REPORT

Kingfisher Oil Project ESIA - Air Quality Impact Assessment

CNOOC UGANDA LIMITED

Submitted to:

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Distribution List

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List of Abbreviations and Terms

Chemical Formulae	
As	Arsenic
C_6H_6	Benzene
BTEX	Benzene, Ethylbenzene, Toluene & Xylene
Cd	Cadmium
CaO	Calcium oxide / Lime
CaOH	Calcium hydroxide
CO_2	Carbon dioxide
CO	Carbon monoxide
CH_2Cl_2	Dichloromethane
CH_3-S-S-CH_3	Dimethyl disulphide
CH_3-S-CH_3	Dimethyl sulphide
C_8H_{10}	Ethylbenzene
Pb	Lead
CH_4	Methane
C_4H_8O	Methyl ethyl ketone
CH_3S-H	Methyl mercaptan
Ni	Nickle
NO_2	Nitrogen dioxide
NO	Nitrogen oxide
NO_X	Nitrogen oxides
PM_{10}	Particulates with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulates with an aerodynamic diameter of less than 2.5 µm
PAH	Polycyclic aromatic compounds
Na_2CO_3	Sodium bicarbonate
NaOH	Sodium hydroxide / Caustic soda / Soda ash
SO_2	Sulphur dioxide
H_2SO_4	Sulphuric acid
H_2SO_3	Sulphurous acid
C_7H_8	Toluene
TRS	Total Reduced Sulphur
TSP	Total Suspended Particulates
VOC	Volatile Organic Compounds
C_8H_{10}	Xylene
Countries	
EU	European Union
RSA	South Africa
UK	United kingdom
US	United States
Direction	

N	North
NNE	North-North-East
NE	North-East
ENE	East-North-East
E	East
ESE	East-South-East
SE	South-East
SSE	South-South-East
S	South
SSW	South-South-West
SW	South-West
WSW	West-South-West
W	West
WNW	West-North-West
NW	North West
NNW	North-North-West
Environmental management	
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQMPr	Air Quality Management Programme
CS	Concept Study
DMP	Dust Management Plan
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
LoM	Life of Mine
PFS	Pre-Feasibility Study
S&SD	Safety and Sustainable Development
S&EIA	Social and Environmental Impact Assessment
WRD	Waste Rock Dump
Equipment	
PiD	Photo Ionisation Detector
Health	
COHb	Carboxyhaemoglobin
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
MSDS	Material safety data sheets
Measurement	
amsl	Above mean sea level
asl	Above sea level
BDL	Below detection limit
°	Degrees

°C	Degrees Celsius
g/s	Grams per second
K	Kelvin
km	Kilometre
km/h	Kilometre per hour
m	Metres
m/s	Metres per second
µg	Microgram
$\mu g/m^3$	Micrograms per cubic meter
mg	Milligrams
mg/m^3	Milligrams per cubic meter
$mg/m^2/day$	Milligrams per meter squared per day
ppb	Parts per billion
tpa	Tons per annum
t/day	Tons per day
t/hr	Tons per hour
Organisations	
EA-NPI	Environment Australia - National Pollutant Inventory
EC	European Commission
IFC	International Finance Corporation
SANAS	South African National Accreditation System
UE-EA	United Kingdom - Environmental Agency
UK-EA	European Union - Environmental Agency
US-EPA	United States - Environmental Protection Agency
WHO	World Health Organisation

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1.0 INTRODUCTION

The China National Offshore Oil Corporation (CNOOC) requested Golder Associates Africa (Pty) Ltd. (GAA) to undertake an Environmental and Social Impact Assessment (ESIA) for the development of the Kingfisher oilfield.

This report presents the specialist air quality baseline assessment for the oilfield which will inform the ESIA, conducted in terms of the International Finance Corporation (IFC) standards and Ugandan legislative requirements, specifically:

- Environmental Assessment Regulations; and
- Environmental Quality Guidelines for Ambient Air.

1.1 Project Description

Tullow Uganda Operations Pty Ltd (Tullow), Total E&P Uganda Ltd (Total) and CNOOC Uganda Limited (CNOOC) are planning to develop oilfields within the Albertine graben in western Uganda. The three companies have formed a partnership with equal interests in three government-designated exploration areas (EAs) or “Blocks”, with Tullow assuming operatorship of EA2, Total of EA1 and CNOOC of Kingfisher field, formerly in EA3A. The EAs and oilfields (Figure 1) lie along the eastern border of Lake Albert, a 160 km-long, up to 30 km-wide water body which is shared by Uganda and the Democratic Republic of the Congo (DRC). On the 16th of September 2013, the first oil production license in Uganda was awarded to CNOOC. The license gives CNOOC the right to develop the Kingfisher field in EA3 to full production (Figure 1).

1.2 Project Location

The Kingfisher oilfield is located within the administrative boundary of the Buhuka Sub-County in the Hoima District; it is approximately 15.2 km long by 3.0 km wide and covers an oil area of 32.3km^2. Although much of the field lies under Lake Albert, the structural culmination in the Kingfisher lies under a narrow strip of land, some 10km by 2km, formed against the basin bounding fault known as the Buhuka Flats. The location of EA3A and the project area are indicated in Figure 2.

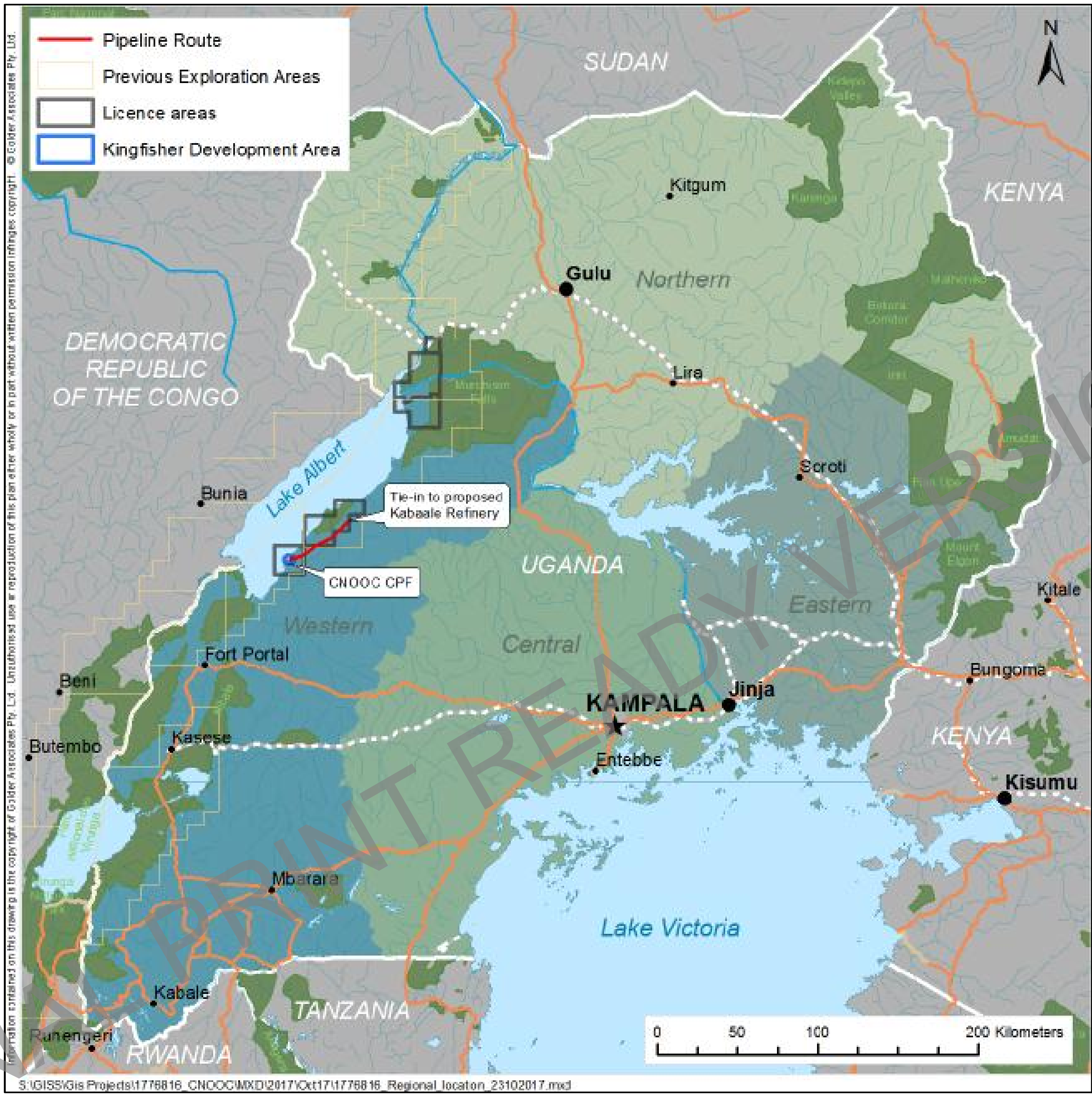

Figure 1: Location of the Kingfisher field in Uganda.

