Lamu Power Station Air Dispersion Modelling Report

Atmospheric Dispersion Modelling Report

Prepared for: Kurrent Technologies

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Acronyms

%	Percent
°C	Degrees Celsius
$\mu g/m^3$	Micro Gram per Metre Cubed
ADM	Air Dispersion Modelling
AIHA	American Industrial Hygiene Association
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EC	European Commission
EHS	Environmental Health and Safety
ERPG	Emergency Response Planning Guideline
EU	European Union
g/s	gram per second
Hg	Mercury
IAQM	Institute of Air Quality Management
IFC	International Finance Corporation
kg	kilogram
K	Kelvin
km	kilometre
KTL	Kurrent Technologies Limited
m	metre
m E	metre East
mg	milligram
mm	millimetre
m N	metre North
m/s	metre per second
m^3	metre cubed

MW	Megawatt
MWth	Megawatt thermal input
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
ppm	parts per million
PM	Particulate Matter
$PM_{2.5}$	Particulate matter with an aerodynamic area of less than 2.5µm
PM_{10}	Particulate matter with an aerodynamic area of less than 10µm
SO_2	Sulphur Dioxide
SO_x	Oxides of Sulphur
SRTM	Global Shuttle Radar Topography Mission
tph	tons per hour
TSP	Total Suspended Particulates
UK	United Kingdom
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WHO	World Health Organisation
WKC	WardKarlson Consulting Group Ltd.
WRF	Weather Research and Forecasting

1 Introduction

WardKarlson Consulting Ltd (WKC) has been commissioned by Kurrent Technologies Limited (KTL) to conduct an air dispersion modelling (ADM) study for the proposed Lamu Coal Power Plant (hereafter referred to as the 'Project'), located within the Lamu region of northern Kenya. This study has considered pollutant emissions from the power plant boilers as well as dust associated with coal handling and ash disposal activities. Dispersion modelling has been undertaken utilising internationally recognised United States Environmental Protection Agency (US EPA) regulatory dispersion models.

Given the height of the boiler stacks, in excess of 200 meters (m), and the proximity of the power station to the sea, the US EPA regulatory model CALPUFF was used to model emissions of criteria pollutants from the main boilers. CALPUFF is recommended by the US EPA in instances where coastal effects are likely to influence plume dispersion, and where pollutants can potentially be transported relatively large distances due to tall stacks.

In terms of assessing the impacts of fugitive dust from coal handling and ash disposal AERMOD was selected, as the impacts from fugitive material handling are expected to be near field (limited to within a few kilometres of the site). AERMOD's performance for near-field regulatory modelling applications is well documented by the US EPA and therefore deemed appropriate for assessing fugitive dust sources [1].

1.1 Study Objectives

This report, forming part of the Environmental and Social Impact Assessment focuses on the atmospheric emissions associated with the Project, using design data specifications and experience of similar projects. The key objectives of this assessment are as follows:

- To undertake a review of relevant Kenyan (and where relevant, international) ambient air quality legislation and provide a summary of the minimum standards that will need to be achieved in ambient air; and,
- To quantify and assess the potential construction and operational impacts of the Lamu Power Station with regards to ambient air quality.

2 Project Description

2.1 Project Location

The Lamu Power Station will be located on the north side of the New Lamu Port area, Manda Bay situated in Lamu County, northern Kenya (Figure 2-1 and Figure 2-2).

Figure 2-1 – Project Location, Regional Setting

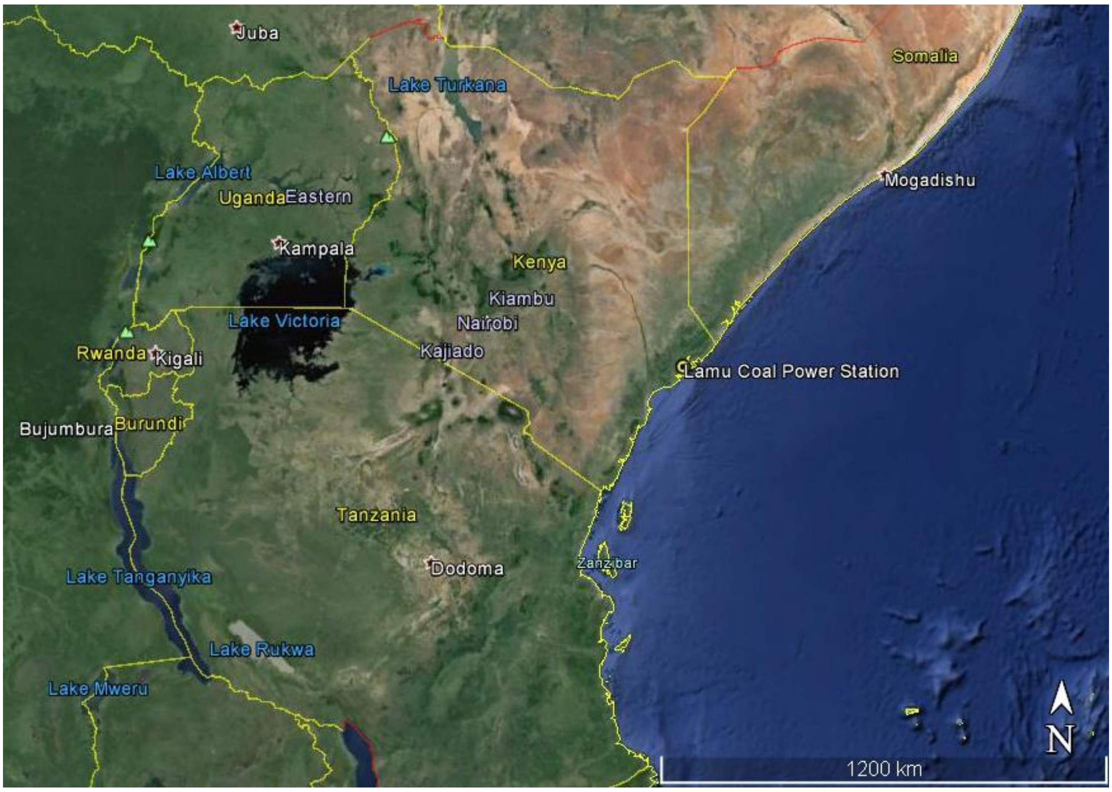


Figure 2-2 – Project Location, Local Setting

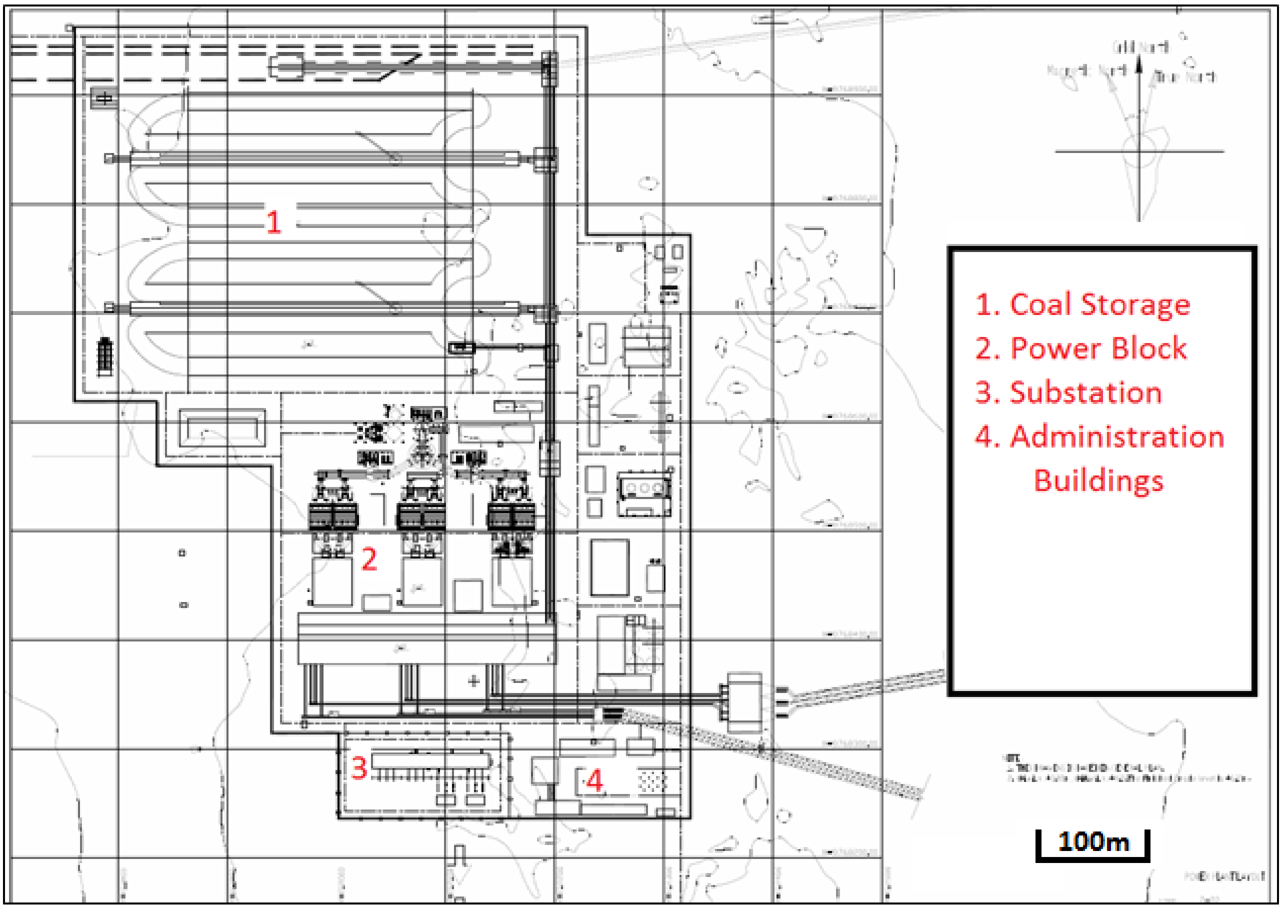
2.2 Project Layout

The project will consist of 3 x 350 megawatts (MW) coal units to be built on a tract of land identified and reserved for its construction by the Government of Kenya. The general arrangement plan of the plant is divided into four main areas (Figure 2-3):

1) Coal yard and coal handling facilities;
2) The main power block;
3) 400kV substation; and,
4) The administration buildings and canteen, and construction/ operating quarters.

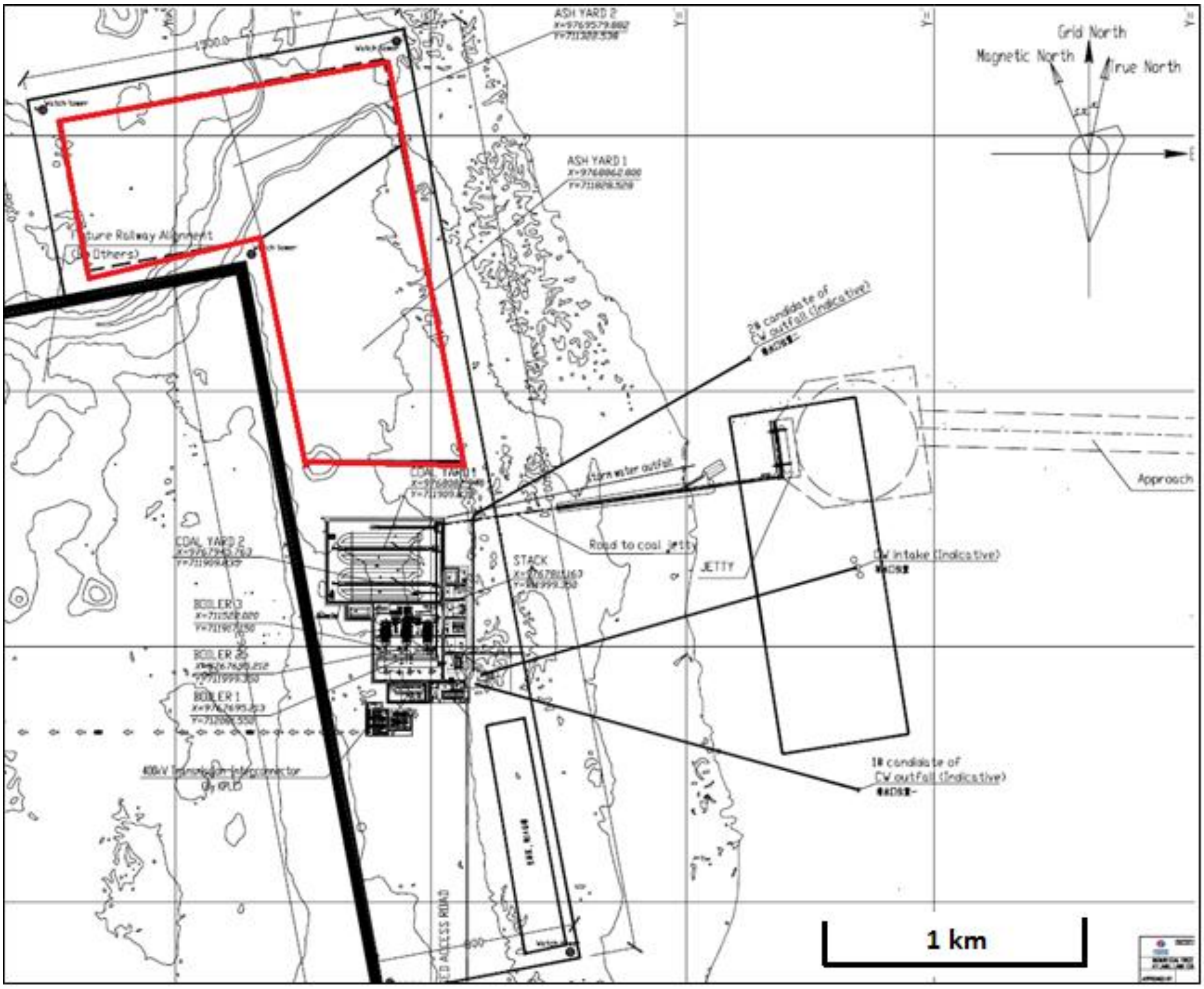
Figure 2-3 has been taken and adapted from the PDF labelled –'16B-Preliminary Power Plant Layout (04-20-2014)'.

Figure 2-3 – General Plant Layout



The ash storage areas are located to the north of the plant and are shown in Figure 2-4. The figure above has been adapted from the PDF labelled – '16A- Power Plant Site Plan (02-24-2015)' provided by the client.

Figure 2-4 – Ash Yards in Relation to Main Areas



2.3 Process Description

The power station will operate at an installed capacity of 1,050 MW, based on the provision of 3 x 350 MW coal-fired high-pressure super critical units with condensing steam turbines.

Coal for the power station will initially be imported by sea from South Africa, which will be unloaded from ships by means of two (one standby) wharf side bucket un-loaders rated at 1,500 tonnes per hour (tph) into a hopper. Annual incoming coal could total to up to 4.6 million tons. Dust suppression will be undertaken during unloading operations. In future, local Kenyan coal will be brought in by rail and road, being offloaded by means of a car dumper on a continuous rail loop and truck dumping station respectively. Indicative specifications of the likely coal types to be used at the facility are presented in Table 2-1.

Table 2-1 – Fuel Coal Specifications

Parameter	Imported Coal (South Africa)		Kenyan Coal
	Eskom	New Vaal	
Calorific Value (MJ/kg) Lower Heating Value	21	16	18
Total Organic Carbon (%)	44	36	55
Sulphur Content (%)	1	0.5	2.4
Plant Coal Consumption (tonnes / day)	10,685	14,248	12,600

From offloading, coal will be transferred via conveyor either to the boilers for direct use or to the active coal storage area by a dual belt conveyor system rated at 1,500 tph. The cumulative capacity of the two proposed coal storage yards will be 420,000 tonnes accommodated within four stockpiles. This will provide supply of 30 days for three boilers operating at 100% boiler load (based on Kenyan coal specification).

Two bucket wheel stacker/reclaimers (each having a stacking capacity of 1,500 tph and reclaiming capacity of 1,000 tph) will be provided in each coal yard. Three bulldozers and two front loaders will facilitate coal movement in areas out of reach of the stacker/reclaimers. Two ground reception bunkers will also be supplied to allow for emergency unit loading in the event of stacker/reclaimer outages. A single reversible belt conveyor, with a width of 1,400 millimeters (mm) and an operating speed of 2.5m/s for a capacity of 1,500 tph, will be provided in each yard.

Downstream of the coal yards, dual reversible belts (1,000 tph) will be provided. A plough discharger will direct coal into the boiler bunkers.

The coal processing system will include a pair of 1,000 tph screens and a pair of 800 tph hammer crushers. Coal will be received at a nominal size of ≤300 mm and shall be crushed to the required size of ≤30 mm. The coal pulverising system will comprise five medium speed mills and primary air fans for positive pressure-direct firing operation.

The main boilers are classified as opposite firing pulverised coal boilers, with a dry bottom ash handling system. In order to reduce emissions of oxides of nitrogen (NO_x), the boilers will be provided with 'low-NO_x' burners procured to meet an emission limit of 450 mg/Nm^3.

Boiler flue gases will be emitted to the atmosphere via a 210 m high stack containing three individual flues.

Flue gas desulphurisation will be achieved through the application of a wet limestone-gypsum system, which will reduce in-stack concentrations of sulphur dioxide (SO_2) to levels prescribed by the International Finance Corporation (IFC). The system will include a limestone yard, crushers and mills and three treatment towers. Gypsum will be produced as a waste product of this system, at a rate of 110 – 564 tons per boiler per day (depending on the sulphur content of the fired coal).

Fly ash will be removed from the flue gas by means of an electrostatic precipitator system and subsequently conveyed to storage silos. A wet mixer and dry ash unloader will be provided at the silo unloading chute to minimise dust at the transfer point before being transported by truck to the ash yard. The system for bottom ash removal will include facilities to remove and crush slag before removal to the ash yard by truck.

The ash yard will cover an area of approximately 900 m x 1,270 m. At the end of the 15 year lifespan of the ash yard, a maximum pile height of 25.8 m will be reached and the total volume of material disposed will be 26,740,000 m^3. The yard will be provided with a water spray dust suppression system, and planting of vegetation to reduce erosion will be undertaken. An auxiliary diesel-fired boiler will be provided as part of the Project.

Twelve sets of 2 MW diesel powered generators (ten operational and two on standby) will be provided to enable 'black start' of the power station – a situation where the power station's operation would need to be re-started without externally-supplied electrical power.

2.3.1 Construction Phase Emissions

Atmospheric emissions will be generated during construction of the facility through the operation of equipment and plant. It is anticipated that the most significant components of such emissions, from an environmental perspective, will be combustion (exhaust) gases and particulate matter (dust) associated with site clearance and the operation of earth moving equipment.

The following equipment or activities will lead to emissions to atmosphere during construction:

- Earthmoving operations (associated with land clearing and site preparation);
- Construction and delivery vehicle emissions (diesel powered equipment, cranes, excavators, barges and ships);
- Cement batching operations; and,
- Power generation at the worker camps, laydown areas and the Project site.

2.3.2 Operations Phase

Once the plant becomes operational the key emission sources consist of:

- Coal-fired boilers;
- Materials handling and storage (including coal storage and ash yard); and,
- Wheel-entrained dust from vehicles travel along site roads.

Other emission sources, though not anticipated to represent routine releases (i.e., they will be operational for less than 500 hours per year) consists of:

- Diesel-fired start-up and emergency generators; and,

- Auxiliary boiler.

The emission sources included within the current project design are summarised in Table 2-2.

Table 2-2 – Summary of Emission Sources

Source Reference	Number of Units Operational	Output Rating per Unit (MW)	Source Type
Coal-fired Boilers	3	350	Continuous (Point Source Emissions)
Diesel-fired Start-Up Generators	10 (2 standby)	2	Black Start-Up Only (Point Source Emissions)
Auxiliary Start-Up Boiler	1	17.4	Black Start-Up Only (Point Source Emissions)
Coal Storage Yards	2	N/A	Continuous (Fugitive Emissions)
Ash Dump	1	N/A	Continuous (Fugitive Emissions)
Materials Handling	Various Sources	N/A	Intermittent (Fugitive Emissions)
Roadways (Dust Re-entrainment)	Various Sources	N/A	Intermittent (Fugitive Emissions)

2.4 Pollutants of Concern

The following emissions have been considered in this assessment due to their known impact on human health and their potential to be released to the atmosphere from project activities:

- NO_x: The sum of nitric oxide (NO) and nitrogen dioxide is commonly called NO_x. NO_x reacts with ammonia, moisture, and other compounds to form small particles. These small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis;

- Nitrogen Dioxide (NO_2): NO_2 is toxic at relatively low concentrations, and can be readily formed from oxidation of NO (released by combustion processes) in the presence of atmospheric oxidants;

- Sulphur Dioxide (SO_2): Anthropogenic emissions of SO_2 originate from the combustion of sulphur-containing fuels and materials. SO_2 in the ambient environment is linked with increased rates of respiratory illness including asthma;

- Particulate Matter (PM): PM_{10} and $PM_{2.5}$ (fine particulate matter with an aerodynamic diameter of less than 10 and 2.5 micrometres respectively) pose a health risk as the particles can penetrate deep into the lungs, and may even enter into the bloodstream. Exposure to such particles can affect both the lungs and heart. Dust (the larger particle size fractions) can affect the ability of nearby vegetation to survive and maintain effective evapotranspiration. It may also pose health risks and irritation or nuisance to humans;

- Mercury (Hg) is present in coal in relatively low concentrations (approximately 0.1 ppm), and is emitted into the environment at combustion temperatures above 150°C. Exposure to high levels Hg can lead to mental impairment and organ failure; and,
- Metals are present in trace quantities in coal ash. The European Commission (EC) Directive 2004/107, has identified arsenic, cadmium, and nickel (which are present in coal ash in trace quantities) as pollutants of concern.

When considering large combustion sources, carbon monoxide (CO) is emitted in similar quantities to other regulated pollutants of concern (for example NO_2), however as CO is comparatively less toxic than the other gaseous criteria pollutants the standards are roughly three orders of magnitude less stringent. In this instance CO was screened out from further detailed modelling assessment using US EPA SCREEN3[1] (Refer to Appendix A for summary of SCREEN3 results).

