April		May				June			
	21	28	5	12	19	26	2	9	16	23
1. Mapping out distances of unpaved road segments	■									
2. Defining polygons for each unpaved road segment		■	■							
3. Emission Inventory for PM_{10}, $PM_{2.5}$ and Dust				■						
4. Calpuff Dispersion Modelling				■	■	■				
5. Model post processing							■			
6. Draft Report								■		
7. Eskom peer review									■	
8. Final Report										■

6. ASSUMPTIONS/LIMITATIONS FOR DELIVERABLES

To meet the project deliverable timeously for this activity as per the proposed schedule (section 5) it assumed that:

i. The modelling will be conducted for the period 2020 to 2022, hence the same CALMET output file used for the Sharpeville dispersion modelling study conducted in 2024 (ARM, 2024) will be used for this study.

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

iii. In this study, it is assumed that Eskom's flyash dust reduction mechanisms are applied on unpaved roads.

iv. Eskom will timeously review and comment on the respective documents as per schedule.

Any deviation to the items above will result in a revision and delays to the committed project schedule timeline (section 5).

7. COST BREAKDOWN

The cost breakdown and cash forecast are presented in Table 6.

Table 6: Cost Forecast for Activity

Study Phase	PMV Phase 1 Activity No.	Activity description	Cost (Excluding VAT)
Phase 1 & 2	16	Characterisation & development of an Emission Inventory for the unpaved roads in Sharpeville	R60 000,00
Phase 3		Dispersion modelling of unpaved roads for Sharpeville	R200 000,00
Total			**R260 000,00**

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