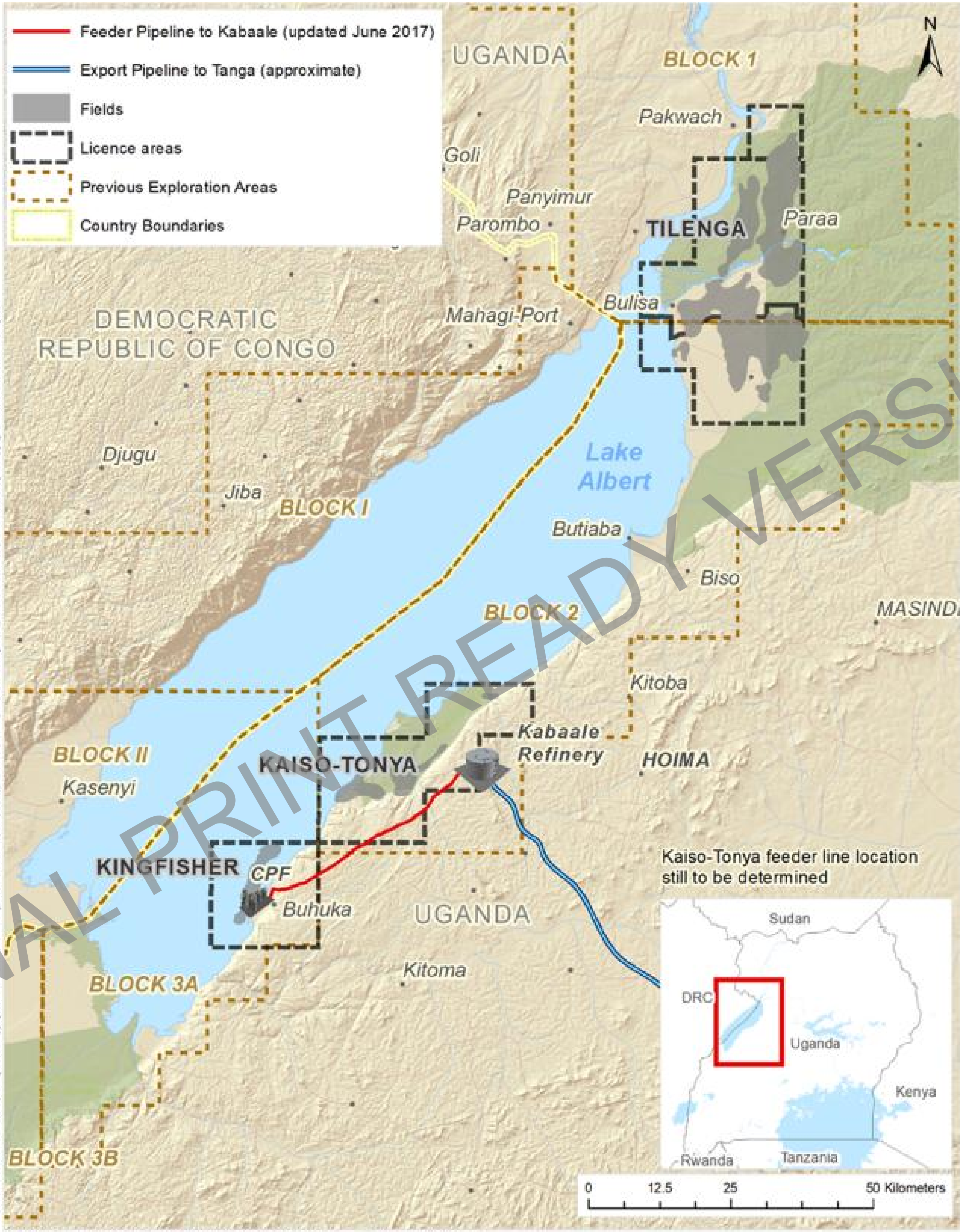

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Figure 2: Location of the Kingfisher Development.

2.0 TERMS OF REFERENCE

2.1 Objectives of the Air Quality Impact Assessment

The objectives of the air quality impact assessment are to:

- To describe the baseline meteorology and ambient air quality of the study area;
- To develop an inventory of potential sources of air emissions associated with the proposed project, and assess these emissions in in relation to:
  - Local emission standards (Ugandan); and
  - International emission guidelines (IFC);
- To perform dispersion modelling to simulate the spatial and temporal impacts of emissions of key pollutants from the proposed project, and assess these predictions in relation to the risk to human health and nuisance factor (odour etc.) by comparison to:
  - Local air quality standards (Ugandan); and
  - International air quality guidelines (IFC);
- Assess and recommend various technological alternatives to minimise air quality impacts associated with the proposed project.

2.2 Scope of Work

The scope of work is for an air quality impact assessment report comprising of a:

- Baseline assessment; and
- Impact Assessment.

2.2.1 Baseline Assessment

The baseline air quality assessment will include:

- The sourcing and collating of available baseline air quality and meteorological information;
- Literature review of the potential health effects associated with emissions from the proposed development;
- Identification of sensitive receptors, such as local communities, within the surrounding areas;
- Review of applicable air quality legislation, policies and standards (local and IFC);
- Analysis of site-specific or MM5 modelled meteorological data;
- A gaps analysis to determine what additional air quality information is required; and
- The development of a baseline air quality monitoring network.

2.2.2 Impact Assessment

The air quality impact assessment for the proposed projects will involve the following activities:

- Identification and quantification of potential sources of air emissions from the proposed development, where measurements aren't available United States Environmental Protection Agency (EPA) and /or Australian National Pollutant Inventory (NPI) emission estimation techniques will be used. Air emissions sources surrounding the proposed development (if information is available) will also be taken into consideration considered to determine cumulative effects.

- Dispersion modelling for the normal operations, emergency events, start up and shut down, pollutant parameters to be considered include:
  - Nitrogen Dioxide (NO_2);
  - Sulphur Dioxide (SO_2),
  - Hydrogen Sulphide (H_2S);
  - Particulates (PM_{10}) and ($PM_{2.5}$); and selected
  - Volatile Organic Compounds (Benzene, Toluene, Ethyl Benzene and Xylene).
- Analysis of dispersion modelling results and associated air quality impact;
- Comparison of the modelling results to the observed baseline data (If suitable baseline data is available);
- Provide recommendations for mitigating / managing the impact of air emissions; and
- An air quality management planning section for inclusion into the facilities EMP.

2.3 Regulatory Context

Prior to assessing the impacts, reference needs to be made to the environmental regulations and guidelines governing the emissions and impacts thereof. This section presents the policy, legal, and administrative framework within which the AQIA and EBS will be carried out. It summarizes policies, laws, regulations, standards and guidelines relevant to the environmental management of the proposed project. It also identifies agencies, departments and institutions responsible for the monitoring and enforcement of legal requirements specified therein.

Table 1: Regulatory context.

Instrument/Legislation	Summary	Relevance to the project
National Policies		
The National Environment Management Policy, 1994		
The National Oil and Gas Policy, 2008		
The National Energy Policy, 2002		
National Laws		
The Constitution of the Republic of Uganda, 1995	The Constitution, as the supreme law, provides the legal and regulatory framework in the country and provides for all aspects pertaining to the environment and other related aspects.	
The National Environment Act, Cap. 153	The National Environment Act is the principal environmental law of Uganda and establishes the Authority (NEMA) as the principal agency in Uganda for the management of the environment. Under Section 19, the Act states the criteria under which EIA shall be required for a proposed development.	In accordance with the Act, the proposed project qualifies for EIA as per Section 19(1) (a) and the Third Schedule.
The Petroleum (Exploration and Production) Act, Cap 150	The Petroleum (Exploration and Production) Act, Cap 150 regulates the 'upstream' (i.e. exploration and production) sector of the industry.	Under Section 31, the Act outlines the obligations and duties of the licensee that include the duty to implement good oil field practices and prevent pollution of the

		development area through the escape of petroleum, drilling fluid, water or any other substance associated with exploration and development activities
The Petroleum (Exploration, Development and Production) Act, 2013	The Petroleum (Exploration, Development and Production) Act operationalises the National Oil and Gas Policy of Uganda. Among its other functions, the Act seeks to establish institutions to manage petroleum resources and regulate petroleum activities including licensing, exploration, development, production and decommissioning.	Section 3 outlines the environmental principles to which all licensees shall comply including the duty to comply with the principles of the National Environment Act, the duty to: Manage waste arising out of petroleum activities in accordance with the National Environment Act and all applicable legislation; and Contract a separate entity to manage the transportation, treatment and disposal of waste arising out of petroleum activities.
The Local Governments Act, Cap 243	The Local Governments Act, Cap 243 establishes a form of government based on the District as the main unit of administration. The Districts are given legislative and planning powers under this Act. They also plan for the conservation of environment within their local area.	District Environment Committees established under Section 15 of the National Environment Act are supposed to guide the district authorities in matters relating to conservation of the environment. District authorities must therefore be involved at an early stage of project implementation since they have a stake as overseers of environmental issues in their areas of jurisdiction.
The Public Health Act, Cap 281	The main objective of the Public Health Act is to safeguard and promote public health.	Section 54 provides a general prohibition of nuisances or conditions liable to be hazardous to health on any land.
National Regulations		
The Environmental Impact Assessment Regulations, 1998	The EIA Regulations, 1998 specify the general requirements for good EIA practice in Uganda.	The proponent is required to undertake the ESIA in accordance with the regulations including, preparation and submission of Terms of Reference, provision of all contents for an environmental impact statement outlined under Regulation 14.
		Public participation: Sub-regulation (1) of Regulation 12 requires the developer to take all measures necessary to seek the views of the people in the communities which

		may be affected by the project. Regulations 19, 20, 21, 22 and 23 outline further requirements for public participation.
The Petroleum Exploration and Production (Conduct of Exploration Operations) Regulations, 1993	These outline the minimum standards governing the exploration and production activities in Uganda.	In accordance with Section 51 (1), the proponent is required to implement all necessary measures to prevent pollution of the environment during development and production operations and the transportation of petroleum.