2.5 Source Emission Limits

The Kenyan Air Quality Regulations provide emission limits for controlled and non-controlled emission sources [2]. The relevant emission limits for solid-fired boilers in the criteria range relevant to the Project (50 - 600 MWth) in non-degraded areas are provided in Table 2-3.

Table 2-3 – Kenyan Source Emission Limits for Solid Fuel-fired Boilers

Pollutant	Emission Limit (mg/m^3)
NO_x	510
SOx	900 - 1,500
PM	50

The emission guidelines stipulated in the IFC Thermal Power Plant Sector Guidance [3] are provided in Table 2-4.

[1] SCREEN3 is a single source Gaussian plume model which provides maximum ground-level concentrations for point, area, flare, and volume sources, as well as concentrations in the cavity zone, and concentrations due to inversion break-up and shoreline fumigation.

Table 2-4 – Emission Guidelines for Solid Fuel-fired Boiler (Plant ≥ 600 MWth)

Pollutant	Emission Limit (mg/m^3)
	Non Degraded Airshed (assumption based on baseline results)[a]
NO_x	510[c] Or up to 1,100 if volatile matter of fuel <10 %
SO_x	200-850[b]
PM	50

[a]: Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if World Health Organisation (WHO) Air Quality Guidelines are exceeded significantly.

[b]: Targeting the lower guidelines values and recognizing variability in approaches to the management of SO_2 emissions (fuel quality vs. use of secondary controls) and the potential for higher energy conversion efficiencies (FGD may consume between 0.5% and 1.6% of electricity generated by the plant). Larger plants are expected to have additional emission control measures. Selection of the emission level in the range is to be determined by Environmental Assessment considering the project's sustainability, development impact, and cost-benefit of the pollution control performance.

Where the IFC guidelines are more stringent than the Kenyan Standards, these values have been adopted in the design basis. The adopted Project Standards are presented below for reference purposes (Table 2-5).

Table 2-5 – Adopted Project Emission Limits

Pollutant	Emission Limit (mg/m^3)
NO_x	450
SO_x	<350
PM	50

2.6 Ambient Air Quality Standards

2.6.1 Kenyan Legislation

Projects seeking to access capital from Equator Principal Financial Institutions are normally expected to meet the requirements of the IFC General Environmental Health and Safety (EHS) Guidelines [4], which requires that emissions do not result in pollutant concentrations that reach or exceed relevant ambient air quality standards, or in their absence, other internationally recognised standards such as European Union (EU) Directive 2008/50/EC [5].

In terms of national legislation, the Environmental Management and Co-ordination Act (1999) facilitates a framework for the introduction of Kenyan standards, which were issued as the Air Quality Regulations in 2014 [2]. The regulations include ambient air quality tolerance limits for industrial and residential areas (Table 2-6), as well as ambient air quality guidelines at property boundaries.

Table 2-6 – Selected Kenyan Regulations Ambient Air Quality Tolerance Limits

Pollutant	Averaging Period	Permitted Number of Exceedances	Industrial Area ($\mu g/m^3$)	Residential, Rural & Other Areas ($\mu g/m^3$)
NO_2	Annual	None	150	102.7 *(0.05 ppm)*
	24 hours	None	100*	205.3 *(0.1 ppm)*
	1 hour	None	No applicable standard	410.7 *(0.2 ppm)*
NO_x	Annual	None	80**	60**
	24 hours	3 exceedances per year	150**	80**
	1 hour	None	No applicable standard	1,642.9 *(0.8 ppm)*
SO_x (assumed to be as SO_2)	Annual	None	80	60
	24 hours	3 exceedances per year	125	80
	Instant Peak (10 mins)	None	No applicable standard	477.9 *(0.191 ppm)*
PM_{10}	Annual	None	70	50
	24 hours	3 exceedances per year	150	100
$PM_{2.5}$	Annual		35	No applicable standard
	24 hours		75	No applicable standard

*This value is assumed to be erroneous or a translational error as the 24 hour standard is lower than the annual standard.
** Assumed to be an error (NO_x AAQS < NO_2 AAQS).

Table 2-7 – Selected Kenyan Regulations Ambient Air Quality Standards at Property Boundary for General Pollutants

Pollutant	Averaging Period	Permitted Number of Exceedances	Property Boundary ($\mu g/m^3$)
NO_x	Annual	None	80
	24 hours	3 exceedances per year	150
SO_x	Annual	None	50
	24 hours	3 exceedances per year	125
PM	Annual	None	50
	24 hours	3 exceedances per year	70

2.6.2 European Air Quality Standards

As the Kenyan standards are fairly recent, the EU Directive 2008/50/EC [5] standards have also been considered for assessment purposes in order to provide context against the Kenyan standards. The EU standards are summarised in Table 2-8 below.

Table 2-8 – EU Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)
NO_2	Annual	40
	1 hour	200[a]
SO_2	24 hours	125[b]
	1 hour	350[c]
PM_{10}	Annual	40
	24 hours	50[d]
$PM_{2.5}$	Annual	25
CO	8 hours	10,000

[a]: 18 exceedences of the ambient standard are permitted per year
[b]: 3 exceedences of the ambient standard are permitted per year
[c]: 24 exceedences of the ambient standard are permitted per year
[d]: 35 exceedences of the ambient standard are permitted per year

2.6.3 Metals

Hg could potentially be emitted in the gas phase during the combustion of coal. As there are no Kenyan air quality standards for Hg, the following levels have been adopted for assessment purposes (Table 2-9) in accordance with the IFC General EHS [4].

Table 2-9 – Mercury Guidelines for Ambient Air

Pollutant	Averaging Period	Concentration	Source
Hg	Annual	1 $\mu g/m^3$	WHO [6]

Table 2-10 below presents the maximum daily deposition rates allowable for metals in accordance with the UK Environment Agency guidelines. The maximum deposition rate is the quantity of pollutant which can be added to the soil daily over 50 years before the selected soil quality criteria is exceeded (Table 2-10). The key project sources potentially associated with these metals included the ash dumps.

Table 2-10 – Maximum Allowable Metal Deposition Rates

Pollutant	Averaging Period	Guideline Limit	Source [7]
Hg	$mg/m^2/day$	0.004	H1 Annex F
Arsenic	$mg/m^2/day$	0.02	H1 Annex F
Cadmium	$mg/m^2/day$	0.009	H1 Annex F
Nickel	$mg/m^2/day$	0.11	H1 Annex F
Lead	$mg/m^2/day$	1.1	H1 Annex F

2.6.4 Emergency Response Planning Guidelines

It is acknowledged that short-term ambient air quality standards are often not reasonably attainable under certain emergency conditions, for example, during the power station black start which is expected to occur very short periods in instances when the power station needs to be restarted without assistance from the national grid. In these instances the model results have been compared against the Emergency Response Planning Guideline (ERPG) values developed by the American Industrial Hygiene Association (AIHA)[2] which gives a more direct assessment of the health impacts that may be experienced by exposed people. The relevant values for the pollutants of concern are presented in Table 2-11.

Table 2-11 – ERPG Values for the Assessment of Emergency Conditions

Species	ERPG-1 ($\mu g/m^3$)	ERPG-2 ($\mu g/m^3$)	ERPG-3 ($\mu g/m^3$)
SO_2	857	8,566	42,830
NO_2	2,052	30,784	61,569

ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour.

ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

[2] https://www.aiha.org/get-involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Documents/2014%20ERPG%20Values.pdf

ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

2.6.5 Project Adopted Standards

Adopting a conservative approach, the limits and guidelines detailed above have been combined into a single table for assessment purposes, refer to Table 2-12 below. The Kenyan air quality standards for "residential, rural and other areas" have been adopted and where no standards are applicable, the air quality standards for "industrial areas" have been applied. Where the Kenyan legislation lacks applicable standards, the EU standards or WHO guidelines are applied.

Table 2-12 – Project Adopted Standards

Pollutant	Averaging Period	Permitted Number of Exceedances	Project Adopted Standards ($\mu g/m^3$)
NO_2	Annual	None	102.7 *(0.05 ppm)*
	24 hours	None	205.3 *(0.1 ppm)*
	1 hour	None	410.7 *(0.2 ppm)*
NO_x	Annual	None	60*
	24 hours	3 exceedances Per year	80*
	1 hour	None	1,642.9 *(0.8 ppm)*
SOx (assumed to be as SO_2)	Annual	None	60
	24 hours	3 exceedances per year	80
	1 hour	24 exceedances	350
	Instant Peak (10 mins)	None	477.9 *(0.191 ppm)*
PM_{10}	Annual	None	50
	24 hours	3 exceedances per year	100
$PM_{2.5}$	Annual	None	35
	24 hours	None	75
Hg	Annual	None	1
Key:			
Kenyan Regulations Ambient Air Quality Tolerance Limits: Residential, rural and other areas			(red)
EU Ambient Air Quality Standards			(blue)
Kenyan Regulations Ambient Air Quality Tolerance Limits: Industrial areas			(orange)
WHO Guidelines			(purple)

* Assumed to be an error (NO_x AAQS < NO_2 AAQS)
**SO_x as SO_2

3 Existing Ambient Air Quality

Baseline ambient air quality data for the Project area has been obtained from the specialist baseline air quality report prepared by SGS [8]. Measurements of key pollutant (NO_2, SO_2 and PM) concentrations were taken at ten locations at and in the vicinity of the Project site.

3.1 Baseline Air Quality Collection Methodology

The monitoring of ambient conditions was undertaken during the period spanning 10 January to 17 February 2015. Monitoring of NO_2 and SO_2 was conducted using Radiello™ passive diffusion sampling tubes located at positions both up- and down-wind of the Project site.

Fine particulate monitoring was undertaken using Minivol™ air samplers to collect 4-hour samples at each of the monitoring sites. The samples were then submitted to a laboratory for gravimetric determination. The sampler was fitted with both PM_{10} and $PM_{2.5}$ specific sampling inlets so as to enable the determination of ambient concentrations of both these size fractions.

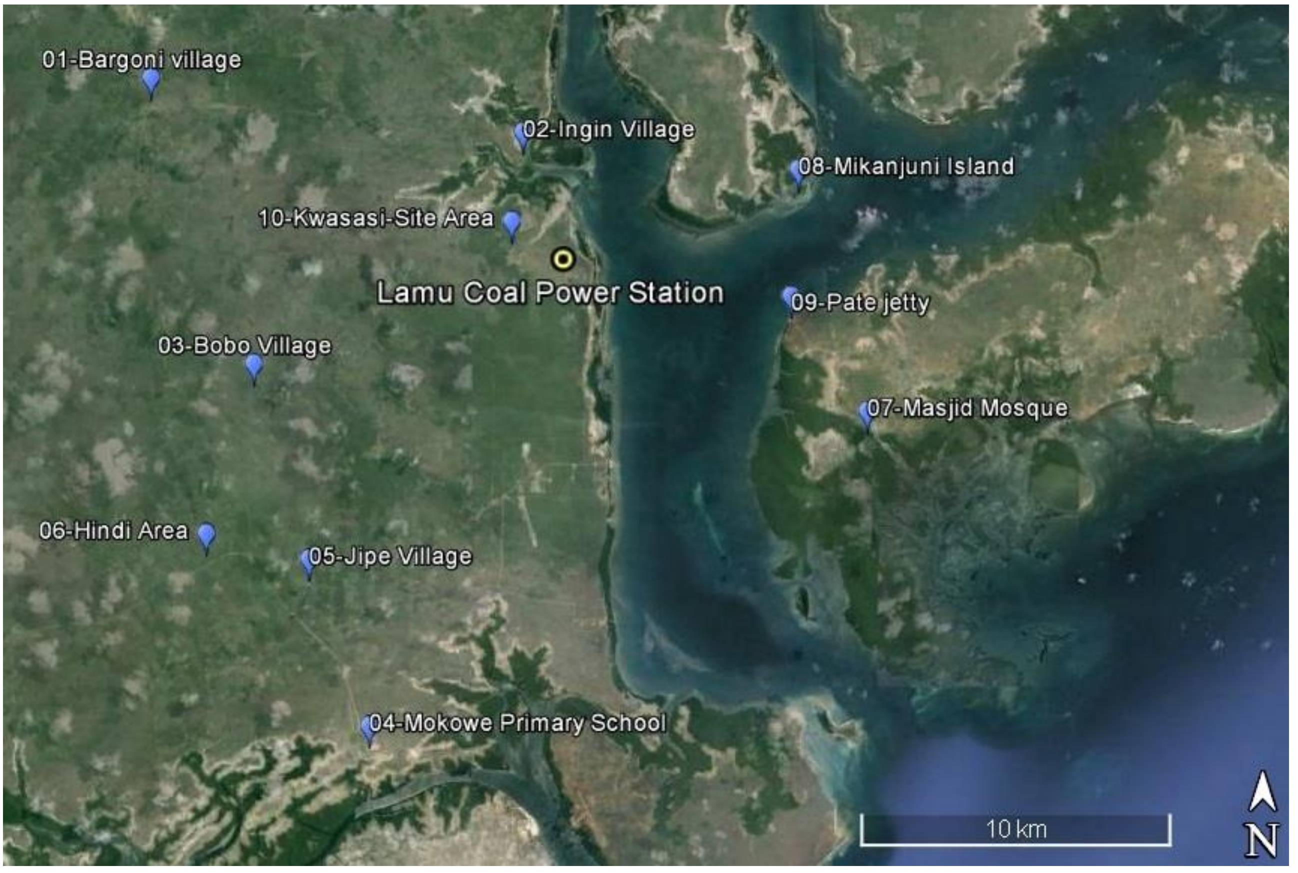
3.2 Air Quality Monitoring Sites

The locations and basis descriptions of the baseline air quality monitoring sites are provided in Table 3-1 and an annotated aerial photograph image presented in Figure 3-1.

Table 3-1 – Sampling Point Locations

Sampling Point	UTM Coordinates		Site Description
	Easting (m)	Northing (m)	
Bargoni Village	698,656	9,773,597	Village along Hindi-Kiunga road.
Ingin Village	710,726	9,771,853	Small residential village off the Hindi-Kiunga road.
Bobo Village	702,003	9,764,391	Village along Hindi-Kiunga road.
Mokowe Primary School	705,761	9,752,730	School within Mokowe town, where air quality is currently influenced by primarily by road traffic.
Jipe Village	703,802	9,758,099	Residential village mostly inhabited by farmers.
Hindi Area	702,010	9,758,912	Hindi is a busy shopping village.
Masjid Mosque Pate Village	721,898	9,762,890	Residential village mostly inhabited by fishermen and farmers.
Mikanjuni Island Opposite Resort	719,656	9,770,671	This area is an island surrounded by the ocean.
Mtandawanda-Pate Jetty	719,423	9,766,589	Island location.
Kwasasi (Project Site Area)	710,361	9,768,990	Simsim farming is currently undertaken in the vicinity of the Project site.

Figure 3-1 – Baseline Sampling Locations



3.3 Monitoring Results

3.3.1 Nitrogen Dioxide

The sampling for ambient NO_2 concentrations was undertaken across a period of approximately one month and the results have been compared to the Project annual average standards. The results presented in Table 3-2 show that at the time of the survey, concentrations at all monitoring locations were below the respective standard.

Table 3-2 – Baseline NO_2 Monitoring Results

Location ID	Monitoring Duration (hours)	Measured Concentration (µg/m³)	Ambient Standard (µg/m³)	Compliant with Project Standard?
Bargoni Village	888	17.3	102.7	Yes
Ingin Village	816	9.4		Yes
Bobo Village	745	15.5		Yes
Mokowe Primary School	730	3.2		Yes
Jipe Village	735	5.2		Yes
Hindi Area	840	*		N/A
Masjid Mosque Pate Village	865	26.6		Yes

Location ID	Monitoring Duration (hours)	Measured Concentration (µg/m³)	Ambient Standard (µg/m³)	Compliant with Project Standard?
Mikanjuni Island Opposite Resort	864	2.2		Yes
Mtandawanda-Pate Jetty	820	*		N/A
Kwasasi (Project Site Area)	768	10.0		Yes

*The diffusion tube samplers were either destroyed or missing.

3.3.2 Sulphur Dioxide

The SO_2 sampling results have been compared to the Kenyan annual average limit value. The results presented in Table 3-3 reveal that concentrations at all monitoring locations were below the standard at the time of measurement.

Table 3-3 – Baseline SO_2 Monitoring Results

Location ID	Monitoring Duration (hours)	Measured Concentration (µg/m³)	Ambient Standard (µg/m³)	Compliant with Project Standard?
Bargoni Village	888	BDL	60	Yes
Ingin Village	816	BDL		Yes
Bobo Village	745	BDL		Yes
Mokowe Primary School	730	BDL		Yes
Jipe Village	735	BDL		Yes
Hindi Area	840	*		N/A
Masjid Mosque Pate Village	865	BDL		Yes
Mikanjuni Island Opposite Resort	864	BDL		Yes
Mtandawanda-Pate Jetty	820	*		N/A
Kwasasi (Project Site Area)	768	BDL		Yes

*The diffusion tube samplers were either destroyed or missing.
BDL: Below Detection Limits. The detection limit represents an ambient concentration of SO_2 of 10µg/m³.

3.3.3 Particulate Matter

The sampling for ambient PM_{10} concentrations was undertaken across a period of approximately 4 hours at each of the monitoring sites, and the results have been compared to the Project annual average standards. The results presented in Table 3-4 reveal that concentrations at all monitoring locations were below the limit value for PM_{10}.

Table 3-4 – Baseline PM_{10} Monitoring Results

Location ID	Monitoring Duration (hours)	Measured Concentration (µg/m³)	Ambient Standard (µg/m³)	Compliant with Project Standard?
Bargoni Village	4	16.5	50	Yes
Ingin Village	4	0.3		Yes
Bobo Village	4	0.2		Yes
Mokowe Primary School	4	0.3		Yes
Jipe Village	4	0.2		Yes
Hindi Area	4	0.7		Yes
Masjid Mosque Pate Village	4	0.4		Yes
Mikanjuni Island Opposite Resort	4	0.6		Yes
Mtandawanda-Pate Jetty	4	0.3		Yes
Kwasasi (Project Site Area)	4	3.7		Yes

The sampling for ambient $PM_{2.5}$ was undertaken concurrently with PM_{10} (approximately 4 hours per monitoring site). The monitoring results have been compared to the Project annual average standard. The results presented in Table 3-5 reveal that concentrations at all monitoring locations were below the standard.

Table 3-5 – Baseline $PM_{2.5}$ Monitoring Results

Location ID	Monitoring Duration (hours)	Measured Concentration (µg/m³)	Ambient Standard (µg/m³)	Compliant with Project Standard?
Bargoni Village	4	18.0	35	Yes
Ingin Village	4	0.1		Yes
Bobo Village	4	0.3		Yes
Mokowe Primary School	4	0.3		Yes
Jipe Village	4	0.1		Yes
Hindi Area	4	0.1		Yes
Masjid Mosque Pate Village	4	0.3		Yes
Mikanjuni Island Opposite Resort	4	0.5		Yes
Mtandawanda-Pate Jetty	4	1.0		Yes
Kwasasi (Project Site Area)	4	0.6		Yes

The baseline measurements indicate that the air quality in the study area complies with the relevant ambient air quality standards.

3.4 Baseline Measurement Limitations

The sampling period was limited in duration – in particular for PM_{10} and $PM_{2.5}$ – which to some extent lowers the confidence that can be placed in making this conclusion. In addition, short term elevations in pollutant concentrations that the area may experience cannot be determined given the sampling methodologies used.

4 Construction Phase Impact Assessment

4.1 Introduction

Atmospheric emissions from construction activities can be broadly categorised into the following:

- General dust and more specifically, the PM_{10} fraction within it from earth working and on-site vehicle movement activities;
- Exhaust emissions associated with vehicles transporting materials and personnel to and from the site, i.e. off-site emissions; and,
- Exhaust emissions associated with construction activities on-site (e.g. equipment, heavy machinery and vehicle idling).

The majority of the releases are likely to occur during the 'working week'. However, for some potential release sources (e.g. exposed soil or dusty building materials) in the absence of dust control mitigation measures, dust generation has the potential to occur 24 hours per day over the period during which such activities are to take place.

The potential sources of emissions and resultant impacts are considered to be relatively universal across the different phases of construction. A brief summary of the construction phase emissions and likely impacts are presented in the following sections.

4.2 Methodology

4.2.1 Construction Plant and Vehicles

Emissions of carbon dioxide (CO_2), CO, SO_2, NO_x and PM_{10} will result from the operation of construction equipment (such as graders, loaders and cranes) and road vehicles during this phase of the Project.

An inventory has been prepared quantifying the atmospheric emissions from significant combustion sources (vehicles, equipment and engines) that represents a ‘peak’ year in terms of activities. The inventory has used information related to the construction and the type and quantity of equipment provided by the Engineering, Procurement and Construction contractors (presented in in Table 4-1) as a basis for the calculations. The inventory has utilised the internationally recognised US EPA Non-road Engine, and Vehicle Emissions Study methodology [9] in conjunction with the Project-specific information. The estimated, total quantities of emissions are presented within Table 4-1. Where necessary, certain equipment types have been categorised into the most appropriate category for which emissions data are available.

Table 4-1 – Construction Equipment Inventory

Equipment	Number in Operation	Estimated Emission Quantities (tonnes per week*)				
		CO	CO_2	NO_x	SO_2	PM_{10}
Bore / Drill Rigs	10	1	426	2	<1	<1
Excavators	6	<1	127	1	<1	<1
Cement and Mortar Mixers	3	<1	3	<1	<1	<1
Cranes	4	<1	72	1	<1	<1
Off-Highway Trucks	26	3	789	7	1	1
Crushing/Processing Equipment	2	<1	52	<1	<1	<1
Loaders	16	1	269	2	<1	<1
Dozers	4	<1	88	1	<1	<1
Dumpers/Tenders	14	<1	20	<1	<1	<1
Other Construction Equipment	4	1	308	1	<1	<1
Pump <50hp	28	<1	3	<1	<1	<1
Welders <50hp	10	<1	19	<1	<1	<1
4 x 4 Petrol	30	<1	2	<1	<1	<1
4 x 4 Diesel	30	<1	2	<1	<1	<1
Busses	15	<1	3	<1	<1	<1

* Assuming a 12-hour working day and 6-day working week.

4.2.2 Assessment of Dust and PM_{10} Emissions from On-site Activities

Dust generated during construction will primarily result from clearing and earthworks, materials handling and storage, general construction activities and vehicle movements along unpaved roads.

Airborne soil dust is typically coarse and therefore remains airborne only for short periods. Under normal meteorological conditions, dust impacts would likely be limited to a few hundred metres of the construction spread, however, under strong wind conditions these effects could extend further. US EPA research [10] shows that in excess of 90% of total airborne dust returns to the earth's surface within 100 m of the emission source and over 98% within 250 m.

A qualitative assessment of the risk associated with dust and PM_{10} emissions during the construction phase has been undertaken using guidance produced by the United Kingdom (UK) Institute of Air Quality Management (IAQM) [11]. This guidance considers the risks associated with four broad categories of activities; i.e. demolition (not relevant to this project), earthworks, construction and vehicle track-out of material onto tarred roads.

The following potential impacts of dust and PM_{10} generated during the construction phase have been considered within the risk assessment:

a) Annoyance due to dust soiling; and

b) The risk of health effects due to an increase in exposure to PM_{10}.

The risks associated with these potential impacts has been assessed by identifying:

- The size of the site and the area of which construction activities are likely to take place;
- The construction activities associated with the Project that could generate dust and their likely duration;
- The proximity and type of receptors which may be sensitive to changes in air quality;
- The prevailing wind direction and local precipitation patterns in the area;
- The presence of vegetation surrounding the site, which might act as a buffer; and,
- The potential distance which the construction traffic will travel across unpaved roads on the construction Site, prior to accessing the local road network (referred to as 'track-out').

The risk assessment for each of the four activity categories has taken into account both the scale and nature of the works, which determines the potential dust emission magnitude, in conjunction with the sensitivity of the area. Risks were described in terms of there being a 'low', 'medium' or 'high' risk for each of the four activity categories. Site-specific mitigations, corresponding to the level of risk anticipated, have also been identified and proposed.

WKC's experience and professional judgement has been applied in this assessment to ascertain the magnitude of dust and PM_{10} emissions associated with each activity category, the degree of sensitivity of the affected receptors, and the suitable mitigation measures to be applied.

4.2.3 Assessment of Dust Emission Magnitude

The generation of dust in the four defined activity categories is classed as large, medium or small, based on criteria provided in the IAQM guidance. The results of the assessment are summarised below.

Demolition

The project site is currently undeveloped, so there is no requirement to undertake any demolition activities.

Earthworks

The total Project construction area footprint is classified as "large" according to IAQM criteria and based on the indicative site equipment list it is considered likely that more than 10 heavy earthmoving vehicles could operate on-site at any given time. The soil type has been assumed to be moderately dusty. Overall, it has been estimated that the magnitude of dust and PM_{10} emissions is considered large for earthworks activities.

Construction

The total volume of buildings to be constructed would likely be classified as “large” according to IAQM criteria and many of the structures are to be constructed with concrete (necessitating on-site concrete batching plants). Therefore the magnitude of dust and PM_{10} emissions is considered large for construction activities.

Track-out

There is likely to be more than 50 heavy vehicle outward movements in any one day during the construction period which corresponds to the IAQM “large” category range. The ground surface material is likely to have a moderate potential for dust release and the majority of the roads to be traversed by construction vehicles (>100 m) will be unpaved, at least initially. Therefore, it is considered that the magnitude of dust and PM_{10} emissions is large for track-out.

4.2.4 Assessment of Sensitivity of the Study Area

The primary wind directions in the study area are southerly and easterly (refer to Figure 5-1). Any receptors located to the west and north of the site are more likely to be affected by any dust emitted/re-suspended from construction activities and track-out.

Assuming that the baseline surveys described in Section 3 and the associated assumptions are valid, local background PM_{10} concentrations are typically below 75% of the annual mean standard for this pollutant. Therefore, PM_{10} generated by the construction phase of the Project is considered unlikely to cause an exceedance of the standards at nearby receptors, given the distance between the construction site and the nearest settlements.

The Project site is located in a remote area where only scattered, isolated residential dwellings may be expected within a radius of a few hundred metres of the site boundary.

Taking into account the IAQM guidance, the area surrounding the proposed development is considered to be of low sensitivity to changes in dust and PM_{10} as a result of construction activities.

4.3 Results

4.3.1 Construction Plant and Vehicles

Table 4-2 summarises the estimated emissions from construction plant and vehicles involved the construction phase activities of the Project.

Table 4-2 –Construction Phase Emissions Inventory

Pollutant	Emission Quantity (tonnes) / Peak Year
CO	356
CO_2	109,305
NO_x	764

Pollutant	Emission Quantity (tonnes) / Peak Year
SO_2	78
PM_{10}	716

4.3.2 Assessment of Dust and PM_{10} Emissions from On-site Activities

A risk assessment was undertaken to determine the risk associated with each of the construction activity categories; the results of which are summarised in Table 4-3.

Table 4-3 –Dust and PM_{10} Risk Assessment Summary

Potential Impact	Risk			
	Demolition	Earthworks	Construction	Track-out
Dust Fallout / Soiling	N/A	Low	Low	Low
Human Health	N/A	Low	Low	Low

The risk category identified for each activity has been considered when defining the list of site specific mitigation measures for each relevant construction component. The list of proposed mitigation measures are presented in Section 6.1.1.

Taking into account all of the above, the overall sensitivity of the surrounding area in terms of human receptors is low, and the overall magnitude of change prior to mitigation is considered to be large. Therefore overall, there is likely to be a direct, temporary, short- to medium-term impact on nearby sensitive receptors of slight adverse significance prior to the implementation of mitigation measures.

5 Operation Phase Assessment

5.1 Introduction

In order to estimate ground level concentrations for each study pollutant, an ADM study has been undertaken using the US EPA preferred CALPUFF and AERMOD dispersion models. As discussed in Section 1, CALPUFF was used to model the point source emissions and AERMOD was used for modelling fugitive near field emissions associated with coal and ash handling. Further details regarding the US EPA preferred dispersion models and suitability for assessment purposes can be found at http://www.epa.gov/ttn/scram/dispersion_prefrec.htm.

5.2 Modelling Scenarios

The modelling scenarios for the ADM assessment are presented in Table 5-1.

Table 5-1 – Scenarios Considered in the Modelling Assessment

Scenario	Description	Operating Mode	Duration	US EPA Model Used	Pollutants Considered
Scenario 1	The three main power station boilers operating at 100% load	Normal	Continuous	CALPUFF	NO_2, SO_2, PM_{10}, $PM_{2.5}$, Hg
Scenario 2	Fugitive dust from coal and ash handling and storage activities including dust mitigation controls (including emissions from three main boilers)	Normal	Continuous	AERMOD	PM_{10} and $PM_{2.5}$*
Scenario 3	Total Suspended Particulates (TSP) fallout for selected metals as a result of fugitive dust from ash operations	Normal	Continuous	AERMOD	Selected metals (arsenic, cadmium, nickel, lead and Hg)
Scenario 4	Black Start of Power Station	Emergency	Less than 5% of the year	CALPUFF	NO_2 and SO_2

* Considers combined effect of PM from boilers and fugitive dust handling operations, as these emissions arise from both Scenario 1 and 2. Gaseous pollutants are addressed through Scenario 1

5.3 Emission Parameters

Key characteristics associated with emission sources, which may affect dispersion of exhaust gases and particulates, include the parameters listed in Table 5-2. The locations of the key emission sources are provided in Table 5-3.

Table 5-2 – Emission Parameters which Affect Dispersion

Parameter	Description
Stack dimensions (m):	Stack height in relation to the vertical profile of the atmosphere can significantly affect dispersion of pollutants.
Exit gas velocity (m/s):	Gas velocity (correlated to stack diameter) provides plume momentum, influencing vertical (and horizontal) dispersion.
Exit gas temperature (K):	Affects the buoyancy of the gas and thus the vertical dispersion of pollutants.
Emission rate (g/s):	Proportional to the associated ground level concentrations of a particular pollutant (assuming conservation of mass within the dispersing plume).
Dimensions (m):	Length, width and height of all relevant sources where applicable. This particularly affects the fugitive dust dispersion.

Table 5-3 – Combustion Sources within the Power Station

Source ID	Operating Case	UTM	
		East (m)	North (m)
Black Start Generator 1	Emergency Black Start	712,252	9,768,506
Black Start Generator 2	Emergency Black Start	712,248	9,768,506
Black Start Generator 3	Emergency Black Start	712,252	9,768,501
Black Start Generator 4	Emergency Black Start	712,252	9,768,496
Black Start Generator 5	Emergency Black Start	712,247	9,768,496
Black Start Generator 6	Emergency Black Start	712,247	9,768,501
Black Start Generator 7	Emergency Black Start	712,252	9,768,511
Black Start Generator 8	Emergency Black Start	712,247	9,768,516
Black Start Generator 9	Emergency Black Start	712,252	9,768,516
Black Start Generator 10	Emergency Black Start	712,247	9,768,511
Auxiliary Boiler	Emergency Black Start	712,234	9,768,565
Main Boiler 1 (common stack)	Normal	712,084	9,768,592
Main Boiler 2 (common stack)	Normal		
Main Boiler 3 (common stack)	Normal		

5.3.1 Point Sources

The tables below present the modelling input data in the form on an emission inventory. The information is based on vendor data or in the absence of detailed data, internationally recognised emission factors [12].

Table 5-4 – Boiler Data

Parameter:	Unit	Main Boilers (Based on New Vaal Coal)	Auxiliary Boiler (Startup Only)
Quantity:	-	3	1
Fuel Type:	-	Coal	Diesel
Thermal Input Per Boiler:	MW	875.5	19
Fuel Energy Value:	MJ/kg	16	44.8
Fuel Flow Per Boiler:	tonnes / hour	197.9	0.4
Stack Height:	m	210.00	20
Stack Width:	m	5.3	0.9
Temperature:	°C	140	155
Actual Exhaust Flow:	Am^3/s	522	9.4
Normal Exhaust Flow:	Nm^3/s	334	6
Velocity:	m/s	18.6	15
Exhaust Gas Concentrations:			
NO_x:	mg/Nm^3	450	250
SO_2:	mg/Nm^3	343	200
PM:	mg/Nm^3	42	30
Hg Emission Factor [12]:	kg/tonne	0.0004	Not defined
Emission Rates:			
NO_2:	g/s	116.4	1.1
SO_2:	g/s	118.3	1.2
*$PM_{10/2.5}$:	g/s	14.5	0.2
Hg Emission Rate:	g/s	0.0021	Not defined

*Conservatively assumes $PM_{2.5}$ emisison rate = PM_{10} emission rate

Table 5-5 – Black Start Generator Data

Parameter:	Unit	Generators
Number of Sources:	-	12 (10 active 2 on standby)
Fuel Type:	-	Diesel
Thermal Input:	MW	5.04
Lower Heating Value:	MJ/kg	42.8
Stack Height:	m	20
Stack Width:	m	0.40
Temperature:	°C	300
Actual Exhaust Flow:	Am^3/s	4.70
Normal Exhaust Flow:	Nm^3/s	2.30
Velocity:	m/s	37.70
Exhaust Gas Concentrations:		
NOx:	mg/Nm^3	2,366
SO_2:	mg/Nm^3	98
PM:	mg/Nm^3	15
Emission Rates:		
NO_2:	g/s	4.00
SO_2:	g/s	0.22
$PM_{10/2.5}$*:	g/s	0.03

* Conservatively assumes all PM_{10} and $PM_{2.5}$ emission rates are the same

5.3.2 Fugitive Sources

In addition to the point sources associated with the boilers and diesel generators, there are a number of area and volume emission sources associated with coal and ash handling. The emission rates have been determined using the Australian National Pollutant Inventory (NPI) emission factors for coal handling and include the proposed control measures [13]. A full emission table can be found in Appendix B.

Table 5-6 – Summary of All Fugitive Dust Inputs

Operation/ Activity	Type	Description	Reference
Materials handling and transfer	Loading and unloading ships/barges. Transfer to and from conveyor belts. Truck loading and unloading	All activities that alternate source of dust from one transportation method to another	NPI, Mining: Table 2, [13]
Heavy Duty Vehicles	Excavators/Shovels/Front End loaders Bulldozers	Transportation of coal and reforming of stockpile	NPI, Mining: Table 2, [13]
Stockpile loading and unloading	Bucket wheel stacker and reclaimer	Coal and ash stored in stockpiles before consumption	NPI, Mining: Table 2, [13]
Wind Erosion	Coal and ash stockpiles	Finely granulated dust is collected deposited across surrounding areas	NPI, Mining: Table 2, [13]
Paved Roads	Tracks and tank cars	Transportation of ash from boilers to ash stockpiles	NPI, aggregated emissions from paved and Unpaved Roads, [14]
Unpaved Roads	Tracks and tank cars	Transportation of ash from boilers to ash stockpiles	NPI, aggregated emissions from paved and Unpaved Roads, [14]

Dust emissions from the transport of ash to the ash yard were calculated based on US EPA emission factors for paved and unpaved roads [14].

5.4 Model Settings

The model versions and meteorological pre-processors utilised within the study are presented in Table 5-7, and the model parameters for each of the models are presented in Table 5-8 and Table 5-9.

Table 5-7– Model Setting Options

Parameters	CALPUFF	AERMOD
Model	US EPA CALPUFF Model EPA Approved Version	US EPA AERMOD Model 14134
Meteorological Processing Software	CALMET 6.x	AERMET 8.0.5 Rural classification

Table 5-8 – Key Model Parameters CALPUFF

Parameter	Size
Model Domain	50 km x 50 km
Weather Research and Forecasting (WRF)	50 km x 50 km (4 km grid spacing)
CALMET	50 km x 50 km (1 km grid spacing)
Number of Vertical Layers in CALMET	11
Terrain	Global Shuttle Radar Topography Mission (SRTM) 90 m terrain
Land Use	United States Geological Survey (USGS) 1 km Resolution Land Use Data
Receptor Grid Spacing	Receptor spacing was set with 50 m receptors along the facility fenceline and 100 m receptors in the immediate vicinity outside of the facility. Nested grids of receptors with spacing of 500 m, and 1000 m were located at further distances.
Coastline Features	Coastline option enabled

Table 5-9 – Model Domain Parameters AERMOD

Parameter	Size
Model Domain	50 km x 50 km
Meteorological Data	WRF AERMET Processed
Terrain	Global Shuttle SRTM 90 m terrain
Land Use	AUER classification method based on USGS 1 km Resolution Land Use Data
Receptor Grid Spacing	Receptor spacing was set with 50 m receptors along the facility fenceline and 50 m receptors in the immediate vicinity outside of the facility. Nested grids of receptors with spacing of 100 m, and 200 m were located at further distances.
Centre Point	Latitude: 2.092778 S Longitude: 40.900042 E Zone:37M

5.5 Meteorological Data

Local meteorological conditions affect the plume dispersion of emissions with plumes being largely transported in the direction of the wind. Furthermore the atmospheric stability criteria influence both plume fall-out and consequently the resulting pattern of dispersion. The meteorological data for each of the models is discussed in the following sections. In the absence of suitable quality assured site specific meteorological data, commercial prognostic data was purchased from Lakes Environmental for both CALPUFF and AERMOD.

5.5.1 CALPUFF

The meteorological dataset generated for the site was conducted in accordance with recognised techniques for meteorological modelling. The three-dimensional meteorological dataset for the Lamu region required an acceptable prognostic meteorological model that was capable of capturing the distinct geographic features of the study area, and able to take into account larger-scale events.

The CALPUFF modelling system requires hourly surface and upper meteorological data (as well as geophysical data). Surface hourly meteorological data includes wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure, relative humidity and precipitation. Upper air meteorological data includes wind speed, wind direction, temperature, pressure and elevation (geophysical data includes gridded fields of terrain height, land use categories, surface roughness, albedo and leaf area index).

The WRF model was selected and the configuration of the WRF model was customised to reflect the geographic features of the area. The configuration of the model also considered the location of the Project area, to ensure the larger-scale flows and key meteorological features predominant in the area were adequately captured. The WRF data was processed in CALMET for use in the CALPUFF model using five years' data (2009-2013).

5.5.2 AERMOD

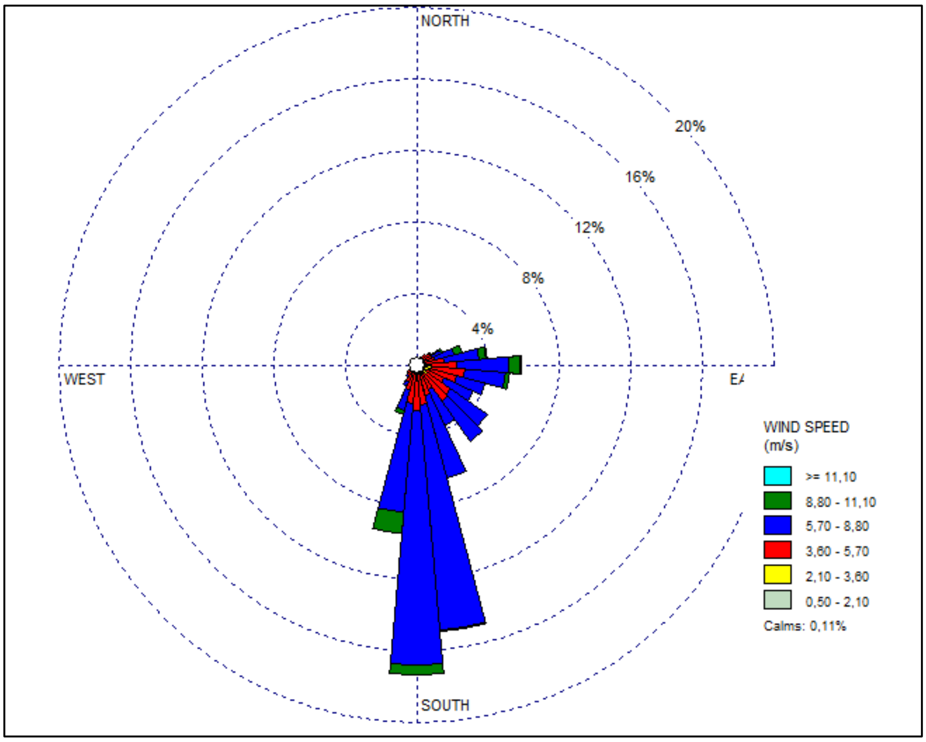
AERMOD requires hourly measurements of wind speed and direction, ambient temperature, air-mass stability) and estimates of the urban and rural mixing heights. AERMOD also utilises hourly sequential upper atmospheric meteorological data for the calculation of vertical profiles of wind turbulence and temperature.

The AERMOD model was set up using five years' WRF mesoscale meteorological data (2009–2013). WRF data has been selected given the absence of complete and quality assured surface and upper air meteorological data in the vicinity of facility.

5.5.3 Wind Rose

The prevailing wind directions within the general project area are from the south and easterly regions. Wind directions from the other sectors occur relatively infrequently. The typical wind is presented in Figure 5-1 below.

Figure 5-1 – Wind Rose for the Project Site (2009-2013)



5.6 Study Assumptions and Limitations

The following assumptions are applicable to the modelling study, and wherever possible, a conservative approach is adopted:

- It has been assumed that the measured baseline data is reflective of annual conditions;
- Given the height of the main stack (210 m) buildings were not included in the assessment as the plume will not be influenced by building downwash;

- The assessment only considers environmental receptors (impacts beyond the plant boundary);
- UTM co-ordinates have been based on best approximation of the sources based on the plot plan;
- The NO_x/ NO_2 conversion factor of 80% by volume (although the conservative aspect of this value is recognised) for long-term and short term averages was adopted. As these assumptions are regarded as being conservative, it is likely to lead to a higher estimation of ground level NO_2 concentration than would actually occur in reality;
- Emission factors defined in the Australian NPI [13] for coal handling sources have been applied to all material handling sources;
- Based on the preliminary data provided it has been assumed that all crushing and milling activities will take place within a housed enclosure, and therefore emissions from these activities are considered negligible;
- For all coal handling emission sources, the particle size distribution was assumed to be consistent with published data [15];
- For all particulate emissions from boilers, the particle size distribution was based on the US EPA AP42 data [16];
- For all ash handling emission sources, the particle size distribution was based on published data [17]; and,
- As specific Hg emissions speciation and particle size distribution was not available for this analysis, only Hg inhalation through the gas phase was assessed (based on emission rates derived from US EPA emission factors [12]).

5.7 Air Dispersion Modelling Results

Modelled ground level concentrations have been compared to Kenyan standards and, in the absence of applicable standards, the WHO guidelines, EU standards or the UK Environmental Agency Guidelines for the pollutants of concern to determine whether the facility is likely to cause breaches in such standards.

Where applicable the assessment includes an evaluation of cumulative impact by comparing modelled outputs in an additive context with the measured background data, where it was available. It has been assumed that the measured baseline data is reflective of annual conditions, and therefore as a conservative measure the measured background data has been doubled for short term averaging periods for assessment purposes [7]. The results for each of the four scenarios are presented in the following sections, with isopleths for each scenario presented in Appendix C.

5.7.1 Scenario 1: Three Main Boilers at 100% Load

The results for Scenario 1 (normal operation of the three main boilers in isolation) are presented in Table 5-10.