2.3.1 Institutional framework

The following are the key institutional stakeholders who have an interest in the project.

2.3.1.1 National Environment Management Authority

The National Environment Management Authority (NEMA) is the principal agency in Uganda for the management of the environment, mandated to coordinate, monitor and supervise all activities in the field of the environment. In accordance with its functions stipulated under section 6, subsection (1) of the National Environment Act Cap 153; the authority is mandated to ensure observance of proper safeguards in the planning and execution of all development projects, including those already in existence that have or are likely to have significant impact on the environment.

2.3.1.2 Petroleum Exploration and Production Department

The Petroleum Exploration and Production Department (PEPD) operate as one of the technical departments under the Ministry of Energy and Mineral Development (MEMD) and are mandated to establish the petroleum potential of the country, and is therefore the key lead agency for the project. In accordance with Section 22 (1) of the National Environment Act, the authority (NEMA) shall in consultation with lead agency be responsible for carrying out audits of all activities that are likely to have significant effects on the environment.

2.3.1.3 District Government

District Local Government is defined as one of the lead agencies under the National Environment Act and is mandated to establish a District Environment Committee that coordinates with NEMA on all issues relating to environment management. The District Environment Officer (DEO) in particular will play an active role in monitoring of environmental aspects, and liaise with the NEMA on all matters relating to the environment. The Act also provides for the establishment of Local Environment Committees that may be appointed to monitor all activities within their local jurisdiction to ensure that such activities do not have any significant impact on the environment, and to report any events or activities which have or are likely to have significant impacts on the environment to the District Environment Officer.

2.4 Assessment Criteria

2.4.1 Local Standards

2.4.1.1 Emission Limits

There are currently no Ugandan point source emission limits; in the absence of these, emissions will be assessed according to IFC guidelines.

2.4.1.2 Air Quality Standards

Ugandan air quality standards are currently in the draft stage, air impacts will therefore be assessed according to IFC ambient air quality guidelines.

2.4.2 International Guidelines

This section contains the most updated versions of the World Bank Group Environmental, Health, and Safety Guidelines (known as the "EHS Guidelines"). The EHS Guidelines were developed as part of a two and a half year review process that ended in 2007. They are intended to be living documents and are occasionally updated.

The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP), as defined in IFC's Performance Standard 3: Resource Efficiency and Pollution Prevention. IFC uses the EHS Guidelines as a technical source of information during project appraisal activities, as described in IFC's Environmental and Social Review Procedures Manual.

The EHS Guidelines contain the performance levels and measures that are normally acceptable to IFC and that are generally considered to be achievable in new facilities at reasonable costs by existing technology. For IFC-financed projects, application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets with an appropriate timetable for achieving them. The environmental assessment process may recommend alternative (higher or lower) levels or measures, which, if acceptable to IFC, become project or site-specific requirements.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects will be required to achieve whichever is more stringent. If less stringent levels or measures than those provided in the EHS Guidelines are appropriate in view of specific project circumstances, a full and detailed justification must be provided for any proposed alternatives through the environmental and social risks and impacts identification and assessment process. This justification must demonstrate that the choice for any alternate performance levels is consistent with the objectives of Performance Standard 3.

2.4.2.1 Emission Guidelines

Guideline values for process emissions in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are assumed to be achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment

Emission guidelines applicable to gas engines and turbines the project are provided in Table 2, Table 3 and Table 4.

Table 2: IFC Emission Guidelines for Small Combustion Facilities (3MW – 50MW)

Small Combustion Facilities Emissions Guidelines (3MWth – 50MWth HHV heat input) – (in mg/Nm^3 or as indicated)				
Combustion Technology / Fuel	Particulate Matter (PM)	Sulphur Dioxide (SO_2)	Nitrogen Oxides (NO_X)	Dry Gas, Excess O_2 Content (%)
Engine				
Gas	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) 1,600 (Compression Ignition)	15%
Liquid	50 or up to 100 if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)	1.5 percent Sulphur or up to 3.0 percent Sulphur if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent Sulphur, and available environmental capacity of the site)	If bore size diameter [mm] < 400: 1460 (or up to 1,600 if justified to maintain high energy efficiency.) If bore size diameter [mm] > or = 400: 1,850	15%
Turbine				
Natural Gas =3MWth to < 15MWth	N/A	N/A	42ppm (Electric generation) 100ppm (Mechanical drive)	15%
Natural Gas =15MWth to < 50MWth	N/A	N/A	25ppm	15%
Fuels other than Natural Gas =3MWth to < 15MWth	N/A	0.5 percent Sulphur or lower percent Sulphur (e.g. 0.2 percent Sulphur) if commercially available without significant excess fuel cost	96ppm (Electric generation) 150ppm (Mechanical drive)	15%
Fuels other than Natural Gas =15MWth to < 50MWth	N/A	0.5% S or lower % S (0.2%S) if commercially available without significant excess fuel cost	74ppm	15%
Boiler				
Gas	N/A	N/A	320	3%
Liquid	50 or up to 150 if justified by environmental assessment	2000	460	3%
Solid	50 or up to 150 if justified by environmental assessment	2000	650	6%
Notes: N/A/ - no emissions guideline; Higher performance levels than these in the Table should be applicable to facilities located in urban / industrial areas with degraded airsheds or close to ecologically sensitive areas where more stringent emissions controls may be needed.; MWth is heat input on HHV basis; Solid fuels include biomass; Nm3 is at one atmosphere pressure, 0°C.; MWth				

Small Combustion Facilities Emissions Guidelines (3MWth – 50MWth HHV heat input) – (in mg/Nm³ or as indicated)
category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack except for NOx and PM limits for turbines and boilers. Guidelines values apply to facilities operating more than 500 hours per year with an annual capacity utilization factor of more than 30 percent.

Table 3: IFC Emission Guidelines for Reciprocating Engines (>50MW)

IFC Emissions Guidelines (in mg/Nm³ or as indicated) for Reciprocating Engines (>50MW HHV heat input)							
Note: Guidelines are applicable for new facilities. EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized. For projects to rehabilitate existing facilities, case-by-case emission requirements should be established by the EA considering (i) the existing emission levels and impacts on the environment and community health, and (ii) cost and technical feasibility of bringing the existing emission levels to meet these new facilities limits. EA should demonstrate that emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards, and more stringent limits may be required.							
Combustion Technology / Fuel	Particulate Matter (PM)		Sulphur Dioxide (SO_2)		Nitrogen Oxides (NO_X)		Dry Gas, Excess O_2 Content (%)
Reciprocating Engine	NDA	DA	NDA	DA	NDA	DA	
Natural Gas	N/A	N/A	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) (a)	200 (SI) 400 (Dual Fuel / CI)	15%
Liquid Fuels (Plant >50MWth to <300MWth)	50	30	1,170 or use of 2% or less S fuel	0.5% S	1,460 (Compression Ignition, bore size diameter [mm] < 400) 1,850 (Compression Ignition, bore size diameter [mm] ≥ 400) 2,000 (Dual Fuel)	400	15%
Liquid Fuels (Plant >/=300MWth)	50	30	585 or use of 1% or less S fuel	0.2% S	740 (contingent upon water availability for injection)	400	15%

IFC Emissions Guidelines (in mg/Nm^3 or as indicated) for Reciprocating Engines (>50MW HHV heat input)							
Biofuels / Gaseous Fuels other than Natural Gas	50	30	N/A	N/A	30% higher limits than those provided above for Natural Gas and Liquid Fuels.	200 (SI, Natural Gas), 400 (other)	15%

General notes:
MWth = Megawatt thermal input on HHV basis; N/A = not applicable; NDA = Non-degraded airshed; DA = Degraded airshed (poor air quality); Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if WHO Air Quality Guidelines are exceeded significantly; S = sulphur content (expressed as a percent by mass); Nm^3 is at one atmospheric pressure, 0 degree Celsius; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack. Guideline limits apply to facilities operating more than 500 hours per year. Emission levels should be evaluated on a one hour average basis and be achieved 95% of annual operating hours.
(a) Compression Ignition (CI) engines may require different emissions values which should be evaluated on a case-by-case basis through the EA process.
Comparison of the Guideline limits with standards of selected countries / region (as of August 2008):
Natural Gas-fired Reciprocating Engine – NOx
Guideline limits: 200 (SI), 400 (DF)
UK: 100 (CI) , US: Reduce by 90% or more, or alternatively 1.6 g/kWh
Liquid Fuels-fired Reciprocating Engine – NOx (Plant >5 MWth to <300MWth)
Guideline limits: 1,460 (CI, bore size diameter < 400mm), 1,850 (CI, bore size diameter ≥ 400 mm), 2,000 (DF)
UK: 300 (> 25 MWth), India: 1,460 (Urban area & ≤ 75MWe (≈ 190MWth), Rural area & ≤ 150MWe (≈ 380MWth))
Liquid Fuels-fired Reciprocating Engine – NOx (Plant ≥300MWth)
Guideline limits: 740 (contingent upon water availability for injection)
UK: 300 (> 25MWth), India: 740 (Urban area & > 75MWe (≈ 190MWth), Rural area & > 150MWe (≈ 380MWth))
Liquid Fuels-fired Reciprocating Engine – SO2
Guideline limits: 1,170 or use of ≤ 2% S (Plant >50MWth to <300MWth), 585 or use of ≤ 1% S (Plant ≥300MWth)
EU: Use of low S fuel oil or the secondary FGD (IPCC LCP BREF), HFO S content ≤ 1% (Liquid Fuel Quality Directive), US: Use of diesel fuel with max S of 500 ppm (0.05%); EU: Marine HFO S content ≤ 1.5% (Liquid Fuel Quality Directive) used in SOx Emission Control Areas; India: Urban (< 2% S), Rural (< 4%S), Only diesel fuels (HSD, LDO) should be used in Urban
Source: UK (S2 1.03 Combustion Processes: Compression Ignition Engines, 50 MWth and over), India (SOx/NOx Emission Standards for Diesel Engines ≥ 0.8 MW), EU (IPCC LCP BREF July 2006), EU (Liquid Fuel Quality Directive 1999/32/EC amended by 2005/33/EC), US (NSPS for Stationary Compression Ignition Internal Combustion Engine – Final Rule – July 11, 2006)

Table 4: IFC emission guidelines for combustion turbines (>50MW)

IFC Emissions Guidelines (in mg/Nm³ or as indicated) for Combustion Turbines (>50MW HHV heat input)

Note:
Guidelines are applicable for new facilities.
EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized.
For projects to rehabilitate existing facilities, case-by-case emission requirements should be established by the EA considering (i) the existing emission levels and impacts on the environment and community health, and (ii) cost and technical feasibility of bringing the existing emission levels to meet these new facilities limits.
EA should demonstrate that emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards, and more stringent limits may be required.