Table 5-10 – Scenario 1 Maximum Ground Level Concentrations

Pollutant	Averaging Period	Project Ambient Air Quality Standards (µg/m³)	Modelled Concentrations (µg/m³)	Percentage of the Standard (%)
NO_2	1 hour	410.7	269.3	66
	24 hours	205.3	19.9	10
	Annual	102.7	2	2
NO_x	1 hour	1,642.9	359.3	22
	24 hours	80	17*	21
	Annual	60	2.7	5
SO_2	Instant peak (10 minutes)	447.9	94.7	21
	1 hour	350	66.2**	19
	24 hours	80	12.9*	16
	Annual	60	2.1	4
PM_{10}	24 hours	100	1.6*	2
	Annual	50	0.3	1
$PM_{2.5}$	24 hours	75	2.5	3
	Annual	35	0.3	1
Hg	Annual	1	0.0003	<0.1
	Key:		Predicted Compliance	

*Allows for 3 exceedances
**Allows for 24 exceedances

The modelled maximum ground level concentrations in isolation are all below the relevant standards. In order to present the model results in a cumulative context with measured background values, and therefore to provide a more accurate prediction of whether ambient standards are likely to be breached, the modelled results at each of the sensitive receptors has been added to the background value. These results are presented in Table 5-11. Refer Appendix C for isopleths.

Table 5-11 – Scenario 1 Cumulative Concentrations at Sensitive Receptors

Values in brackets are predicted model results, whilst the second value is the cumulative value (baseline measurements + model results.

	NO_2 (µg/m³)			NO_x (µg/m³)			SO_2 (µg/m³)				PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Hg (µg/m³)
	1 hour	24 hour	1 year	1 hour	24 hour	1 year	10 min	1 hour	24 hour	1 year	24 hour	1 year	24 hour	1 year	1 year
Project Ambient Air Quality Standard (µg/m³)	**410.7**	**205.3**	**102.7**	**1642.9**	**80**	**60**	**477.9**	**350**	**80**	**60**	**100**	**50**	**75**	**35**	**1**
Bargoni Village	(49.1) 83.7	(6.8) 41.4	(0.5) 17.8	(65.6) No data	(7.6) No data	(0.6) No data	(71.4) 71.4	(23.2) 23.2	(5.8) 5.8	(0.5) 0.5	(0.7) 33.7	(0.1) 16.6	(0.9) 36.9	(0.1) 18.1	(<0.1) No Data
Ingin Village	(123.4) 142.2	(8.6) 27.4	(0.4) 9.8	(164.7) No data	(6.9) No data	(0.6) No data	(179.4) 179.4	(21.6) 21.6	(5.3) 5.3	(0.4) 0.4	(0.6) 1.2	(<0.1) 0.3	(1.1) 1.3	(0.1) 0.2	(<0.1) No Data
Bobo Village	(75.1) 106.1	(6.5) 37.5	(0.5) 16.0	(100.2) No data	(5.8) No data	(0.7) No data	(109.3) 109.3	(25.1) 25.1	(4.4) 4.4	(0.5) 0.5	(0.5) 0.9	(<0.1) 0.2	(0.8) 1.4	(0.1) 0.3	(<0.1) No Data
Mokowe Primary School	(28.8) 35.2	(2.3) 8.7	(<0.1) 3.2	(38.4) No data	(0.8) No data	(<0.1) No data	(41.9) 41.9	(0.7) 0.7	(0.6) 0.6	(<0.1) <0.1	(0.1) 0.7	(<0.1) 0.3	(0.3) 0.9	(<0.1) 0.3	(<0.1) No Data
Jipe Village	(43.3) 53.7	(5.5) 15.9	(0.1) 5.3	(57.8) No data	(3.8) No data	(0.2) No data	(63.0) 63.0	(14.3) 14.3	(2.9) 2.9	(0.1) 0.1	(0.4) 0.8	(<0.1) 0.2	(0.7) 0.9	(<0.1) 0.1	(<0.1) No Data
Hindi Area	(35.7) 35.7 No data	(4.5) 4.5 No data	(<0.1) No data	(47.6) No data	(4.0) No data	(0.3) No data	(51.8) 51.8 No data	(17.6) 17.6 No data	(3.2) 3.2 No data	(0.2) 0.2 No data	(0.4) 1.8	(<0.1) 0.7	(0.6) 0.8	(<0.1) 0.1	(<0.1) No Data

Masjid Mosque Pate Village	(6.1) 59.3	(0.9) 54.1	(<0.1) 26.6	(8.1) No data	(<0.1) No data	(<0.1) No data	(8.9) 8.9	(<0.1) <0.1	(<0.1) <0.1	(<0.1) <0.1	(<0.1) 0.8	(<0.1) 0.4	(0.1) 0.7	(<0.1) 0.3	(<0.1) No Data
Mikanjuni Island Opposite Resort	(21.6) 26	(2.0) 6.4	(<0.1) 2.2	(28.9) No data	(<0.1) No data	(<0.1) No data	(31.5) 31.5	(<0.1) <0.1	(<0.1) <0.1	(<0.1) <0.1	(<0.1) 1.2	(<0.1) 0.6	(0.3) 1.3	(<0.1) 0.5	(<0.1) No Data
Mtandawanda -Pate Jetty	(8.8) 8.8 No data	(0.9) 0.9 No data	(<0.1) No data	(11.8) No data	(<0.1) No data	(<0.1) No data	(12.9) 12.9 No data	(<0.1) <0.1 No data	(<0.1) <0.1 No data	(<0.1) <0.1 No data	(<0.1) 0.6	(<0.1) 0.3	(0.1) 2.1	(<0.1) 1.0	(<0.1) No Data
Kwasasi (Project Site Area)	(186.6) 206.6	(15.8) 35.8	(0.4) 10.4	(248.9) No data	(10.1) No data	(0.6) No data	(271.3) 271.3	(33.9) 33.9	(7.7) 7.7	(0.4) 0.4	(0.9) 8.3	(0.1) 3.8	(2.0) 3.2	(<0.1) 0.6	(<0.1) No Data

Key: (green) Predicted Compliance

In all instances the maximum cumulative concentrations (model results added to background concentrations) at the identified sensitive receptors are below the relevant standards or guideline values.

5.7.2 Scenario 2: Fugitive Dust from Coal and Ash Handling

The results for Scenario 2, which related to fugitive dust from coal and ash handling and storage are presented in Table 5-12 below. Scenario 2 also includes particulate emissions from the 3 main boilers. Given the nature of fugitive dust, the maximums occur along the Project boundary. Given that the maximums occur along the project fence line, and in the absence of a PM_{10} and $PM_{2.5}$ Kenyan property boundary standard, the Kenyan industrial standards have been applied.

Table 5-12 – Scenario 2 Maximum Ground Level Concentrations (Project Standards)

Pollutant	Averaging Period	Project Ambient Air Quality Standards ($\mu g/m^3$) Industrial	Modelled Concentrations ($\mu g/m^3$)	Percentage of the Standard (%)
PM_{10}	24 Hours	150	167**	111
	Annual	50	9	18
$PM_{2.5}$*	24 Hours	75	97	129
	Annual	35	3	9
	Key:		Expected Compliance	

*$PM_{2.5}$ modelled concentration has been determined as approximately 29% of PM_{10} concentration.
**Allows for 3 exceedances

Based on the result presented above potential exceedances of the PM_{10} and $PM_{2.5}$ standard for the 24 hour averaging period are possible in close proximity to the eastern Project boundary, however it should be acknowledged that the maximum impacts are all expected within 20 m of the plant boundary. The limited spatial extent of the predicted noncompliance can be seen in the relevant isopleths (Appendix C). In order to provide a comparison of the results presented in Table 5-12 against other internationally recognised AAQS, the model results have been presented against the European Union AAQS [5] (Table 5-13).The model results for PM_{10} 24 hour averaging period are different in tables Table 5-12 and Table 5-13 as the EU and Kenyan standards are based on different percentiles (number of allowable exceedances).

Table 5-13 – Scenario 2 Maximum Ground Level Concentrations (European Union AAQS)

Pollutant	Averaging Period	European Union Ambient Air Quality Standards (µg/m^3)	Model Predicted Results (µg/m^3)	Predicted Compliance?
PM_{10}	24 Hours	50.0	32.7*	Yes
	Annual	40.0	9	Yes
$PM_{2.5}$	24 Hours	No Standard	N/A	N/A
	Annual	25.0	3	Yes

*Allows for 35 exceedances

When the model predicted results are compared against the EU AAQS, compliance is expected for both PM_{10} and $PM_{2.5}$ (24 hour and annual averaging periods). The key difference between the EU AAQS and the Kenyan AAQS (in terms of PM_{10} 24 hour standard), is that although the EU AAQS are lower (50 µg/m^3 as opposed to 150 µg/m^3), the EU allows for 35 exceedances whereas the Kenyan allows for 3 exceedances.

In terms of impacts at sensitive receptors, the model predicted values is provided in Table 5-14, these values include the measured background values and have been compared against the Kenyan residential standards. Values in brackets are predicted model results, whilst the second value is the cumulative value (baseline measurements + model results).

Table 5-14 – Scenario 2 Cumulative Concentrations at Sensitive Receptors

	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	24 hour	1 year	24 hour	1 year
Project Ambient Air Quality Standard (µg/m^3)	**100 (Kenyan Residential Standard)**	**50 (Kenyan Residential Standard)**	**75**	**35**
Bargoni Village	(0.6) 33.6	(<0.1) 16.6	(0.1) 36.1	(<0.1) 18.0
Ingin Village	(4.8) 5.4	(1.0) 1.3	(2.0) 2.2	(0.3) 0.4
Bobo Village	(0.6) 1.0	(<0.1) 0.2	(0.2) 0.8	(<0.1) 0.3
Mokowe Primary School	(<0.1) 0.6	(<0.1) 0.3	(<0.1) 0.6	(<0.1) 0.3
Jipe Village	(0.3) 0.7	(<0.1) 0.2	(0.1) 0.3	(<0.1) 0.1
Hindi Area	(0.6) 2.0	(<0.1) 0.7	(0.1) 0.3	(<0.1) 0.1
Masjid Mosque Pate Village	(<0.1) 0.8	(<0.1) 0.4	(0.1) 0.7	(<0.1) 0.3
Mikanjuni Island Opposite Resort	(1.3) 2.5	(<0.1) 0.7	(1.2) 2.2	(<0.1) 0.5
Mtandawanda-Pate Jetty	(1.0) 1.6	(<0.1) 0.4	(0.7) 2.7	(<0.1) 1.0
Kwasasi (Project Site Area)	(11) 18.4	(1.2) 4.9	(3.9) 5.1	(0.4) 1.0
*Values in brackets are predicted model results, whilst the second value is the cumulative value (baseline measurements + model results)				
Key:			Predicted Compliance	

The cumulative results are below the relevant standards at each of the identified receptors. Refer Appendix C for isopleths.

5.7.3 Scenario 3: Trace Metal Deposition from Ash Stockpiles

The results for trace metal deposition resulting from ash stockpiles is presented below (Table 5-15). This indicates the maximum predicted deposition rate occurring beyond the fence line. The results indicate that the maximum trace metal deposition rates associated with ash storage are expected to be below the daily deposition limits.

Table 5-15 – Trace Metals Deposition from Ash Stockpiles

Metal	Symbol	Modelled Result (Trace Metal Deposition Rate mg/m²/day) [1]	Daily Deposition Limits mg/m²/day	Percentage of the Standard (%)
Arsenic	(As)	0.00129	0.020	6
Nickel	(Ni)	0.00116	0.110	1
Mercury	(Hg)	0.00076	0.004	19
Lead	(Pb)	0.00075	1.100	<0.1
Cadmium	(Cd)	0.00002	0.009	0.2

[1]Trace metal deposition calculated by multiplying the composition of trace metals in ash by the total TSP deposition rate.

Given the distance between the ash dumps and the nearest receptors, the deposition rates for all pollutants at the identified receptor locations are considered negligible.

Note that as the results presented in the table above have been calculated as a percentage of TSP deposition rate, isopleths are not presented for this scenario.

5.7.4 Scenario 4: Emergency Black Start-Up

The results for the emergency black start-up are presented below (Table 5-16). This scenario includes the simultaneous operation of 10 diesel start-up engines for a period of 1 hour. As the black start scenario is expected to occur infrequently (less than 2% of the year), and is considered an emergency occurrence, the results have been compared against the ERPG guideline values as presented in the preceding section.

Table 5-16 – Scenario 4 Results

Species	1 Hour Modelled Maximum Ground Level Concentration	ERPG-1 (1 Hour) Value (µg/m³)	ERPG-2 (1 Hour) Value (µg/m³)	ERPG-3 (1 Hour) Value (µg/m³)
SO_2	96	857	8,566	42,830
NO_2	1,751	2,052	30,784	61,569
		Key:		Predicted Compliance

The maximum ground level concentrations predicted for Scenario 4 are therefore expected to be below the ERPG 1, 2 and 3 values. The values presented in the table above are considered extremely conservative as it assumes that the black start of the power station will occur at the same time as the worst hour meteorological conditions for a given year. The probability of this occurrence is extremely low.

6 Conclusion

6.1 Construction Phase

During the construction phase dust emissions will result from earth moving activities and vehicle movements over unpaved surfaces, and gaseous emissions will result from combustion equipment and vehicle operations.

Gaseous emissions generated by construction vehicles and equipment are expected to have negligible impact as the construction site is large and work activities will be transient in nature due to the phased construction approach.

A risk assessment, based on guidelines given by the UK IAQM, has been applied to assess potential impacts from construction-related dust emissions. The assessment has shown a 'low' risk in terms of impacting both human health and causing nuisance to nearby communities.

In summary, significant impacts to air quality at sensitive receptor locations are therefore not considered likely during the construction phase due to the following factors:

- The distance between the construction site and nearby receptors will allow adequate dispersion of pollutants;
- the overall sensitivity of the surrounding area in terms of human receptors is low;
- The relatively low emission rates of mobile vehicle emissions and equipment; and,
- The short duration/ transient nature of the emissions during project construction.

6.1.1 Monitoring and Management

The findings do not remove the need for active management of the construction site in terms of emissions to atmosphere, especially given that assessments of construction activities necessarily rely on large assumptions regarding localised conditions and practices. In addition, while the assessment has focussed on impacts to environmental receptors, management of dust emissions will also protect the exposure of those working on and around the Project site. It is recommended that the following management practices are considered by the project to ensure adequate management of dust and gaseous emissions:

- Development of a Construction Management Plan (with specific reference to the management of air quality during the construction phase) once detailed information relating to the construction methodology and schedule is available (prior to commencement);
- Diesel-powered equipment to be regularly serviced and diesel fuel quality standards for the sulphur levels will comply with local regulations for on-road vehicles;
- A dust management and monitoring plan will be developed in accordance with the Construction Management Plan to control and manage dust emissions from construction work, measures will include:

- Imposing speed limits on-site to be controlled via posted speed limit signs;
- Vehicles will be kept to marked trafficable areas which would be maintained in a damp and compacted condition to enhance safety and minimise dust emissions;
- Water carts to be used to keep trafficked surfaces damp when conditions are dry when working in close proximity to receptors and/ or when significant plumes of dust are witnessed; and,
- Ensure that vegetation/ground cover is reinstated at non hard covered areas as soon as possible.

6.2 Operations Phase

The assessment has considered potential impacts to ambient air quality from the operation of boilers, auxiliary boilers, generators, and fugitive dust emitting sources using the internationally recognised AERMOD and CALPUFF dispersion modelling systems. Modelled data combined with baseline data (where available) has been compared against the Kenyan air quality standards and other internationally recognised guidelines in order to determine whether the operation of the facility is likely to cause breaches in ambient air quality standards.

Four scenarios were modelled for air dispersion and the results are summarised below.

6.2.1 Scenario 1 (Normal Operations)

Scenario 1 modelled results indicate that there is likely to be compliance with the project ambient air quality standards for all pollutants considered during normal operations. The modelled results have been considered in a cumulative context with previously measured background concentrations in the Project area at specific receptor locations.

6.2.2 Scenario 2 (Fugitive Dust)

The model results indicate that for coal and ash handling and storage activities there is likely to be compliance for both PM_{10} and $PM_{2.5}$ when compared to the annual standards, however when considering the short term standards (24 hour), there is the potential for exceedances of the standards for these pollutants within close proximity to the coal handling areas.

In order to provide a comparison against other internationally recognised AAQS, the results for Scenario 2 were also compared against the EU Directive AAQS. When compared against these standards compliance is expected for PM_{10} and $PM_{2.5}$.

In terms of impacts to nearby receptors, as the maximums related to coal and ash handling are expected within 20 metres of the Project boundary, modelling indicates that the potential impacts at the nearest identified receptors are expected to be well below the relevant standards.

As there are a number of uncertainties and assumptions associated with the modelling of fugitive dust, the modelling study should be updated once more when detailed design data is available. In addition once operational, compliance will need to be demonstrated through monitoring as detailed in Section 6.2.5 below and in terms of the Kenyan Legislation [2].

6.2.3 Scenario 3 (Trace Metals Deposition from Ash Stockpiles)

The model results indicate that the maximum metal deposition rates (resulting from metal contained in the ash) are likely to be well below the guideline values. In addition, given the distance between the ash dumps and the nearest receptors, the deposition rates at the identified receptor locations are considered negligible.

6.2.4 Scenario 4 (Emergency Black Start-Up)

The maximum modelled ground level concentrations predicted from black start-up were below the ERPG 1, 2 and 3 values. The predicted results for this scenario are considered extremely conservative as it assumes that the black start of the power station will occur at the same time as the worst hour meteorological conditions for a given year.

6.2.5 Monitoring and Management

Significant impacts determined by compliance with ambient air quality standards are not expected from operation of the Lamu Power Station. This however does not remove the need for proactive site management. In terms of monitoring and management it is recommended that the following documents should be developed prior to Project implementation:

- Air Quality Monitoring and Management Plan for the operations phase detailing the following (in accordance with the IFC EHS Guidelines for Thermal Plants [3]):
    - Development of and Air Quality Monitoring Plan for pollutants of concern (e.g., PM_{10}/$PM_{2.5}$/SO_2/NO_2) including the details of a continuous ambient air quality monitoring system (typically a minimum of 2 systems to cover predicted maximum ground level concentration point / sensitive receptor / background points);
    - Supplement continuous monitoring with passive samplers (monthly average) or by seasonal manual sampling for parameters consistent with the relevant air quality standards; and,
    - In addition to the requirements of the national regulator, continuous emissions monitoring of NO_2 and SO_2, with annual stack testing for metals, PM_{10} and $PM_{2.5}$.
- Development of an operations phase dust management and monitoring plan to control and manage dust emissions from coal and ash handling:
    - Dust fallout monitoring program (through the use of fallout gauges) including metals analysis of samples; and,
    - The effectiveness of the ambient air quality monitoring program should be reviewed on a quarterly basis.

7 References

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[4] International Finance Corporation, “General EHS Guidelines,” Word Bank Group, Washington, DC, 2007.

[5] European Union, “Directive 2008/50/EC of the Europena Parliament of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe,” European Union, Brussels, 2008.

[6] World Health Organisation, “Air Quality Guidelines for Europe Second Edition,” 2000.

[7] Environment Agency, “H1 Annex F- Air Emissions,” Environment Agency, London, 2011.

[8] SGS, “Baseline Air Quality Assessment Report for the Proposed Lamu Coal Power Plant Project,” 2015.

[9] United Stated Environmental Protection Agency, “Exhaust Emission Factors for Nonroad Engine Modeling-Compression-Ignition Report No. NR-009A,” USEPA, 1998.

[10] United Stated Environmental Protection Agency, “Emission Factor Documentation for AP-42. Section 13.2.2- Unpaved Roads,” US EPA, Washinton, D.C., 1998.

[11] United Kingdom Institute of Air Quality Management, “Guidance on the Assessment of Dust from Demolition and Construction,” IAQM, London, 2014.

[12] USEPA AP42, “Bituminous and Subbituminous Coal Combustion Volume 1 CH1.1,” USEPA, 1998.

[13] Australian Government, “National Pollution Inventory-Emission Estimation Technique Manual for Mining, Version 3.1,” 2012.

[14] United Stated Environmental Protection Agency, Emission Factor Documentation for AP-42 Section 13.2.2-Unpaved Roads, Washington D.C, 1998.

[15] Petzer, “Air Quality Impact Assessment for the Proposed Extension of Three Grindrod Terminals Bulk Materials Facilities,” Online, 2009.

[16] United States Environmental Protection Agency , “AP42, Emission Factors, Table B2.2”.

[17] Airshed Planning Professionals , “Environmental Impact Report,” Bohlweki Environmental , Limpopo , 2006.