Combustion Technology / Fuel	Particulate Matter (PM)		Sulphur Dioxide (SO_2)		Nitrogen Oxides (NO_X)	Dry Gas, Excess O_2 Content (%)
Reciprocating Engine	NDA	DA	NDA	DA	NDA / DA	
Natural Gas (all turbine types of Unit > 50MWth)	N/A	N/A	N/A	N/A	51 (25 ppm)	15%
Fuels other than Natural Gas (Unit > > 50MWth)	50	30	Use of 1% or less S fuel	Use of 0.5% or less S fuel	152 (74 ppm)a	15%

General notes:
MWth = Megawatt thermal input on HHV basis; N/A = not applicable; NDA = Non-degraded airshed; DA = Degraded airshed (poor air quality); Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if WHO Air Quality Guidelines are exceeded significantly; S = sulphur content (expressed as a percent by mass); Nm3 is at one atmospheric pressure, 0 degree Celsius; MWth category is to apply to single units; Guideline limits apply to facilities operating more than 500 hours per year. Emission levels should be evaluated on a one hour average basis and be achieved 95% of annual operating hours.
If supplemental firing is used in a combined cycle gas turbine mode, the relevant guideline limits for combustion turbines should be achieved including emissions from those supplemental firing units (e.g., duct burners).
(a) Technological differences (for example the use of Aero derivatives) may require different emissions values which should be evaluated on a cases-by-case basis through the EA process but which should not exceed 200 mg/Nm³.
Comparison of the Guideline limits with standards of selected countries / region (as of August 2008):
Natural Gas-fired Combustion Turbine – NO_X

IFC Emissions Guidelines (in mg/Nm³ or as indicated) for Combustion Turbines (>50MW HHV heat input)
Guideline limits: 51 (25ppm) EU: 50 (24ppm), 75 (37ppm) (if combined cycle efficiency > 55%), 50*η / 35 (where η = simple cycle efficiency) US: 25 ppm (> 50MMBtu/h (≈ 14.6 MWth) and ≤ 850MMBtu/h (≈ 249MWth)), 15 ppm (> 850 MMBtu/h (≈ 249MWth)) (Note: further reduced NOx ppm in the range of 2 to 9 ppm is typically required through air permit) Liquid Fuel-fired Combustion Turbine – NO_X o Guideline limits: 152 (74 ppm) – Heavy Duty Frame Turbines & LFO/HFO, 300 (146 ppm) – Aero derivatives & HFO, 200 (97 ppm) – Aero derivatives & LFO o EU: 120 (58 ppm), US: 74 ppm (> 50 MMBtu/h (≈ 14.6 MWth) and ≤ 850 MMBtu/h (≈ 249MWth)), 42 ppm (> 850 MMBtu/h (≈ 249 MWth)) Liquid Fuel-fired Combustion Turbine – SOx o Guideline limits: Use of 1% or less S fuel o EU: S content of light fuel oil used in gas turbines below 0.1% / US: S content of about 0.05% (continental area) and 0.4% (non-continental area) Source: EU (LCP Directive 2001/80/EC October 23 2001), EU (Liquid Fuel Quality Directive 1999/32/EC, 2005/33/EC), US (NSPS for Stationary Combustion Turbines, Final Rule – July 6, 2006)

2.4.2.2 Air Quality Guidelines

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

Projects with significant sources[1] of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts by ensuring that:

- Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources; and
- Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, the IFC General EHS Guideline suggests 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed.

IFC ambient air quality guidelines applicable to the project are provided in Table 5, comparative international standards are provide in Table 6.

Table 5: IFC ambient air quality guidelines

IFC Ambient Air Quality Guidelines		
	Averaging Period	Guideline Value in µg/m³
Particulate Matter PM_{10}	1-year	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)
	24-hour	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)
Particulate Matter $PM_{2.5}$	1-year	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline)
	24-hour	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Sulphur dioxide (SO2)	24-hour	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)
	10 minute	500 (guideline)
Nitrogen dioxide (NO2)	1-year	40 (guideline)
	1-hour	200 (guideline)

[1] Significant sources of point and fugitive emissions are considered to be general sources which, for example, can contribute a net emissions increase of one or more of the following pollutants within a given airshed: PM_{10}: 50 tons per year; NO_X: 500tpy; SO_2: 500tpy; or as established through national legislation; and combustion sources with an equivalent heat input of 50MWth or greater. The significance of emissions of inorganic and organic pollutants should be established on a project-specific basis taking into account toxic and other properties of the pollutant.

IFC Ambient Air Quality Guidelines		
Ozone	8-hour daily maximum	160 (Interim target-1) 100 (guideline)
Notes: World Health Organization (WHO). Air Quality Guidelines Global Update, 2005.PM 24-hour value is the 99th percentile. Interim targets are provided in recognition of the need for a staged approach to achieving the recommended guidelines. Ambient air quality standards are ambient air quality levels established and published through national legislative and regulatory processes, and ambient quality guidelines refer to ambient quality levels primarily developed through clinical, toxicological, and epidemiological evidence (such as those published by the World Health Organization) (WHO, 2005).		

Table 6: International air quality guidelines standards

Organisation	Compound	Date Effective	Averaging Time	Concentration (µg/m³)	Comment
European Union	Benzene (C_6H_6)	2015	1 year	5	Not to be exceeded
	Nitrogen Dioxide (NO_2)	2010	1 hour	200	18 exceedances permitted per year
	Nitrogen Dioxide (NO_2)	2010	1 year	40	Not to be exceeded
	Particulate Matter (PM_{10})	2005	1 year	40	Not to be exceeded
	Particulate Matter (PM_{10})	2005	24 hours	50	Not to be exceeded
	Particulate Matter ($PM_{2.5}$)	2015	1 year	25	Not to be exceeded
	Sulphur Dioxide (SO_2)	2005	1 hour	350	24 exceedances permitted per year
	Sulphur Dioxide (SO_2)	2005	24 hours	125	3 exceedances permitted per year
UK Environment Agency	Benzene (C_6H_6)	2015	1 year	5	Not to be exceeded
	Nitrogen Dioxide (NO_2)	2010	1 hour	200	18 exceedances permitted per year
	Nitrogen Dioxide (NO_2)	2010	1 year	40	Not to be exceeded
	Particulate Matter (PM_{10})	2005	1 year	40	Not to be exceeded
	Particulate Matter (PM_{10})	2005	24 hours	50	35 exceedances permitted per year
	Particulate Matter ($PM_{2.5}$)	2010	1 year	25	Not to be exceeded
	Particulate Matter ($PM_{2.5}$)	2020	1 year	20	Not to be exceeded
	Sulphur Dioxide (SO_2)	2005	1 hour	350	35 exceedances permitted per year
	Sulphur Dioxide (SO_2)	2001	1 year	20	Not to be exceeded
	Sulphur Dioxide (SO_2)	2005	24 hours	125	3 exceedances permitted per year
UK Environment Agency (AEL)	Ethylbenzene (C_8H_{10})	2000	1 year	4410	Not to be exceeded
	Toluene (C_7H_8)	2000	1 year	1910	Not to be exceeded
	Xylene (C_8H_{10})	2000	1 year	4410	Not to be exceeded
US EPA	Nitrogen Dioxide (NO_2)	2010	1 hour	188	98th percentile, averaged over 3 years
	Nitrogen Dioxide (NO_2)	2010	1 year	100	Annual Mean
	Particulate Matter (PM_{10})	2012	24 hours	150	Not to be exceeded more than once per year on average over 3 years.

Organisation	Compound	Date Effective	Averaging Time	Concentration (µg/m³)	Comment
	Particulate Matter ($PM_{2.5}$)	2012	1 year	12	Annual mean, averaged over 3 years
	Particulate Matter ($PM_{2.5}$)	2012	24 hours	35	98th percentile, averaged over 3 years
	Sulphur Dioxide (SO_2)	2010	1 hour	141	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years

2.5 Assessment Rating

The methodology and approach to be followed during impact assessment in the detailed ESIS is described below.

Potential impacts during the construction, operational and decommissioning/restoration phases of the project will be considered separately in the ESIA.

The impact assessment process compares the intensity of the impact with the sensitivity of the receiving environment. This method relies on a detailed description of both the impact and the environmental or social component that is the receptor. The intensity of an impact depends on its characteristics, which may include such factors as its duration, reversibility, area of extent, and nature in terms of whether positive, negative, direct, indirect or cumulative.

Once the magnitude of the impact and the sensitivity of the receiving environment have been described, the severity of the potential impact can be determined. The determination of significance of an impact is largely subjective and primarily based on professional judgment (Table 7).

Table 7: Impact assessment criteria and rating scale – Air Quality

Criterion	Rating	Definition
Magnitude (the expected magnitude or size of the impact)	Negligible	Pollutant concentration ≤ 25% of guidelines.[2]
	Very Low	Pollutant concentration >25% and ≤ 50% of guidelines.
	Moderate	Pollutant concentration >50% and ≤ 100% of guidelines.
	Major	Pollutant concentration >100% of guidelines.
Sensitivity of Receptor (VEC)	Negligible	Infrastructure (no human exposure).
	Very Low	Infrastructure (worker occupational exposure).
	Moderate	Camps (worker medium-term exposure)
	Major	Villages (public long-term / repeated exposure)

To provide a relative illustration of impact significance, it is useful to assign numerical descriptors to the impact magnitude and receptor sensitivity for each potential impact. Each is assigned a numerical descriptor of 1, 2, 3, or 4, equivalent to very low, low, medium or high).

The significance of impact is then indicated by the product of the two numerical descriptors, with significance being described as negligible, minor, moderate or major, as in Table 8.

[2] As a general rule, the IFC General EHS Guideline suggests 25% percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed.

Table 8: Determination of impact severity

			Sensitivity of receptor			
			Very low	Low	Medium	High
			1	2	3	4
Magnitude of Impact	Very low	1	1 Negligible	2 Minor	3 Minor	4 Minor
	Low	2	2 Minor	4 Minor	6 Moderate	8 Moderate
	Medium	3	3 Minor	6 Moderate	9 Moderate	12 Major
	High	4	4 Minor	8 Moderate	12 Major	16 Major

Note that this is not a standard Golder methodology it is being used because it has been approved by:

- The Ugandan authorities; and
- CNOOC's partners.

3.0 BASELINE ASSSESSMENT

In characterising the baseline air quality, reference is made to details concerning the Kingfisher oilfield's atmospheric dispersion potential and other potential sources of atmospheric emissions in the area. The consideration of the existing air quality is important so as to facilitate the assessment of the potential for cumulative air pollutant concentrations arising due to proposed developments.

3.1 Topography

The Kingfisher oilfield can be divided into four distinct topographical zones:

- Lake Albert, a typical rift valley lake 619m above mean sea level;
- Sedimentary flats and wetlands along on the shore line of the Lake Albert varying in height up to 20m above the surface of the lake;
- The escarpment rising up to approximately 1000m above mean sea level; and

The Plateau, 1000m to 1200m above mean seal level (Figure 3)

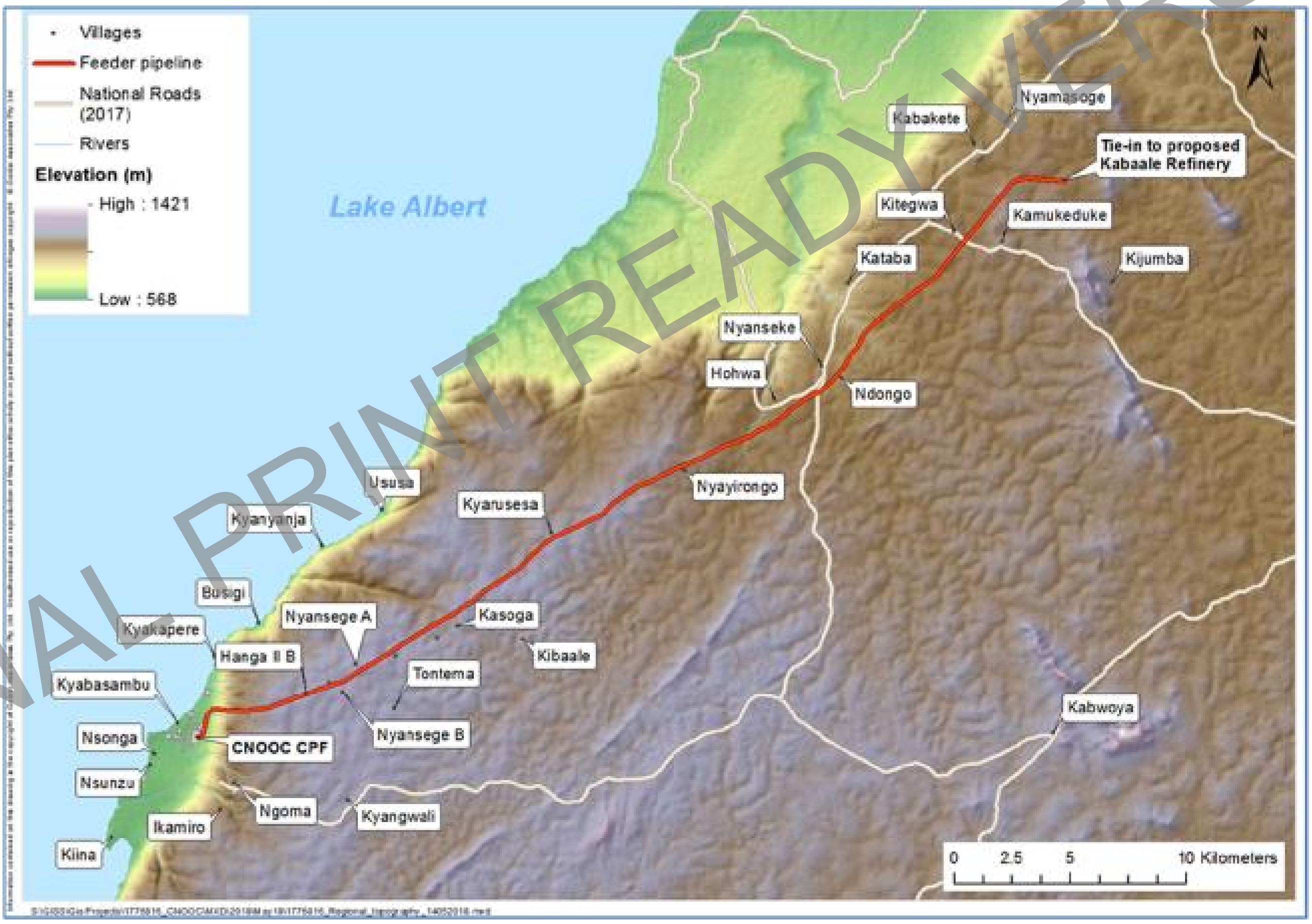


Figure 3: Kingfisher Development topography.

3.2 Land Cover and Use

EA3A comprises of different physical landscapes, climatic conditions and soils which in turn, significantly influence land use systems in the area including agriculture. Because of its location in the rain shadow, the Rift Valley zone is mostly dry and hot and hence the area has serious moisture deficiency problems for agricultural activities especially during critical crop growth periods. Furthermore, except for clay soils in the river Semliki flats, soils on the Rift Valley floor are dominantly sandy with excessive drainage characteristics, making the moisture deficiency problem arising from low rainfall even worse. In addition, the clay soils in the Semliki flats suffer from saline conditions which limit their agricultural potential.