Appendix A- SCREEN 3 Results (CO)

```
08/20/15

14:34:59
  ***  SCREEN3 MODEL RUN  ***
  *** VERSION DATED 96043 ***

 C:\Users\Grant\Desktop\Working\J3092 Lamu\COScreening.scr

 SIMPLE TERRAIN INPUTS:
    SOURCE TYPE            =        POINT
    EMISSION RATE (G/S)    =      13.5000
    STACK HEIGHT (M)       =     210.0000
    STK INSIDE DIAM (M)    =       5.3000
    STK EXIT VELOCITY (M/S)=      18.6000
    STK GAS EXIT TEMP (K)  =     413.0000
    AMBIENT AIR TEMP (K)   =     293.0000
    RECEPTOR HEIGHT (M)    =       0.0000
    URBAN/RURAL OPTION     =        RURAL
    BUILDING HEIGHT (M)    =       0.0000
    MIN HORIZ BLDG DIM (M) =       0.0000
    MAX HORIZ BLDG DIM (M) =       0.0000

 THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
 THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.


 BUOY. FLUX =  372.164 M**4/S**3;  MOM. FLUX = 1723.595 M**4/S**2.

 *** FULL METEOROLOGY ***

 **********************************
 *** SCREEN AUTOMATED DISTANCES ***
 **********************************

 *** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING
DISTANCES ***

   DIST     CONC              U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
    (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   Y (M)   Z (M)
DWASH
 -------  ----------  ----  -----  -----  ------  ------  ------  ------
-----
    100.   0.000        1     1.0    1.2  1301.7 1300.71   63.23   58.92
NO
    200.   0.000        1     1.0    1.2  1301.7 1300.71  103.70   95.48
NO
    300.  0.1374E-11    5     1.0    2.9 10000.0  359.88   46.03   43.70
NO
    400.  0.2666E-07    1     3.0    3.7   960.0  573.57  104.44   85.89
NO
```

```
    500.  0.6454E-03    1      3.0     3.7    960.0  573.57  126.06  118.60
NO
    600.  0.1239        1      3.0     3.7    960.0  573.57  147.06  166.33
NO
    700.   1.176        1      3.0     3.7    960.0  573.57  167.55  224.46
NO
    800.   3.103        1      3.0     3.7    960.0  573.57  187.62  293.12
NO
    900.   5.713        1      2.0     2.5    756.4  755.35  226.95  383.67
NO
   1000.   8.260        1      2.0     2.5    756.4  755.35  247.40  472.90
NO
   1100.   9.489        1      2.0     2.5    756.4  755.35  267.52  573.06
NO
   1200.   9.660        1      2.0     2.5    756.4  755.35  287.34  684.24
NO
   1300.   9.344        1      2.0     2.5    756.4  755.35  305.64  806.04
NO
   1400.   8.954        1      2.0     2.5    756.4  755.35  320.98  938.17
NO
   1500.   8.551        1      2.0     2.5    756.4  755.35  336.41 1081.88
NO
   1600.   8.184        1      1.5     1.9    938.1  937.14  377.78 1244.77
NO
   1700.   7.884        1      1.5     1.9    938.1  937.14  392.27 1410.72
NO
   1800.   7.601        1      1.5     1.9    938.1  937.14  406.87 1588.43
NO
   1900.   7.337        1      1.5     1.9    938.1  937.14  421.54 1777.90
NO
   2000.   7.089        1      1.5     1.9    938.1  937.14  436.26 1979.15
NO
   2100.   6.857        1      1.5     1.9    938.1  937.14  451.03 2192.20
NO
   2200.   6.639        1      1.5     1.9    938.1  937.14  465.84 2417.10
NO
   2300.   6.434        1      1.5     1.9    938.1  937.14  480.66 2653.87
NO
   2400.   6.241        1      1.5     1.9    938.1  937.14  495.50 2902.57
NO
   2500.   6.060        1      1.5     1.9    938.1  937.14  510.35 3163.23
NO
   2600.   5.888        1      1.5     1.9    938.1  937.14  525.20 3435.90
NO
   2700.   5.727        1      1.5     1.9    938.1  937.14  540.05 3720.62
NO
   2800.   5.573        1      1.5     1.9    938.1  937.14  554.89 4017.43
NO
   2900.   5.434        1      1.0     1.2   1301.7 1300.71  615.25 4332.62
NO
```

```
   3000.   5.315        1     1.0    1.2  1301.7 1300.71  628.99 4653.32
NO
   3500.   4.789        1     1.0    1.2  1301.7 1300.71  698.08 5000.00
NO
   4000.   4.356        1     1.0    1.2  1301.7 1300.71  767.45 5000.00
NO
   4500.   4.282        2     2.0    2.5   756.4  755.35  605.23  590.13
NO
   5000.   4.149        2     2.0    2.5   756.4  755.35  660.12  657.66
NO
   5500.   3.941        2     2.0    2.5   756.4  755.35  714.53  726.28
NO
   6000.   3.757        2     1.5    1.9   938.1  937.14  780.65  807.60
NO
   6500.   3.612        2     1.5    1.9   938.1  937.14  833.33  877.02
NO
   7000.   3.446        2     1.5    1.9   938.1  937.14  885.65  947.29
NO
   7500.   3.279        2     1.5    1.9   938.1  937.14  937.61 1018.31
NO
   8000.   3.118        2     1.5    1.9   938.1  937.14  989.21 1090.02
NO
   8500.   3.031        2     1.0    1.2  1301.7 1300.71 1066.09 1185.33
NO
   9000.   2.936        2     1.0    1.2  1301.7 1300.71 1115.84 1256.89
NO
   9500.   2.915        3     2.0    2.7   708.8  707.75  796.36  499.95
NO
  10000.   2.904        3     2.0    2.7   708.8  707.75  832.37  522.07
NO

 MAXIMUM 1-HR CONCENTRATION AT OR BEYOND   100. M:
   1170.   9.687        1     2.0    2.5   756.4  755.35  281.22  648.59
NO

  DWASH=   MEANS NO CALC MADE (CONC = 0.0)
  DWASH=NO MEANS NO BUILDING DOWNWASH USED
  DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
  DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
  DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

  *** INVERSION BREAK-UP FUMIGATION CALC. ***
   CONC (UG/M**3)    =    4.372
   DIST TO MAX (M)  = 40353.89

  *** SHORELINE FUMIGATION CALC. ***
   CONC (UG/M**3)    =    24.02
   DIST TO MAX (M)  =  5364.97
   DIST TO SHORE (M)=   100.00

      ***************************************
```

```
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION         MAX CONC    DIST TO   TERRAIN
  PROCEDURE         (UG/M**3)    MAX (M)    HT (M)
--------------    -----------   -------   -------
SIMPLE TERRAIN      9.687         1170.        0.

INV BREAKUP FUMI    4.372        40354.       --

SHORELINE FUMI      24.02         5365.       --

***************************************************
** **
***************************************************
```

Appendix B – Fugitive Dust Emission Inventory

Table 7-1 – Relevant Emission Parameters related to Coal and Ash Handling

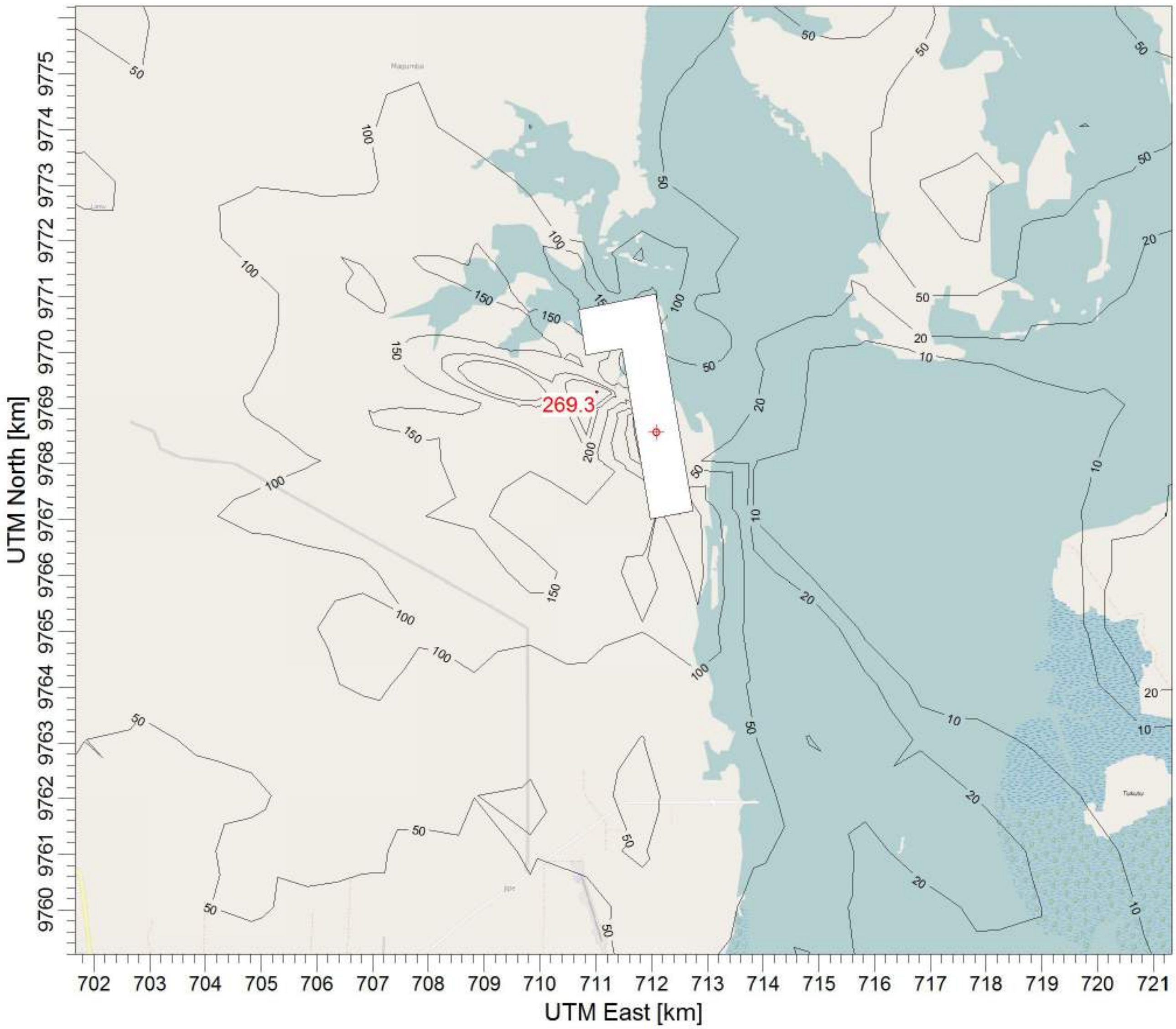
Handling Point	Handling Method	Hourly forecast Volumes (tonnes/ hour)	Dust Control Efficiency	Mitigated Emission Factor PM_{10}	PM_{10} Emission Rate g/s
Offloading onto barge from ship	Bucket Unloaders	1,500	90% (chemical suppressant)	0.00002 kg/tonne	0.001
Offloading at conveyor from barge	Bridge Type Grab Unloader	1,500	90% (chemical suppressant)	0.00002 kg/tonne	0.001
Transfer of coal to stockpile	Conveyor	1,500	99% (enclosure and use of fabric filters at transfer points)	0.00002 kg/tonne	0.001
Transfer point from Conveyor 1-2	Gravity	1,500	99% (enclosure and use of fabric filters at transfer points)	0.00002 kg/tonne	0.001
Transfer point from Conveyor 2-3	Gravity	1,500	99% (enclosure and use of fabric filters at transfer points)	0.00002 kg/tonne	0.001
Stockpile loading from Conveyor	Bucket Wheel Stacker	1,500	50% (watering)	0.0009 kg/tonne	0.35
Coal Stockpile erosion	Exposed Stockpile	-	50% (watering)	0.1 kg/ha/hour	2.8x10-6 $g/m^2/s$
Stockpile unloading to hopper	Reclaimer	600	50% (watering)	0.007 kg/tonne	1.08
Stockpile unloading to hopper	Bulldozers/Excavators	500 per dozer (3 dozers)	Uncontrolled	0.01 kg/tonne	0.65 (per dozer)
Transfer point from Conveyor 3-4	Gravity	1,000	99% (enclosure and use of fabric filters at transfer points)	0.00015 kg/tonne	0.0004
Transfer point from Conveyor 4-5	Gravity	1,000	99% (enclosure and use of fabric filters at transfer points)	0.00015 kg/tonne	0.0004

Handling Point	Handling Method	Hourly forecast Volumes (tonnes/ hour)	Dust Control Efficiency	Mitigated Emission Factor PM_{10}	PM_{10} Emission Rate g/s
Transfer of Coal from conveyor to coal bunkers	Gravity	1,000	99% (enclosure and use of fabric filters at transfer points)	0.00015 kg/tonne	0.0004
Bottom Ash Disposal from boiler	Truck	8	Ash covered on truck	0.0002 kg/tonne	0.0003
Fly Ash Disposal from boiler	Tank Car	72	Enclosed	0.0002 kg/tonne	0.003
Ash stockpile erosion	-	-	50% (watering)	0.06 kg/ha/hour	0.00191 $g/m^2/s$

Appendix C- Isopleths

PROJECT TITLE:

Scenario 1
NO2 1 Hour



1 RANK 1 HOUR AVERAGE CONCENTRATION (NO2)

ug/m**3

Max = 269 [ug/m**3] at (X = 711007.00, Y = 9769288.00)

10 20 50 100 150 200 220 269

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:123,677

0 4 km

DATE:

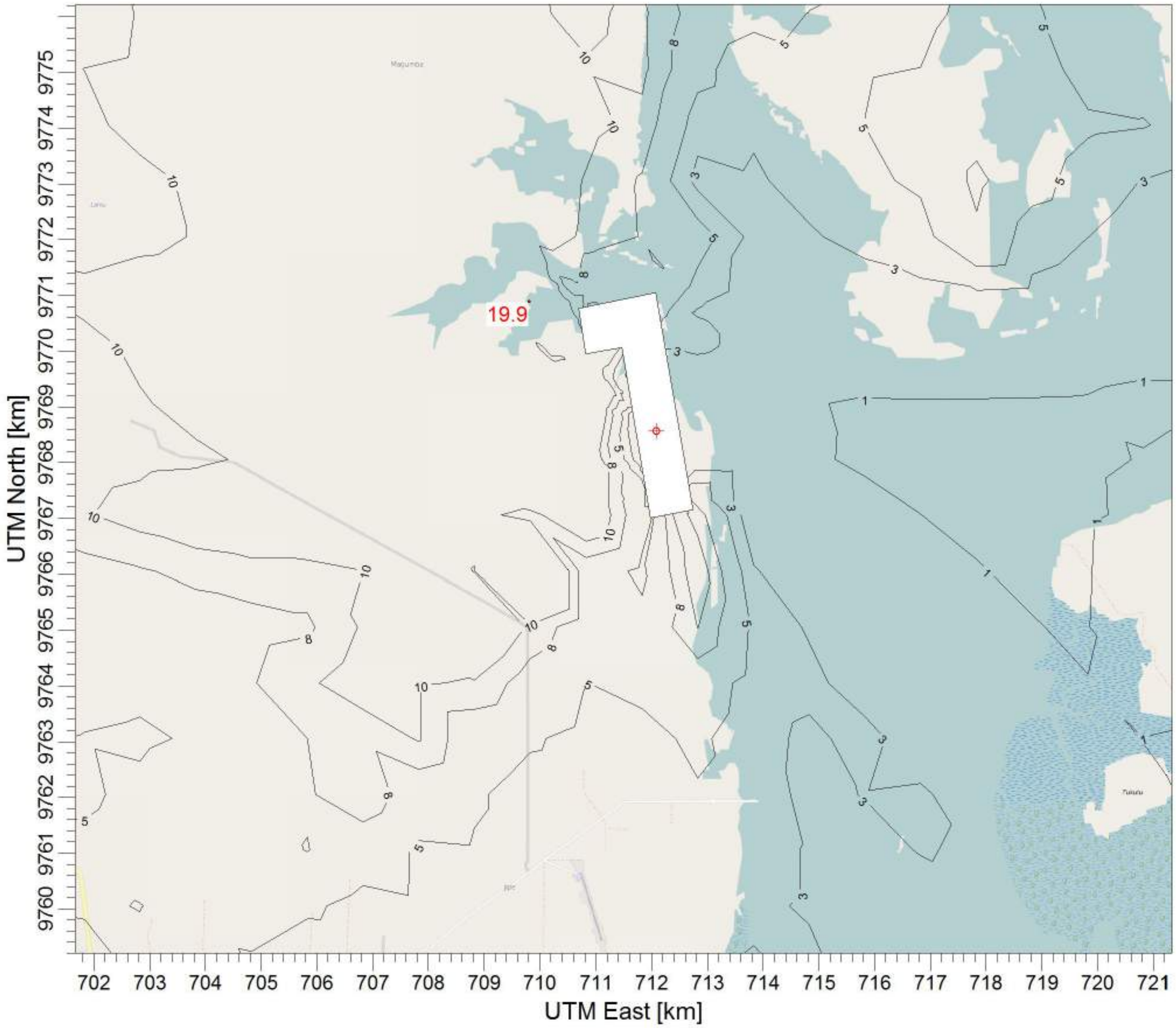
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
NO2 24 Hour



1 RANK 24 HOUR AVERAGE CONCENTRATION (NO2) ug/m**3

Max = 19.9 [ug/m**3] at (X = 709807.00, Y = 9770888.00)

0.2 0.3 0.5 0.8 1.0 3.0 5.0 8.0 10.0 19.9

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:123,670

0 4 km

WARDKARLSON CONSULTING GROUP

DATE:

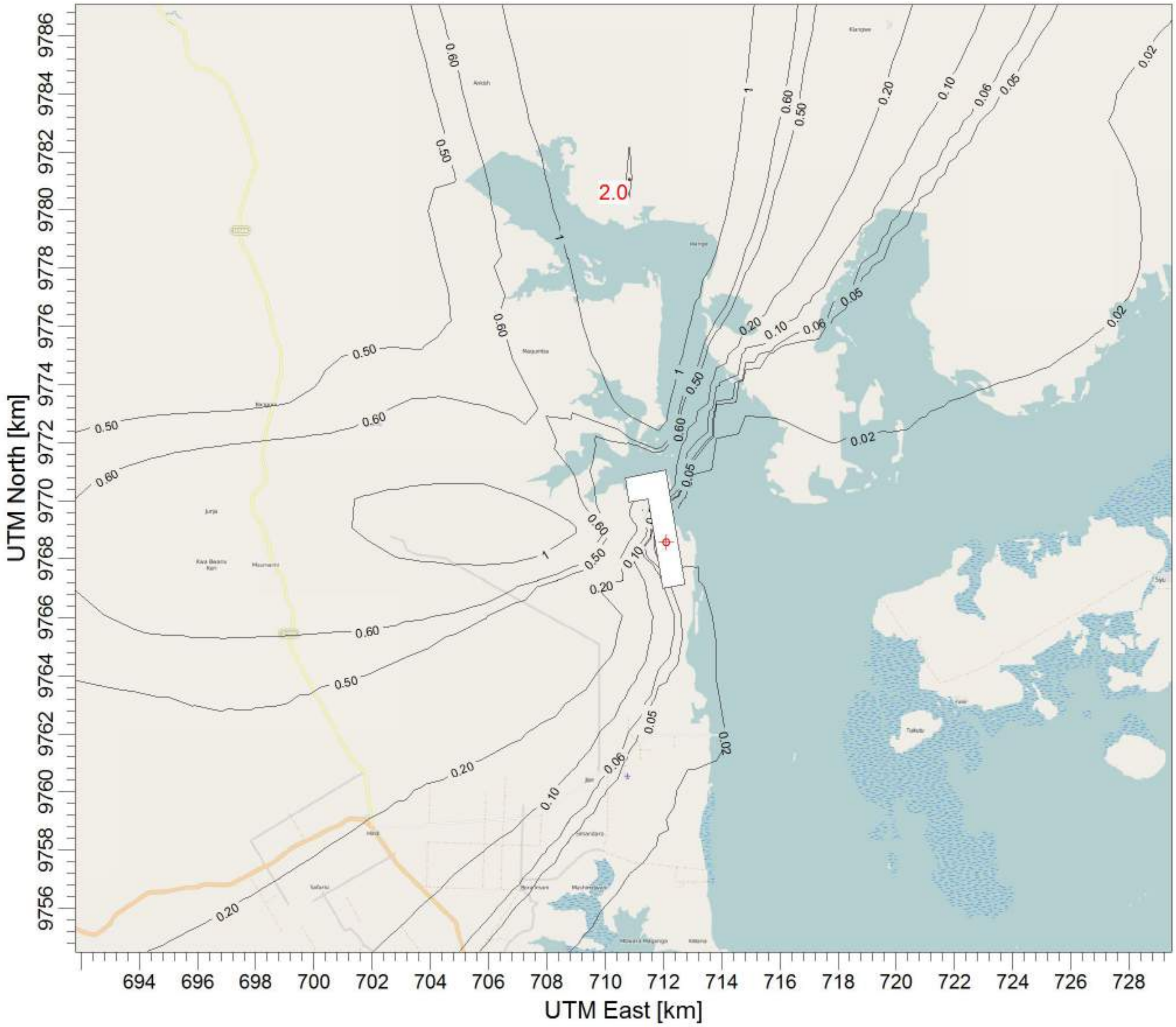
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
NO2 Annual



1 RANK 8760 HOUR AVERAGE CONCENTRATION (NO2) ug/m**3

Max = 2.02 [ug/m**3] at (X = 710826.00, Y = 9781057.00)

0.02	0.05	0.06	0.10	0.20	0.50	0.60	1.00	2.00	2.02

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:236,919

0 5 km

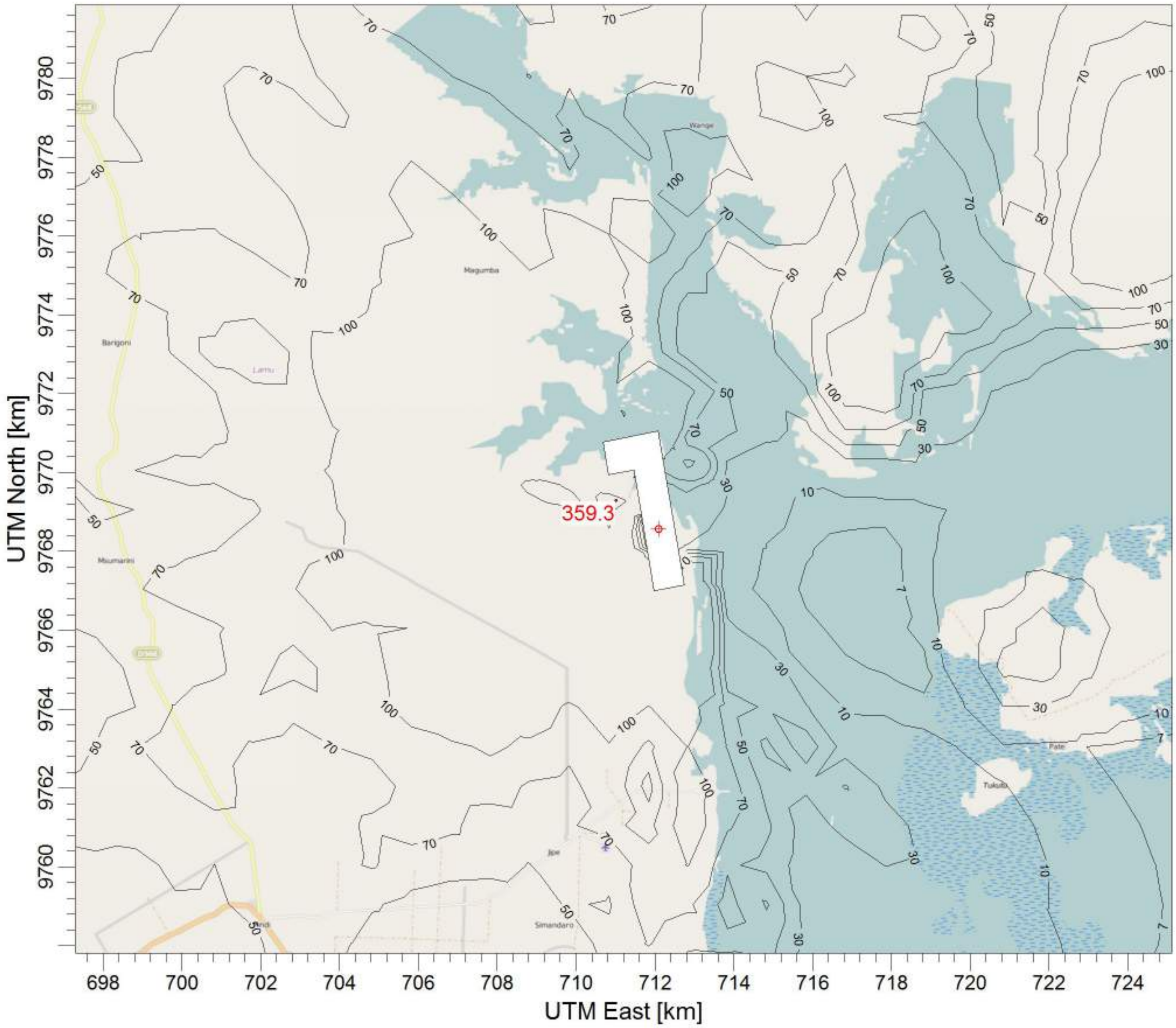
WARDKARLSON CONSULTING GROUP

DATE: **2015-08-28**

PROJECT NO.: **J3092**

PROJECT TITLE:

Scenario 1
NOx 1 Hour



1 RANK 1 HOUR AVERAGE CONCENTRATION (NOX)

ug/m**3

Max = 359 [ug/m**3] at (X = 711007.00, Y = 9769288.00)

4 | 5 | 7 | 10 | 30 | 50 | 70 | 100 | 300 | 359

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:174,935

0 — 5 km

DATE:

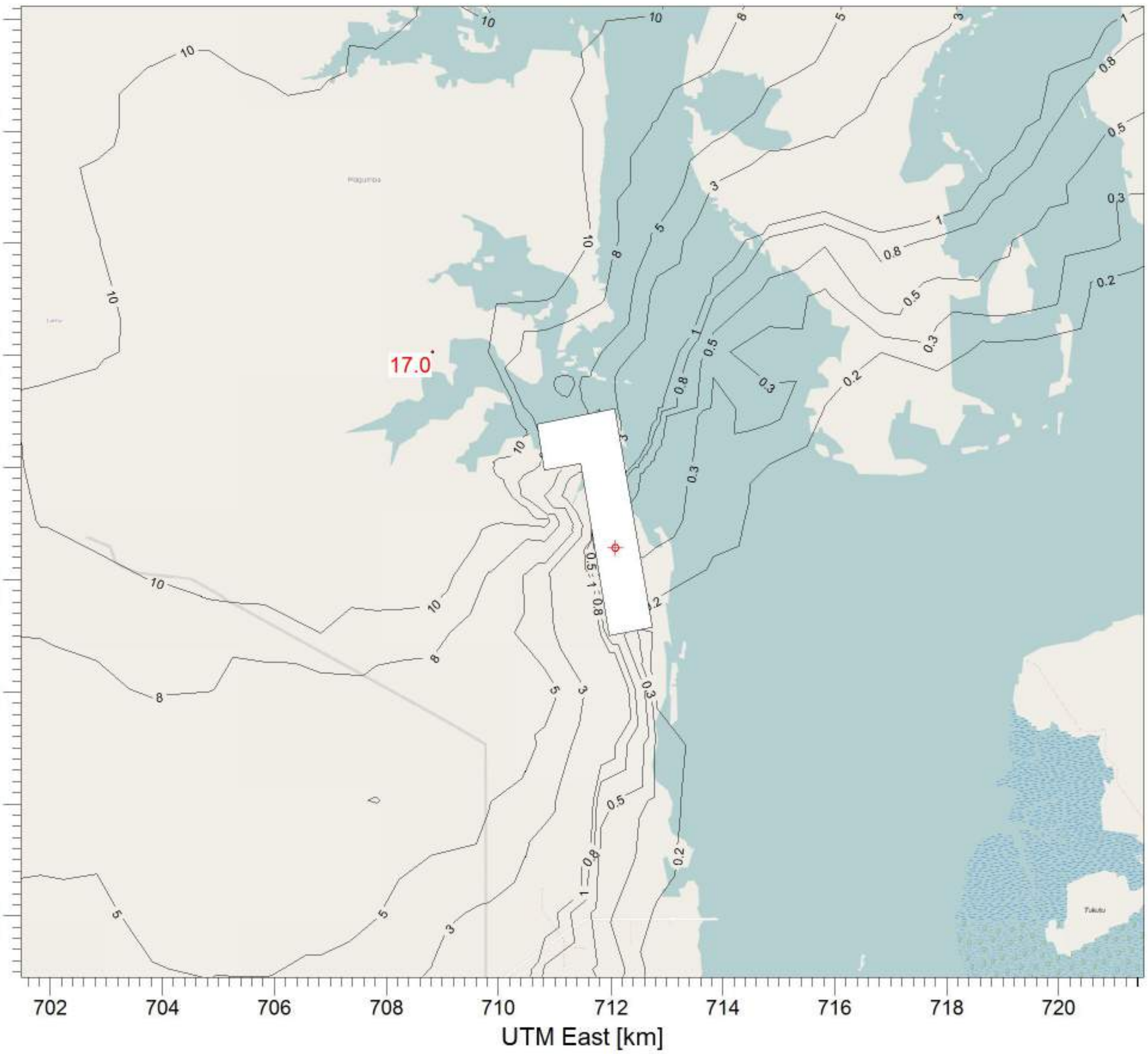
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
NOx 24 Hour



VALUE 99.18TH PERCENTILE 24 HOUR AVERAGE CONCENTRATION (NOX) ug/m**3

Max = 17.0 [ug/m**3] at (X = 708826.00, Y = 9772057.00)

0.2	0.3	0.5	0.8	1.0	3.0	5.0	8.0	10.0	17.0

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:125,994

0 — 4 km

WARDKARLSON CONSULTING GROUP

DATE:

2015-08-28

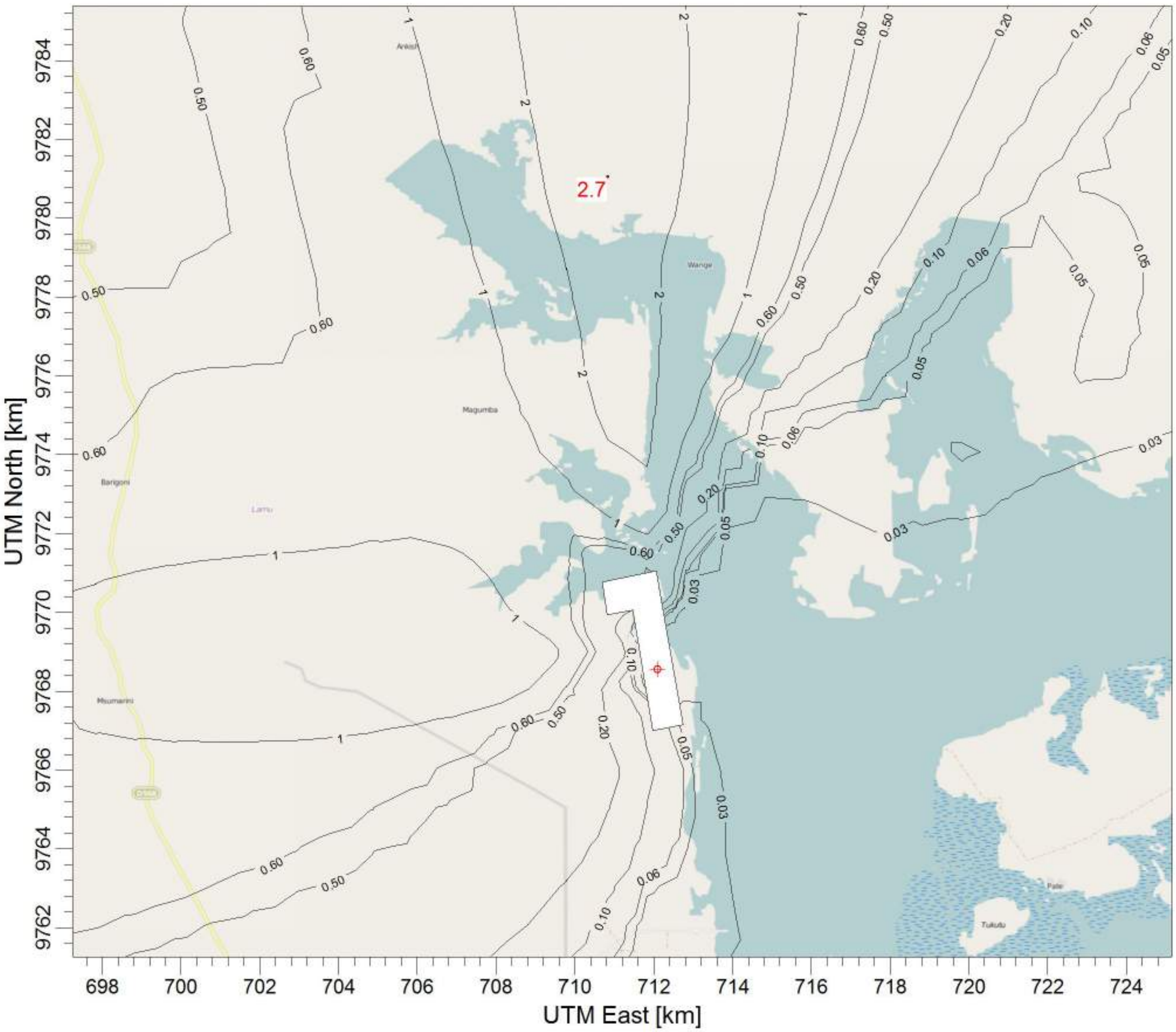
PROJECT NO.:

J3092

CALPUFF View - Lakes Environmental Software

PROJECT TITLE:

Scenario 1
NOx Annual



1 RANK 8760 HOUR AVERAGE CONCENTRATION (NOX) ug/m**3

Max = 2.7 [ug/m**3] at (X = 710826.00, Y = 9781057.00)

0.0	0.1	0.1	0.1	0.2	0.5	0.6	1.0	2.0	2.7

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:175,480

0 5 km

DATE:

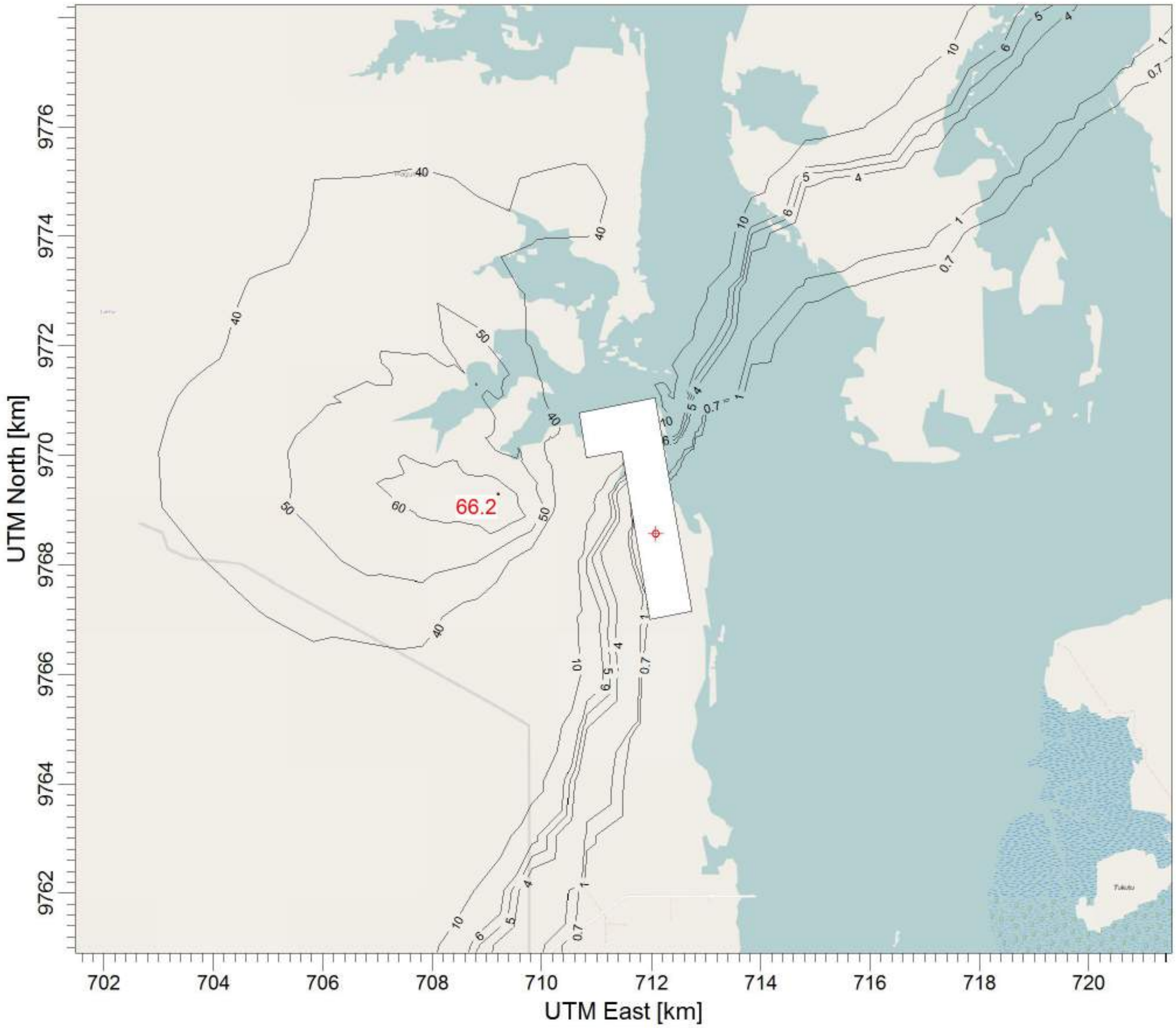
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
SO2 1 Hour



VALUE 99.73TH PERCENTILE 1 HOUR AVERAGE CONCENTRATION (SO2) ug/m**3

Max = 66.2 [ug/m**3] at (X = 709207.00, Y = 9769288.00)

0.7	1.0	4.0	5.0	6.0	10.0	40.0	50.0	60.0	66.2

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:125,994

0 4 km

WARDKARLSON CONSULTING GROUP

DATE:

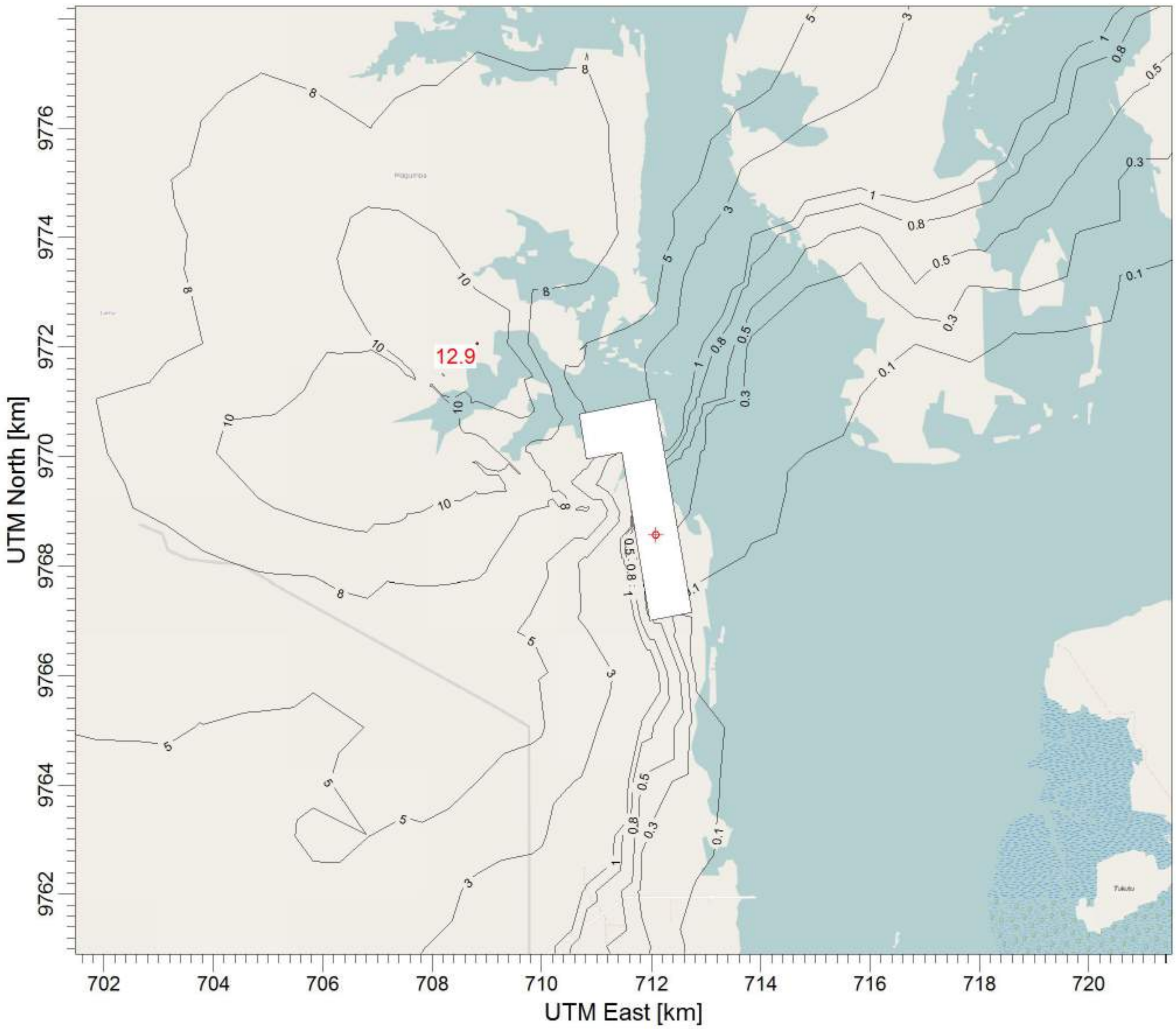
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
SO2 24 Hour



VALUE 99.18TH PERCENTILE 24 HOUR AVERAGE CONCENTRATION (SO2) ug/m**3

Max = 12.9 [ug/m**3] at (X = 708826.00, Y = 9772057.00)

0.1	0.3	0.5	0.8	1.0	3.0	5.0	8.0	10.0	12.9

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:125,994

0 4 km

DATE:

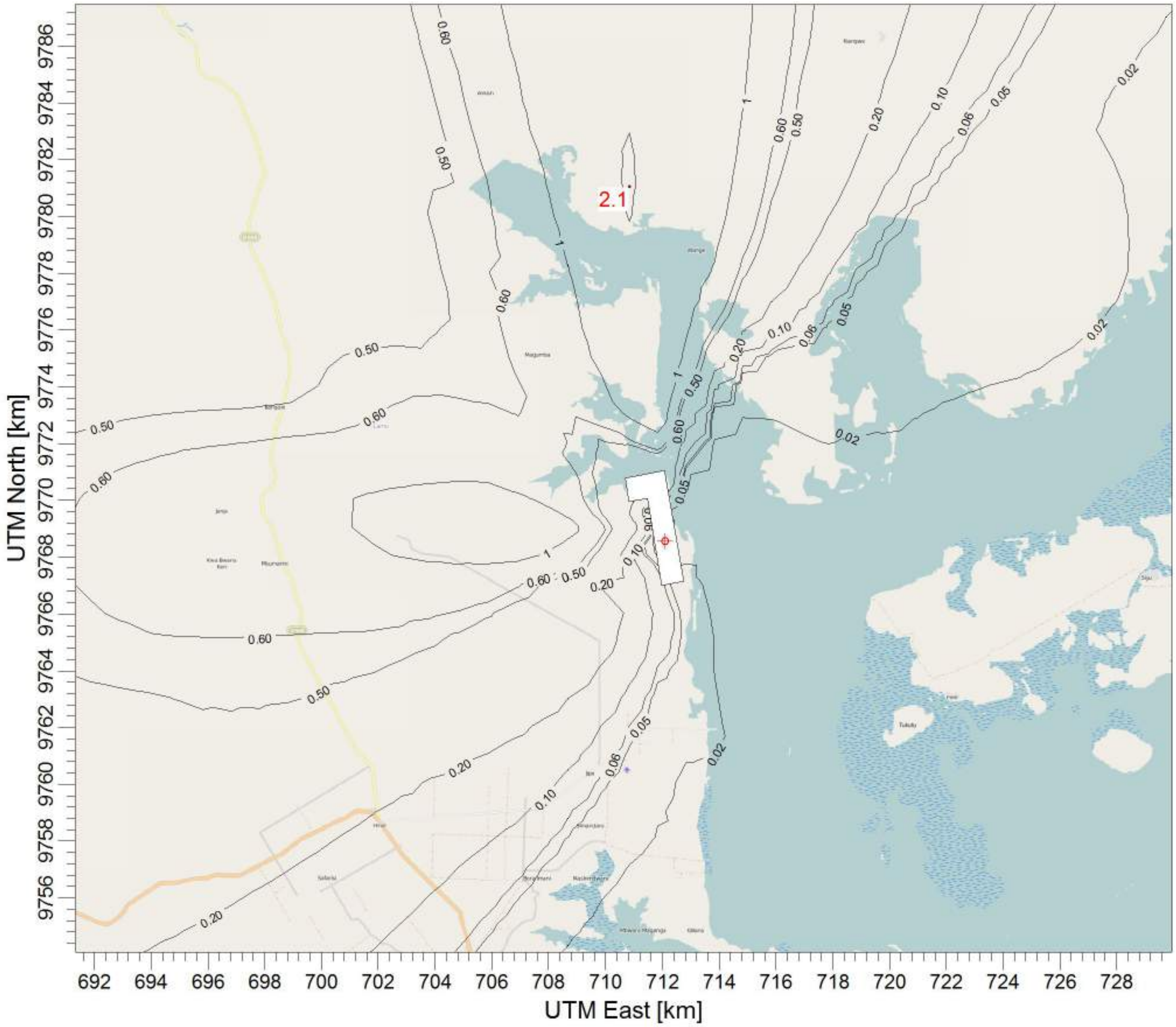
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
SO2 Annual