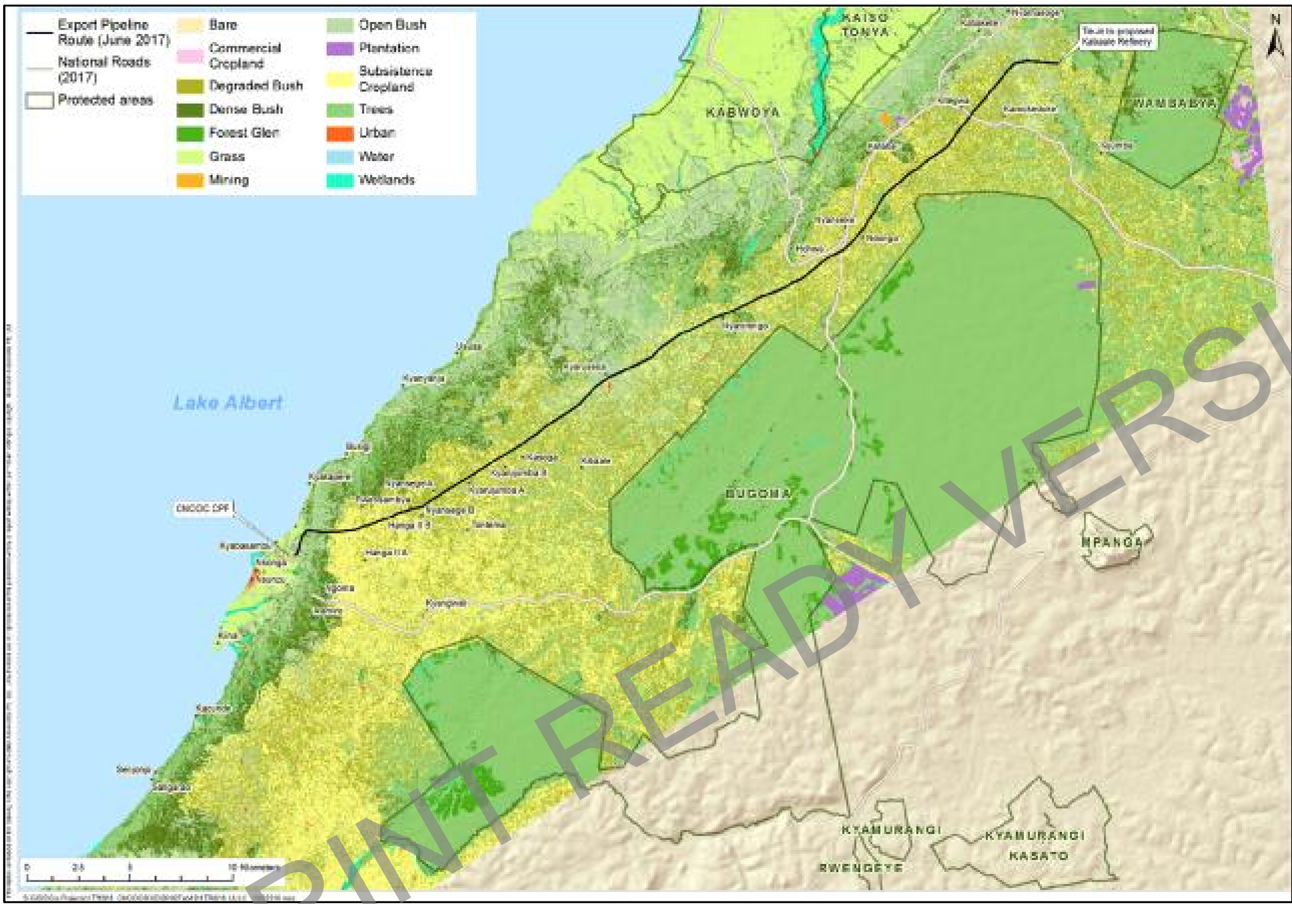


Figure 4: Land cover and use within the local study area.

Note: In the figure above the "export pipeline" refers to the feeder pipeline from the CPF to Kabaale

The largest proportion of the Rift Valley area therefore is, of low agricultural potential. This partly explains the current major use of the Albertine graben as a conservation area. However, the rift escarpment region receives moderate to high rainfall, largely due to orographic factors, which increases with altitude. As a result of both moderate to high rainfall and moderately productive soils in these areas, rich agricultural activities take place based on both food and cash crops. Agriculture in the area is both large scale and small scale. The dominant food crops include beans, maize and bananas although these crops are also often sold for cash income. Tea plantations are found in Bugaambe sub-county in Hoima (Figure 4 and Figure 5) (NEMA 2010).

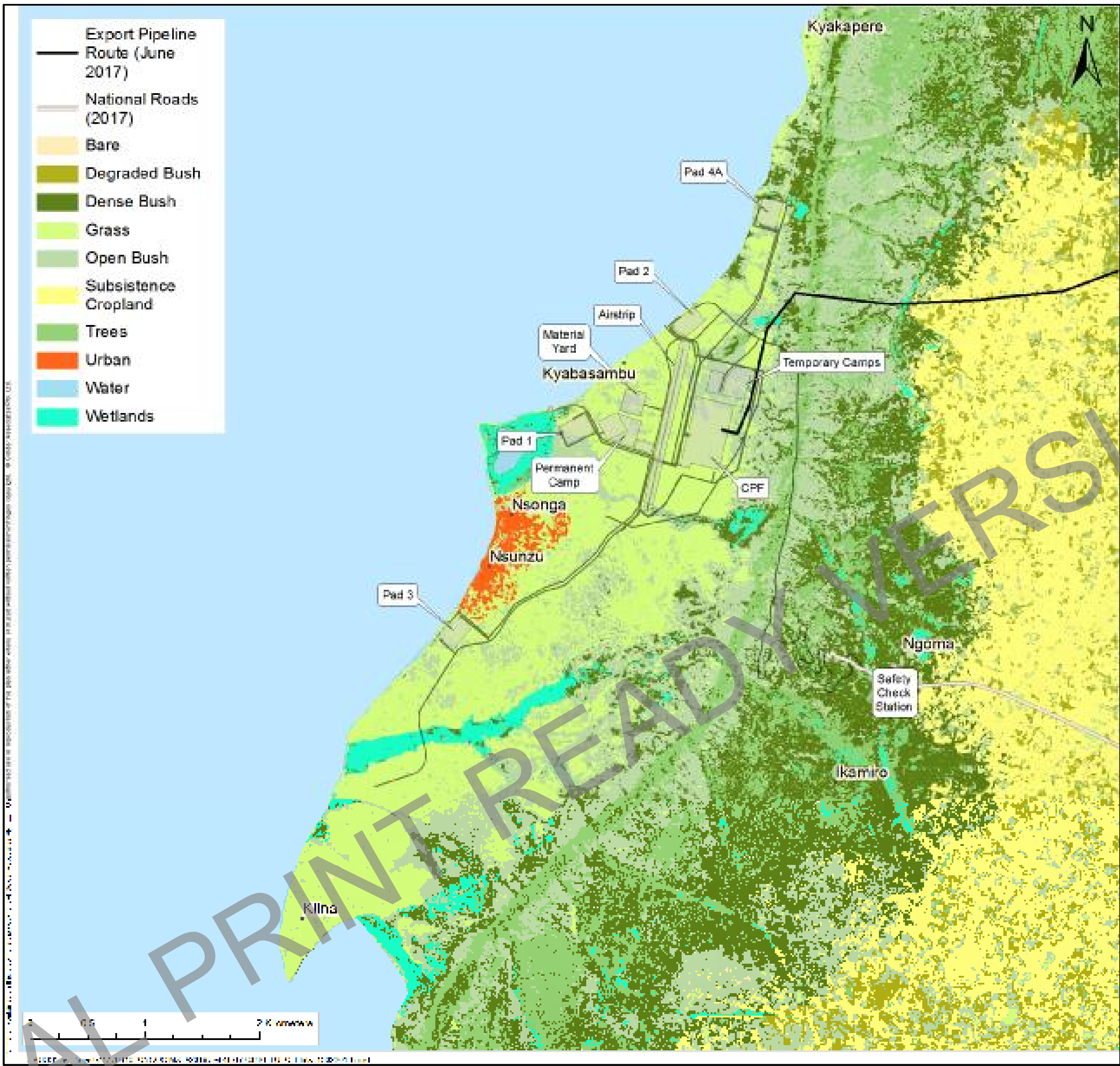


Figure 5: Kingfisher land cover and use.

Note: In the figure above the "export pipeline" refers to the feeder pipeline from the CPF to Kabaale

3.3 Sensitive Receptors

Figure 6: Sensitive receptors.

Villages on the Buhuka Flats and other flats along the Lake Albert shoreline as well as on the escarpment were identified as possible sensitive receptors these include:

- Busigi;
- Ilkamiro;
- Kacunde;
- Kiina;
- Kyabasambu;
- Kyakapere;
- Kyenyanja;
- Ngoma;
- Nsonga;
- Nsunzu;
- Sangarao;
- Senjonjo; and,
- Ususa.

3.4 Atmospheric Dispersion Potential

In the assessment of the possible impacts from air pollutants on the surrounding environment and human

Meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume "stretching". The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction and the variability in wind direction, determine the general path pollutants will follow, and the extent of cross-wind spreading.

Pollution concentration levels fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales. Atmospheric processes at macro-scales and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth (Pasquill, Smith 1983, Godish 1990).

3.4.1 Boundary Layer Properties and Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere and is directly affected by the earth's surface. The earth's surface affects the boundary layer through the retardation of air flow created by frictional drag, created by the topography, or as result of the heat and moisture exchanges that take place at the surface.

During the day, the atmospheric boundary layer is characterised by thermal heating of the earth's surface, converging heated air parcels and the generation of thermal turbulence, leading to the extension of the mixing layer to the lowest elevated inversion. These conditions are normally associated with elevated wind speeds, hence a greater dilution potential for the atmospheric pollutants.

During the night, radiative flux divergence is dominant due to the loss of heat from the earth's surface. This usually results in the establishment of ground based temperature inversions and the erosion of the mixing layer. As a result, night-time is characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer ranges in depth from a few metres during night times to the base of the lowest elevated inversion during unstable, daytime conditions. Elevated inversions occur for a variety of reasons, however typically the lowest elevated inversion occurs at night during winter months when atmospheric stability is typically at its maximum. Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 9.

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

Table 9: Atmospheric stability classes.

Designation	Stability Class	Atmospheric Condition
A	Very unstable	Calm wind, clear skies, hot daytime conditions
B	Moderately unstable	Clear skies, daytime conditions
C	Unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

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

3.5 Regional climate

Uganda is located in east Africa at latitudes of 2°S to 5°N, on the East African Plateau, its climate is tropical, but is moderated by its high altitude. Temperature vary little throughout the year, but the average temperatures increase in the south of the country as the elevation decreases towards the Sudanese plain. Average temperatures in the coolest regions of the south-west remain below 20°C, and reach 25°C in the warmest, northernmost parts.

Seasonal rainfall in Uganda is driven mainly by the migration of the Inter-Tropical Convergence Zone (ITCZ), a relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator. The exact position of the ITCZ changes over the course of the year, migrating southwards through Uganda in October to December, and returning northwards in March, April and May. This causes the Uganda to experience two distinct wet periods – the 'short' rains in October to December and the 'long' rains in March to May. The amount of rainfall received in these seasons is generally 50-200mm per month but varies greatly, exceeding 300mm per month in some localities.

The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and vary from year to year; hence the onset and duration of these rainfalls vary considerably inter-annually. One of the most well documented ocean influences on rainfall in this region is the El Niño Southern Oscillation (ENSO). El Niño episodes usually cause greater than average rainfalls in the short rainfall season (OND), whilst cold phases (La Niña) bring a drier than average season (Mc Sweeny, New, Lizcano et al 2010).

3.6 Meso Scale Meteorology

3.6.1 Wind Direction and Speed

Wind direction and wind speed records indicate a high incidence of strong winds especially in the Rift Valley. The prevailing winds commonly blow along the valley floor in a north-east to south-west direction or vice versa. Winds also blow across the Rift Valley in an east to west direction. On the escarpment and mountain slopes, prevailing wind-blow is largely multi-directional. The long-term wind speed records from the East African Meteorological Department (1975) indicate average annual wind speeds of 2.0m/s and 3.0m/s at 0600 hours and 1200 hours, respectively, for Butiaba; 1.5m/s and 2.5m/s, respectively, for Hoima and; 1m/s and 3m/s, respectively, for Kasese. The wind speed values indicated, therefore, represent conditions of moderate to strong or turbulent conditions. The average number of calms experienced in the area, are indicated to be experienced for 41days at 0600 hours, and 14 days at 1200 hours, respectively, at Butiaba; 99 days and 27 days, respectively, for Hoima; 181 days and 44 days, respectively, for Kasese; and 99 days and 27 days, respectively, for Masindi. The general conclusion from these climatic figures is that for most of the year, the area experiences moderate to strong and gusty winds, increasing in the afternoon. Both wind speed and direction have important implications on oil exploration and production activities particularly the dispersion potential for oil pollutants (NEMA 2010).

3.6.2 Temperature and Humidity

The Albertine graben region lies astride the equator. The region experiences small annual variation in air temperatures; and the climate may be described as generally hot and humid, with average monthly temperatures varying between 27°C and 31°C. The temperature maxima's are consistently above 30°C and sometimes reach 38°C. Average minimum temperatures are relatively consistent and vary between 16°C and 18°C. The recorded lowest and highest monthly mean temperatures in the year vary along the Rift Valley: In Pamoti in Moyo, the lowest mean temperatures are recorded in August (22.6ºC) while the highest are recorded in February (27.1ºC). Southwards at Wadelai, the lowest mean temperatures are recorded in

January (8.7ºC) and the highest in February (39.0ºC) indicating an extreme change in temperatures within a period of one month. At Butiaba, the lowest mean temperatures were recorded in September (18.0ºC) and the highest in February (35.6ºC). Further south at Kasese, the lowest mean temperatures were recorded in July (10.5ºC) and the highest in February (36.0º). The high air temperatures result in high evaporation rates causing some parts to have a negative hydrological balance.

The relative humidity in the Albertine graben is higher during rain seasons with maximum levels prevalent in May. The lowest humidity levels occur in dry seasons with minimum levels occurring in December and January. The average monthly humidity is between 60% and 80%. The relative humidity recorded at Wadelai at 0600 hours ranges between 70% in February and 88% in August while the record at 1200 hours ranged between 35% from January to February and 55% from August to September. The average humidity recorded at 0600 hours for Butiaba ranged between 67% in January and 80% in August while at 1200 hours, the humidity records ranged between 66% in January and 71% in October. At Kasese, the average humidity recorded at 0600 hours ranged between 79% in January and February and 85% from April to July, while records at 1200 hours ranged between 49% in July and 61% in November. Relative humidity records for Moyo and the areas in the extreme south-west of the graben in Rukungiri and Kanungu are not available. It can be concluded therefore, that variation in relative humidity is generally moderate, except for Wadelai where both low and high relative humidity figures have been recorded (35% and 88% respectively) (NEMA 2010).

3.6.3 Rainfall

The Albertine graben has a sharp variation in rainfall amounts, mainly due to variations in the landscape. The landscape ranges from the low lying Rift Valley floor to the rift escarpment, and the raised mountain ranges. The highest landscape is the mountain ranges of Rwenzori, the Rwenzori Mountains towering at over 5000m above mean sea level (amsl).

The Rift Valley floor lies in a rain shadow of both the escarpment and mountains, and has the least amount of rainfall average of less than 875mm per annum much lower than that of the highland area. Rainfall records by Directorate of Water Resources Management indicate that Moyo in the extreme north-east received an annual rainfall mean of 1174.8mm over a seven year period between 2003 and 2009. Over the period the highest annual mean rainfall was recorded in 2006 (1593.9mm) while the lowest was recorded in 2004 (623.6mm) indicating a high variation range in the mean annual rainfall received. Butiaba around Lake Albert in the centre north-east receives 750mm, while Kasese in the central part of the graben receives a slightly higher mean rainfall of 970mm. No records are available for areas in the extreme south-western parts of the graben in Rukungiri and Kanungu. However, the area similarly receives rainfall amounts lower than that in the highland area flanking the Rift Valley. On the highland areas of the rift escarpment, rainfall averages increase largely due to orographic influence. For example, Masindi receives an annual average rainfall of 1,359mm, while Hoima receives 1435mm.

Rainfall amounts are even higher on the slopes of the Ruwenzori's, in most cases increasing to over 1500mm. There is however, a serious lack of coverage of climatic measuring instrumentation, which is a common problem in mountainous regions worldwide. As a result of this, information on the spatial distribution of rainfall in the Rwenzori Mountains remains scanty.

There is also scanty rainfall information in the graben but a high variation in the rainfall received both along and across the Rift Valley. Mean Rainfall amounts in the Murchison Falls Conservation Area for instance vary from 1,500mm per year at Chobe in the east to about 1,100mm at Paraa on the western part of the Rift Valley. Likewise, the mean annual rainfall recorded at Pamoti (Moyo District Farm Institute) in Moyo from 2003 to 2009 was 1174.8mm. The long-term mean rainfall amount recorded at Wadelai in Nebbi is 1,029mm, 750mm at Butiaba and 970mm at Kasese; giving a mean range of 425mm between the most northerly and southerly points where rainfall has been measured in the rift system. There is also significant seasonal variation in the rainfall pattern, mainly as a result of variation in factors influencing rainfall and especially the periodic shifting of the Inter-Tropical Convergence Zone (ITCZ) and the wind blows from the Atlantic Ocean through the Congo basin in central Africa. In the northern part of the region, there are two seasons of high rainfall, associated with the passing of the ITCZ over the region. Generally, rain occurs in all months, but with two peaks occurring between April and May, and August through to October, with two relatively drier spells around January and June (NEMA 2010).

3.7 Local meteorology

Meteorology has been measured on the Buhuka Flats since 2010, and apart from the period from March 2012 to December 2012 monitoring has been continuous. The meteorological station is situated in Bugoma and measures the following parameters:

- Wind direction and wind speed;
- Temperature; and
- Rainfall.

3.7.1 Wind Direction and Speed

Wind direction data for the Buhuka Flats is presented in Figure 7 to Figure 9 and wind speed data in Figure 10 to Figure 11. Data for 2012 is not displayed because of the limited monitoring that took place during that that year. Wind speed data from 2013 is also not displayed, it is suspected that this instrument has been damaged; the data has therefore been rejected.

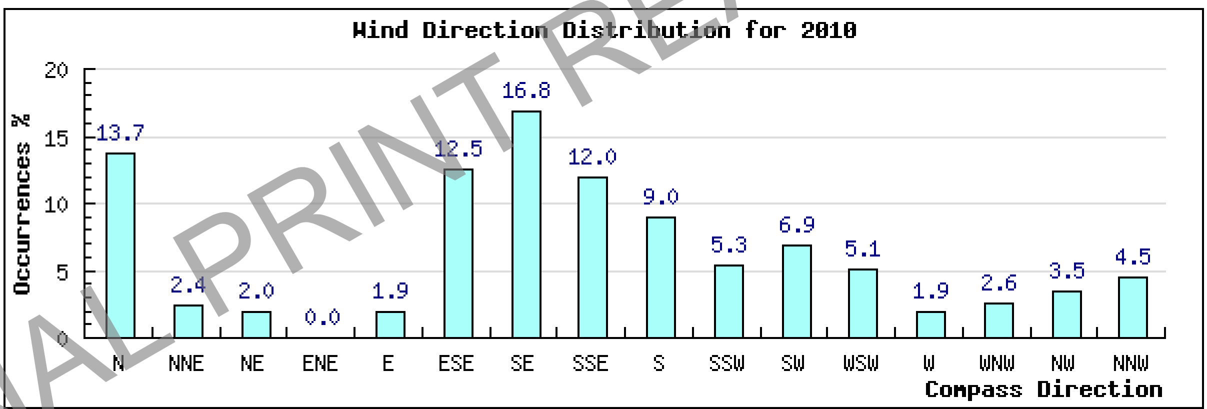


Figure 7: Buhuka Flats – Wind Direction 2010 (iWeathar 2014).