1 RANK 8760 HOUR AVERAGE CONCENTRATION (SO2) ug/m**3

Max = 2.1 [ug/m**3] at (X = 710826.00, Y = 9781057.00)

0.0	0.1	0.1	0.1	0.2	0.5	0.6	1.0	2.0	2.1

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:242,868

0 5 km

DATE:

2015-08-28

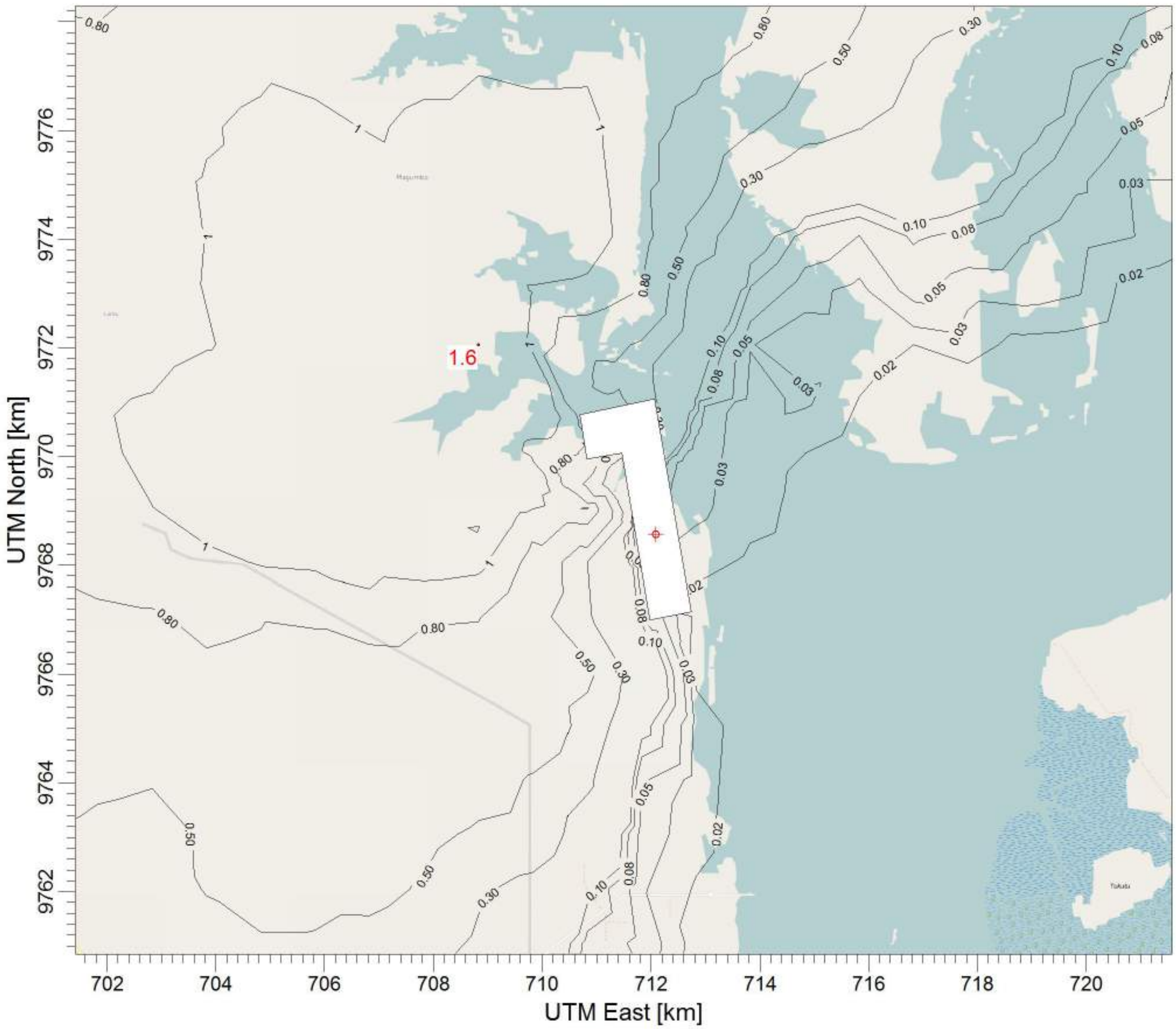
PROJECT NO.:

J3092

CALPUFF View - Lakes Environmental Software

PROJECT TITLE:

Scenario 1
PM10 24 Hour



VALUE 99.18TH PERCENTILE 24 HOUR AVERAGE CONCENTRATION (PM10) ug/m**3

Max = 1.6 [ug/m**3] at (X = 708826.00, Y = 9772057.00)

0.0 0.0 0.1 0.1 0.1 0.3 0.5 0.8 1.0 1.6

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:126,781

0 4 km

WARDKARLSON CONSULTING GROUP

DATE:

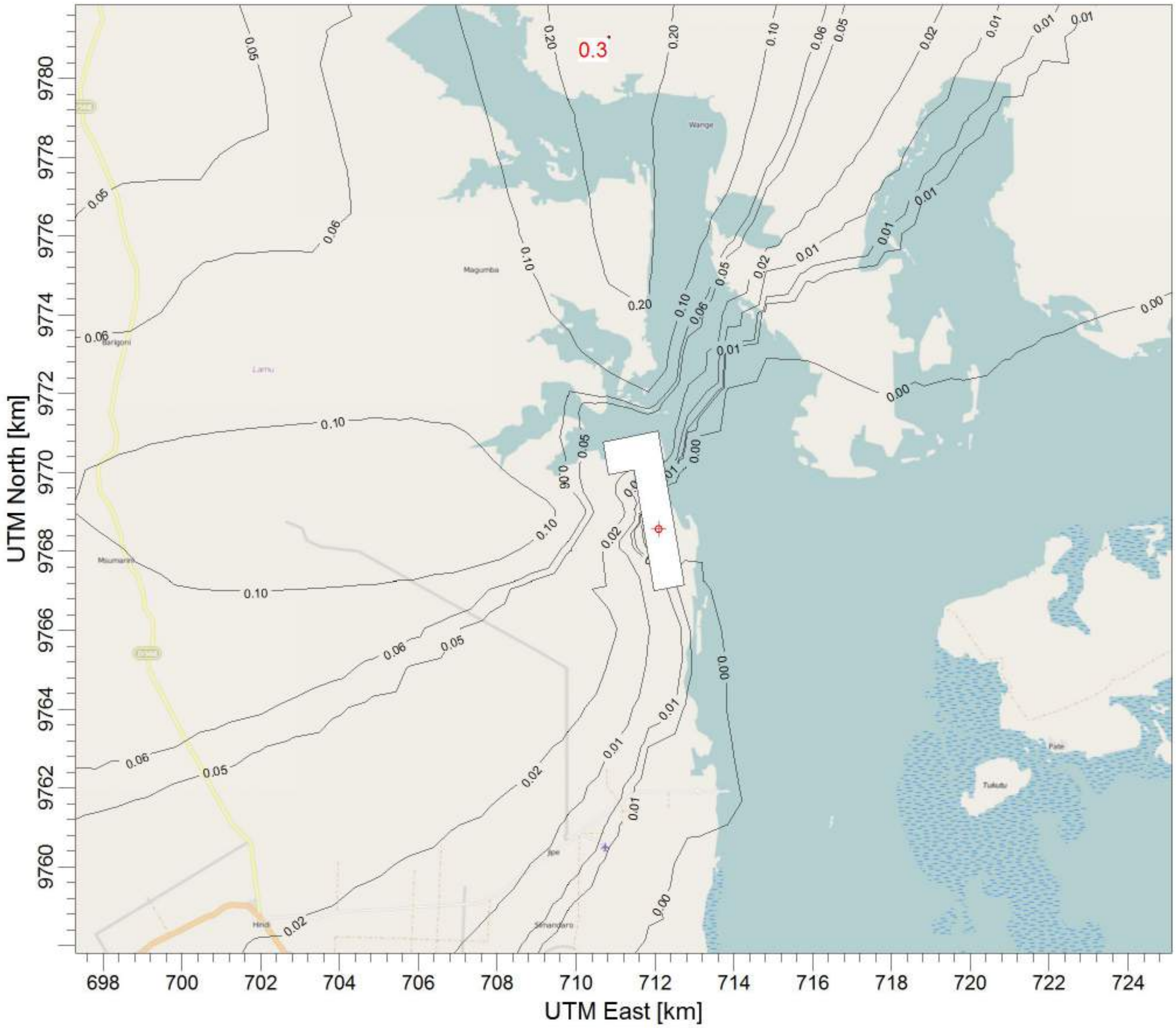
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
PM10 / PM2.5 Annual



1 RANK 8760 HOUR AVERAGE CONCENTRATION (PM10)

ug/m**3

Max = 0.25 [ug/m**3] at (X = 710826.00, Y = 9781057.00)

0.00	0.01	0.01	0.01	0.02	0.05	0.06	0.10	0.20	0.25

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:174,926

0 5 km

WARDKARLSON CONSULTING GROUP

DATE:

2015-08-28

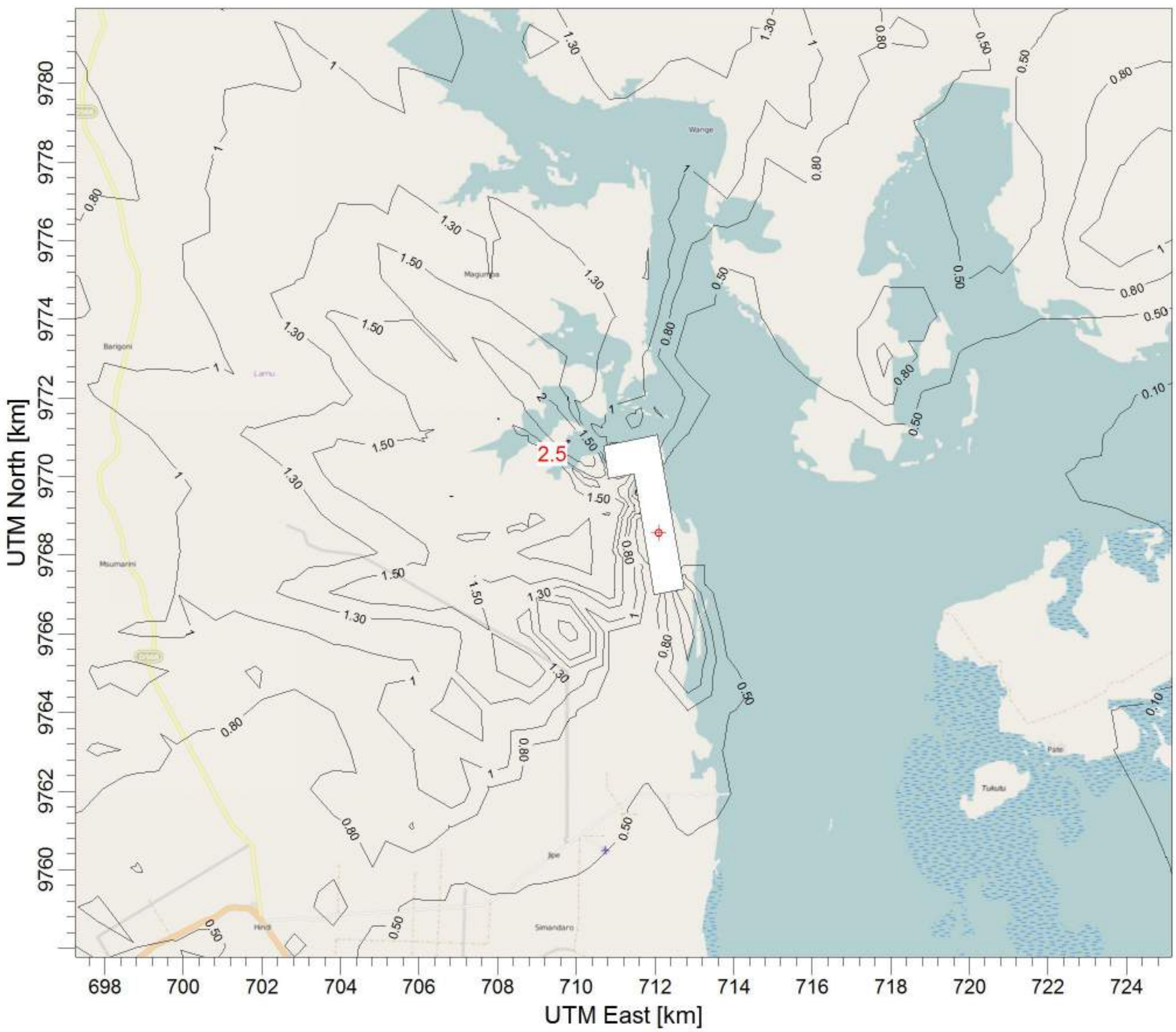
PROJECT NO.:

J3092

CALPUFF View - Lakes Environmental Software

PROJECT TITLE:

Scenario 1
PM2.5 24 Hour



1 RANK 24 HOUR AVERAGE CONCENTRATION (PM10)

ug/m**3

Max = 2.5 [ug/m**3] at (X = 709807.00, Y = 9770888.00)

0.0	0.1	0.1	0.5	0.8	1.0	1.3	1.5	2.0	2.5

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:175,480

0 5 km

DATE:

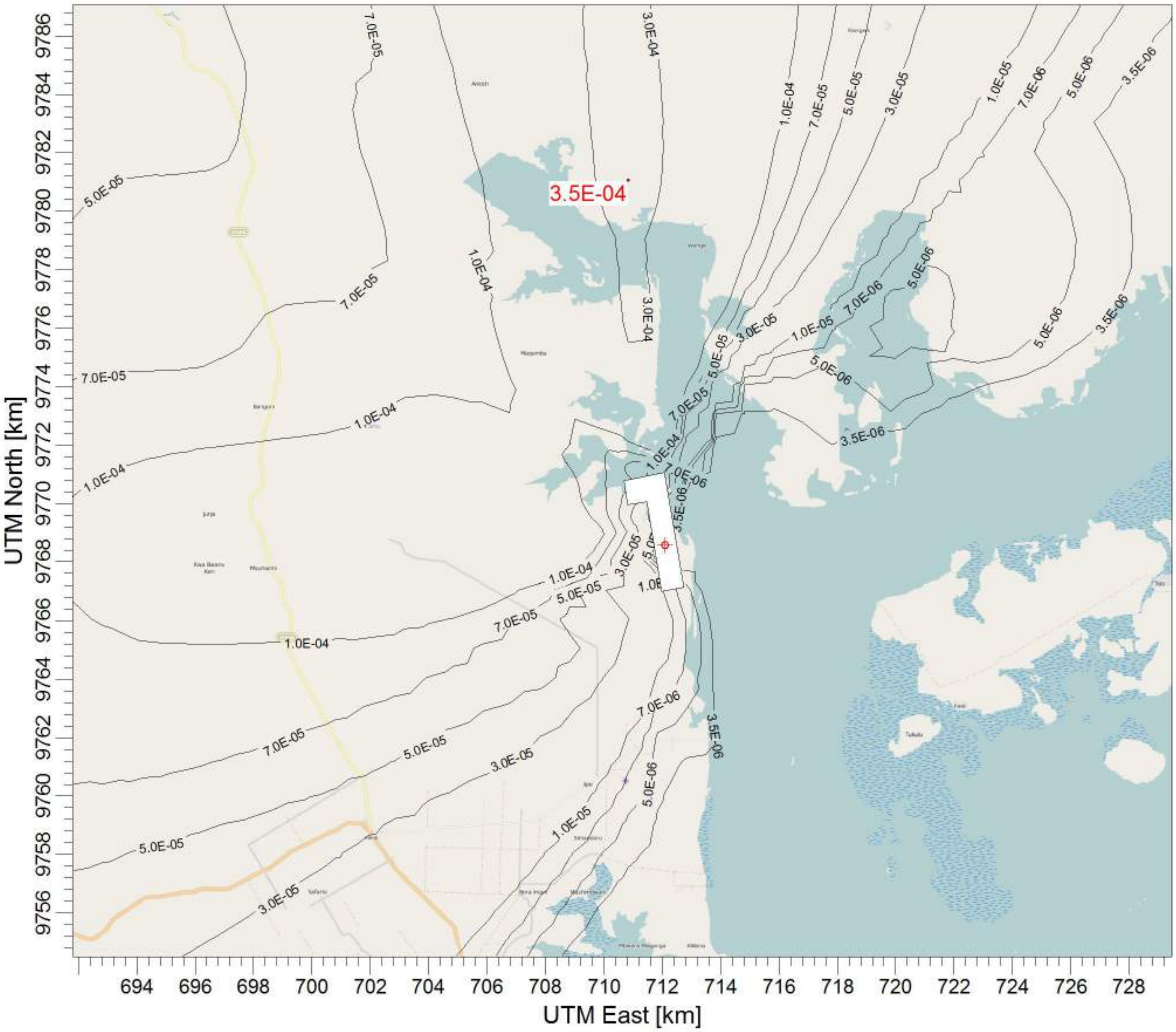
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 1
Hg Annual



1 RANK 8760 HOUR AVERAGE CONCENTRATION (HG)

ug/m**3

Max = 3.5E-04 [ug/m**3] at (X = 710826.00, Y = 9781057.00)

3.5E-06 5.0E-06 7.0E-06 1.0E-05 3.0E-05 5.0E-05 7.0E-05 1.0E-04 3.0E-04 3.5E-04

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:236,840

0 5 km

WKC
WARDKARLSON CONSULTING GROUP

DATE:

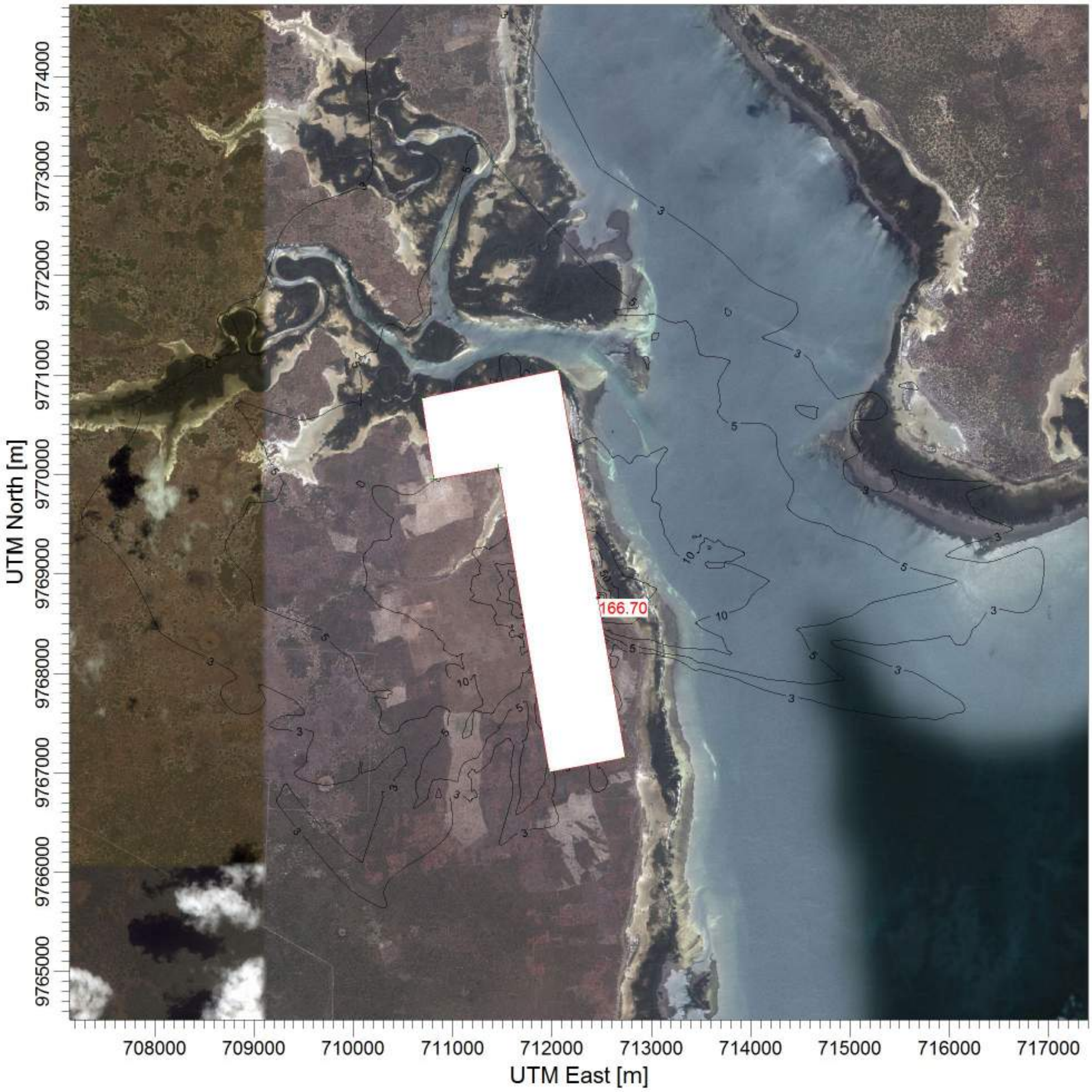
2015-08-28

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 2
PM10 24 Hour



PLOT FILE OF 99.18TH PERCENTILE 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

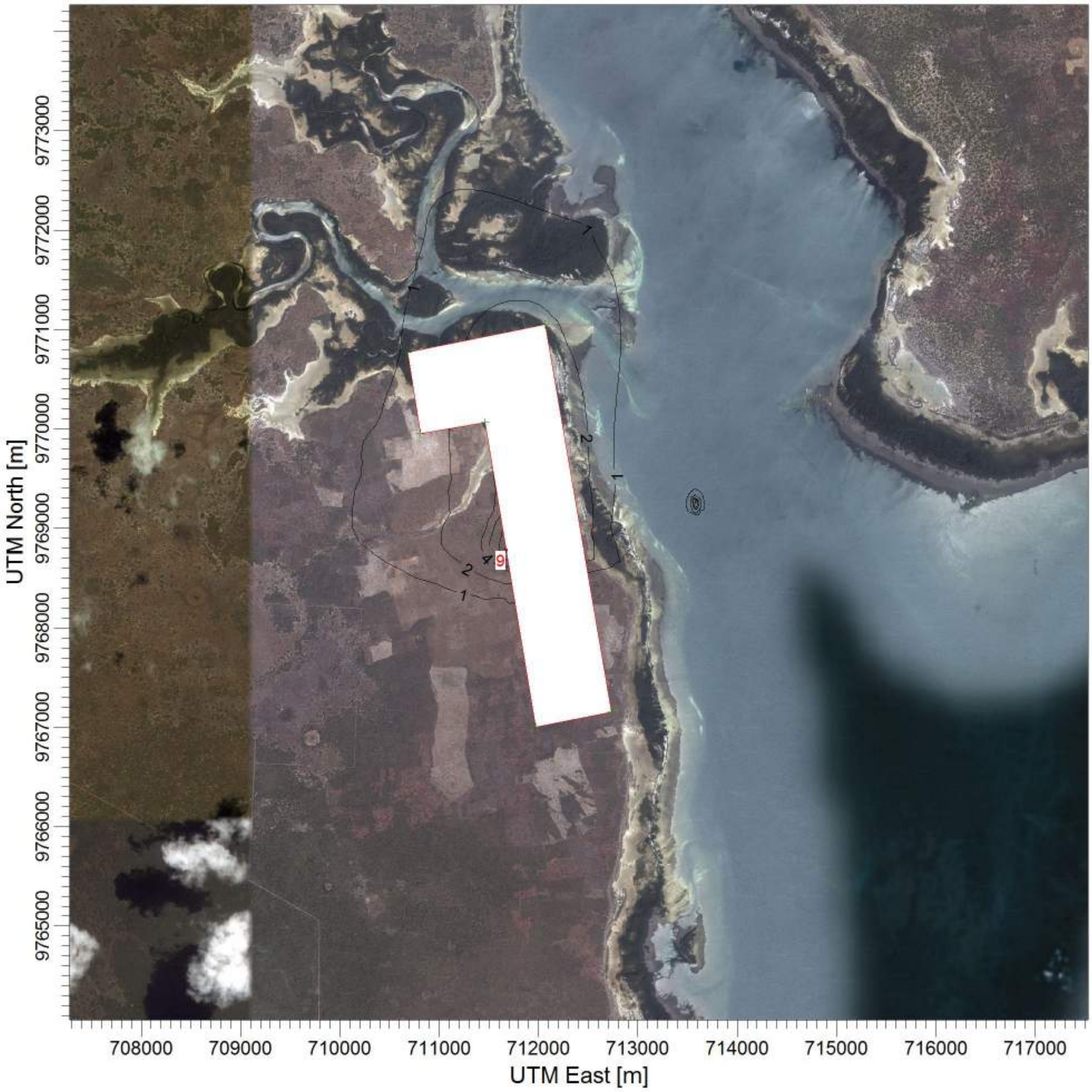
Max: 167 [ug/m^3] at (712459.65, 9768761.81)

3 5 10 30 50 70 100 120 150 167

COMMENTS:	SOURCES: 30	COMPANY NAME:	
	RECEPTORS: 1992	MODELER:	WKC
	OUTPUT TYPE: Concentration	SCALE: 1:66 213 (0 — 2 km)	
	MAX: 167 ug/m^3	DATE: 2015/08/28	PROJECT NO.: J3092

PROJECT TITLE:

Scenario 2
PM10 Annual



PLOT FILE OF PERIOD VALUES FOR SOURCE GROUP: ALL

ug/m^3

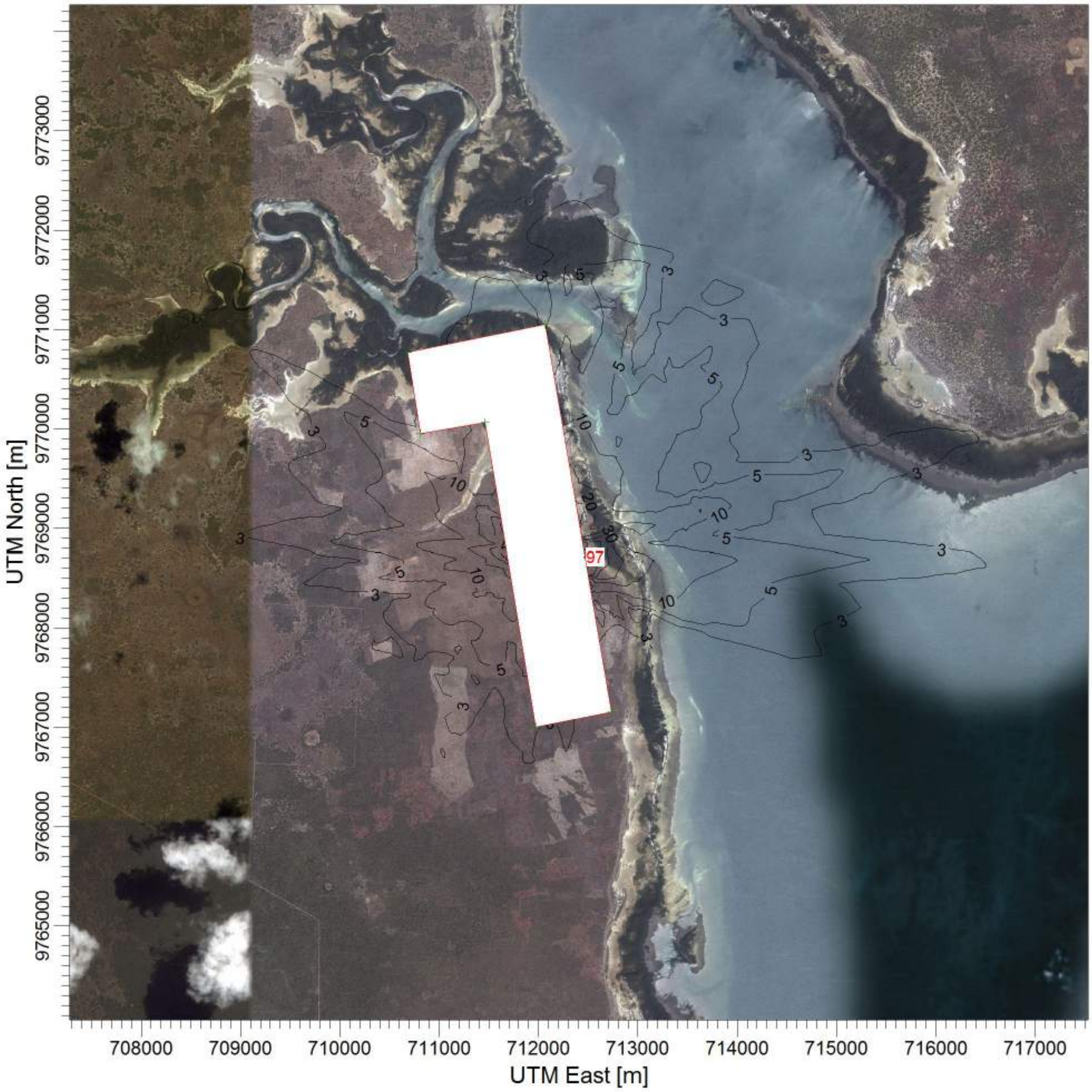
Max: 9.47 [ug/m^3] at (711676.87, 9768779.87)

1.00 | 2.00 | 4.00 | 5.00 | 7.00 | 9.00 | 9.47

COMMENTS:	SOURCES: **30**	COMPANY NAME:	
	RECEPTORS: **1992**	MODELER:	WKC
	OUTPUT TYPE: **Concentration**	SCALE: 1:66 212 (0 — 2 km)	
	MAX: **9.47 ug/m^3**	DATE: **2015/08/28**	PROJECT NO.: **J3092**

PROJECT TITLE:

Scenario 2
PM2.5 24 Hour



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

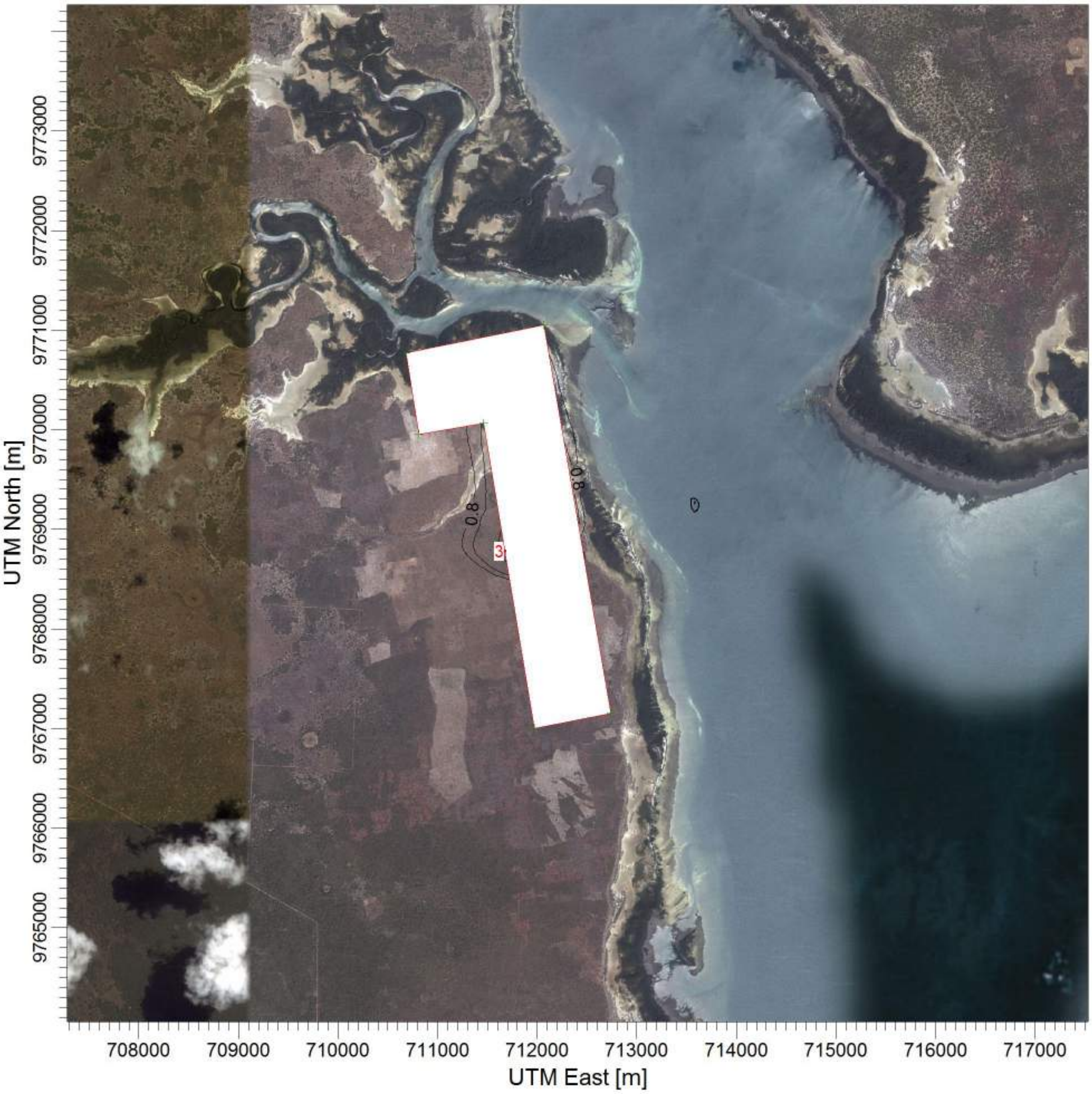
Max: 96.9 [ug/m^3] at (712468.05, 9768713.08)

3.0 | 5.0 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 75.0 | 97.0

COMMENTS:	SOURCES:	COMPANY NAME:	
	30		
	RECEPTORS: **1992**	MODELER:	WKC
	OUTPUT TYPE: **Concentration**	SCALE: 1:66 212 (0 — 2 km)	
	MAX: **96.9 ug/m^3**	DATE: **2015/08/28**	PROJECT NO.: **J3092**

PROJECT TITLE:

Scenario 2
PM2.5 Annual



PLOT FILE OF PERIOD VALUES FOR SOURCE GROUP: ALL

ug/m^3

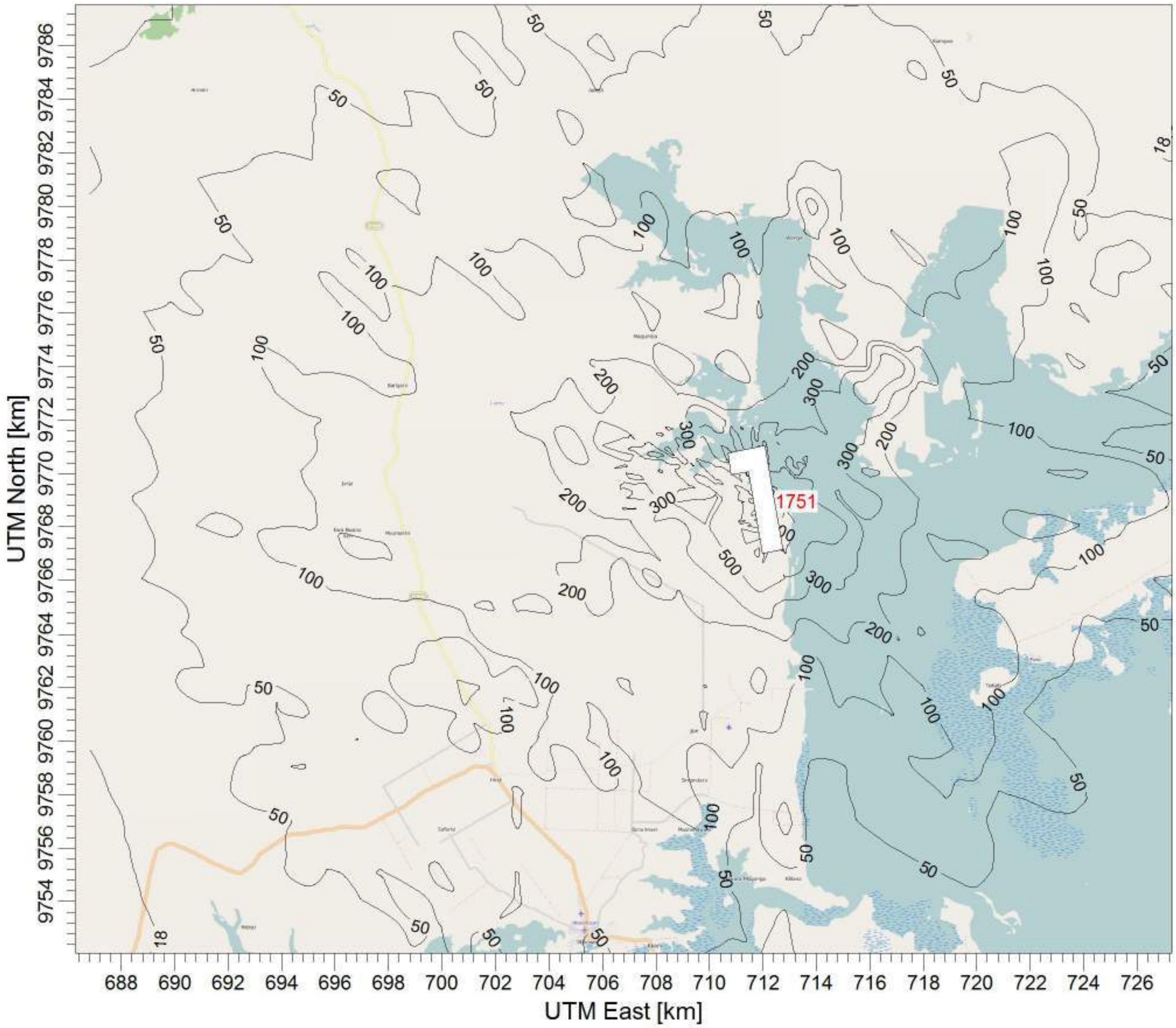
Max: 2.748 [ug/m^3] at (711676.87, 9768779.87)

0.800 1.000 2.000 3.000 4.000 4.737

COMMENTS:	SOURCES:	COMPANY NAME:	
	30		
	RECEPTORS: **1992**	MODELER:	WKC
	OUTPUT TYPE: **Concentration**	SCALE: 1:66 206 (0 — 2 km)	
	MAX: **2.748 ug/m^3**	DATE: **2015/08/28**	PROJECT NO.: **J3092**

PROJECT TITLE:

Scenario 4
NO2 1 Hour



1 RANK 1 HOUR AVERAGE CONCENTRATION (NO2)

ug/m**3

Max = 1751 [ug/m**3] at (X = 712426.00, Y = 9768958.00)

18 50 100 200 300 500 1000 1500 1751

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:257,980

0 5 km

DATE:

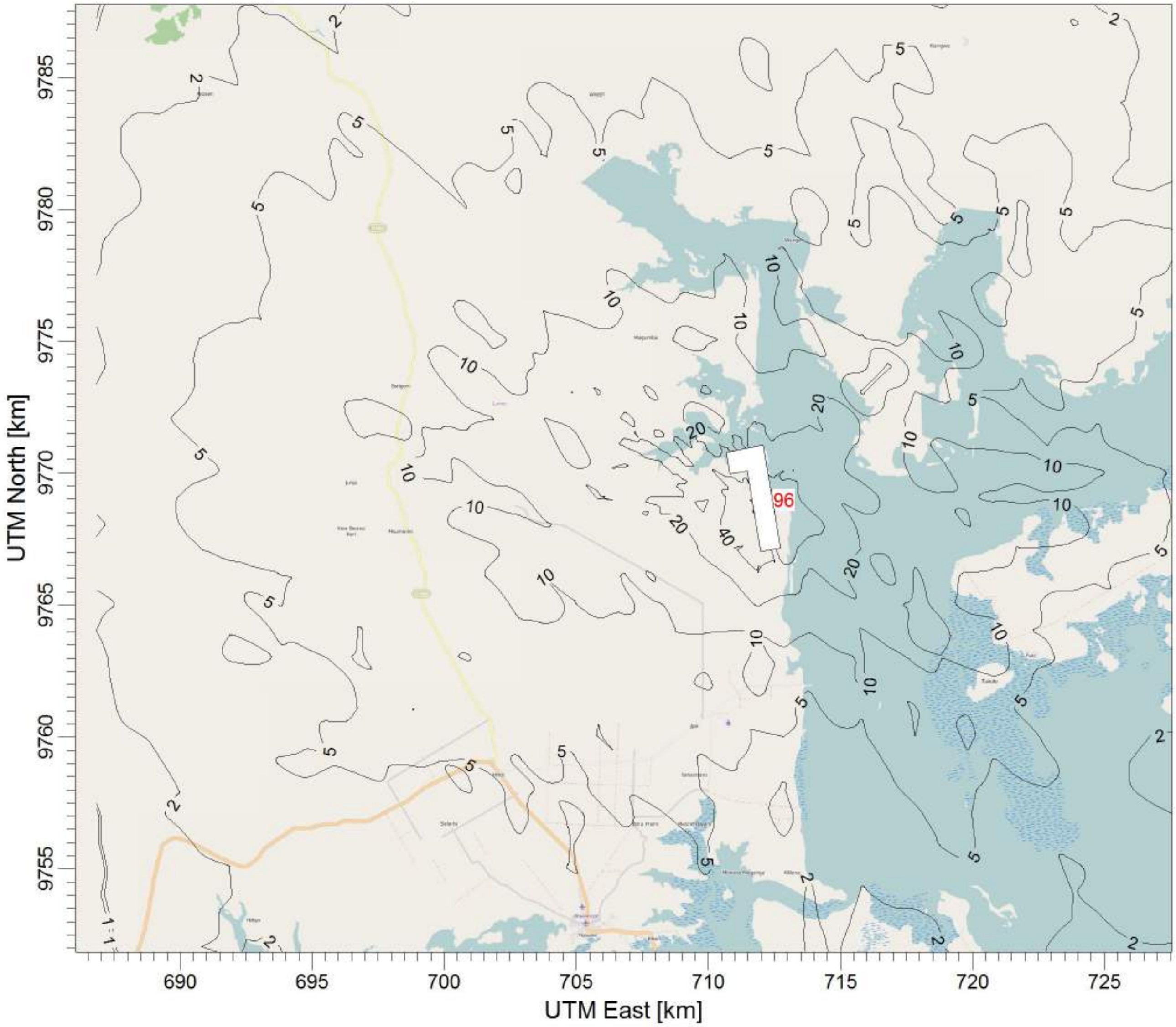
2015-08-16

PROJECT NO.:

J3092

PROJECT TITLE:

Scenario 4
SO2 1 Hour



1 RANK 1 HOUR AVERAGE CONCENTRATION (SO2) ug/m**3

Max = 96 [ug/m**3] at (X = 712426.00, Y = 9768958.00)

1	1	2	5	10	20	40	90	96

COMMENTS:

COMPANY NAME:

WardKarlson Consulting Group

SCALE: 1:261,212

0 5 km

WARDKARLSON CONSULTING GROUP

DATE:

2015-08-16

PROJECT NO.:

J3092