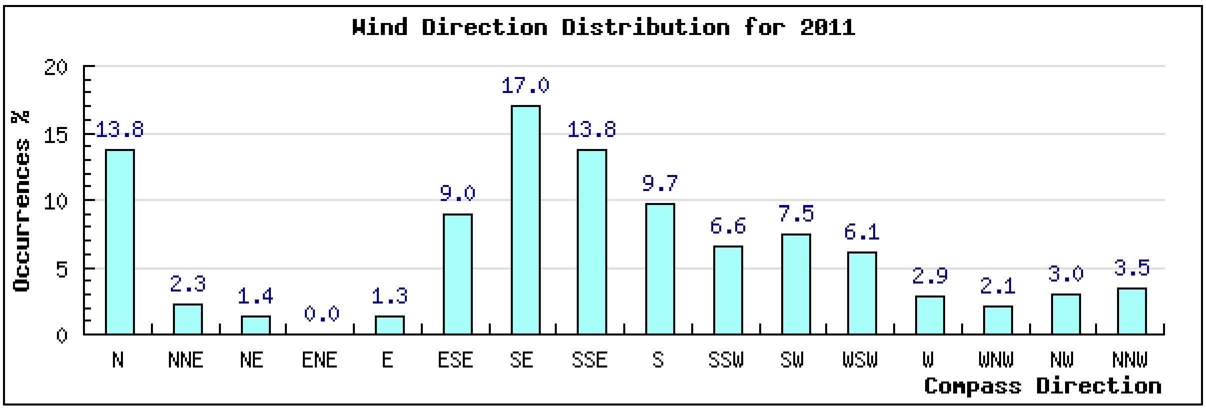


Figure 8: Buhuka Flats – Wind Direction 2011 (iWeathar 2014).

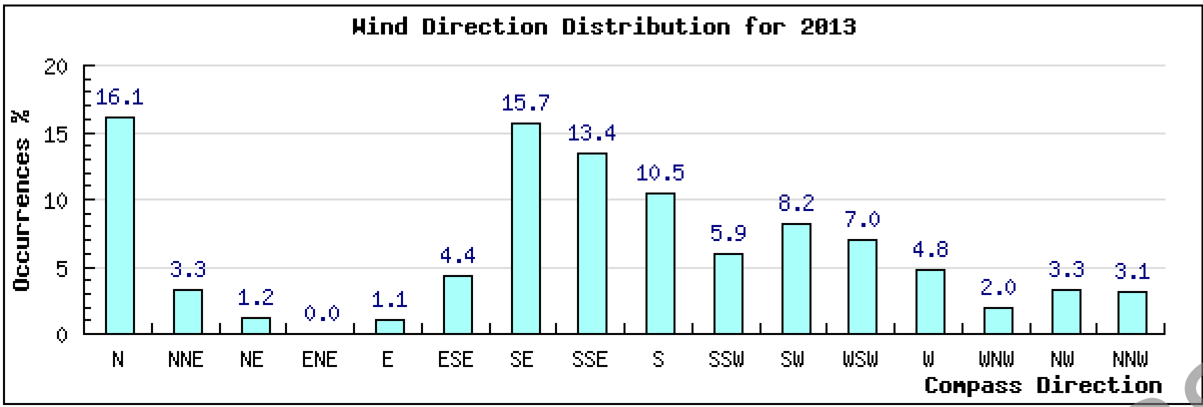


Figure 9: Buhuka Flats – Wind Direction 2013 (iWeathar 2014).

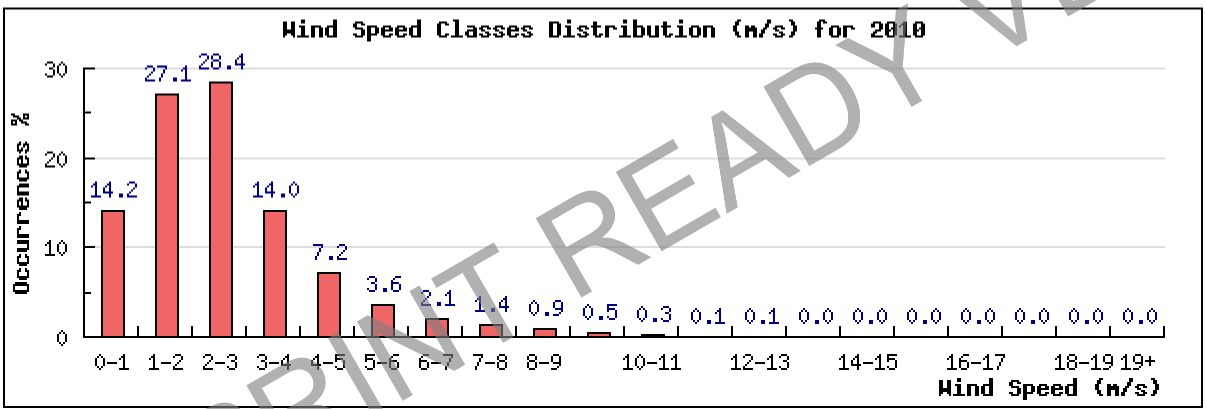


Figure 10: Buhuka Flats – Wind Speed 2010 (iWeathar 2014).

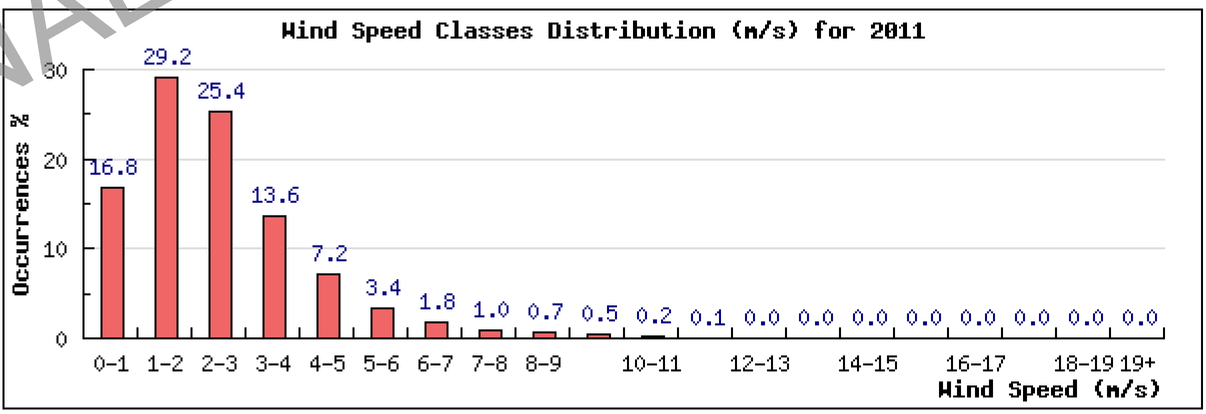


Figure 11: Buhuka Flats – Wind Speed 2011(iWeathar 2014).

3.7.2 Temperature

Average monthly temperature for the Buhuka Flats is displayed in Figure 12 to Figure 15.

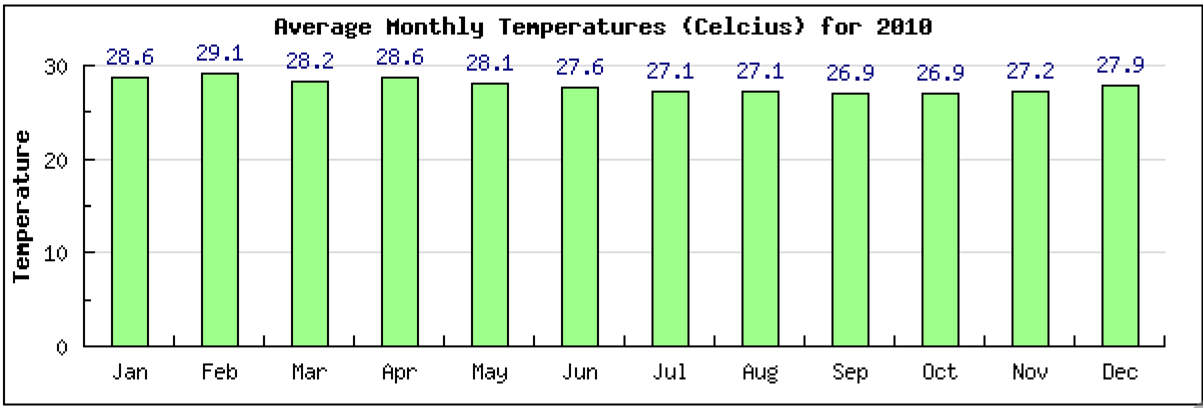


Figure 12: Buhuka Flats – Temperature 2010 (iWeathar 2014).

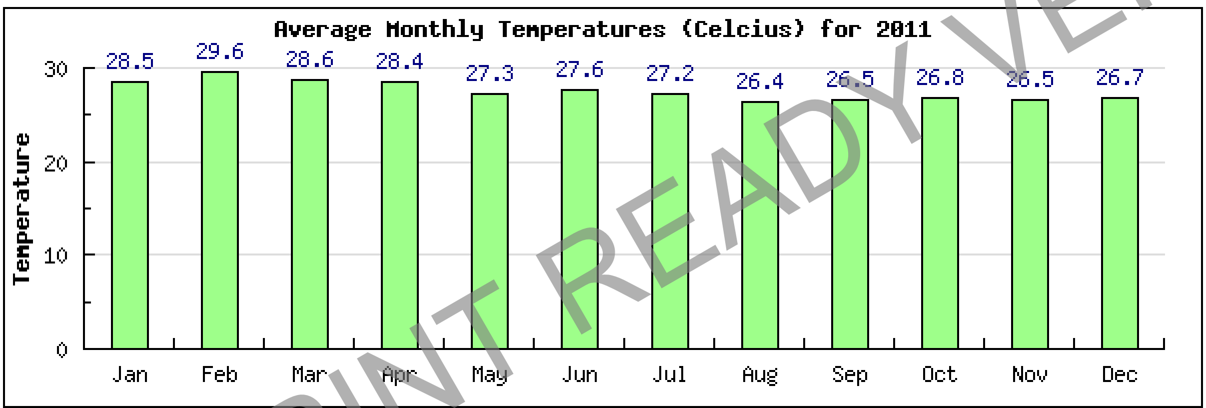


Figure 13: Buhuka Flats – Temperature 2011 (iWeathar 2014).

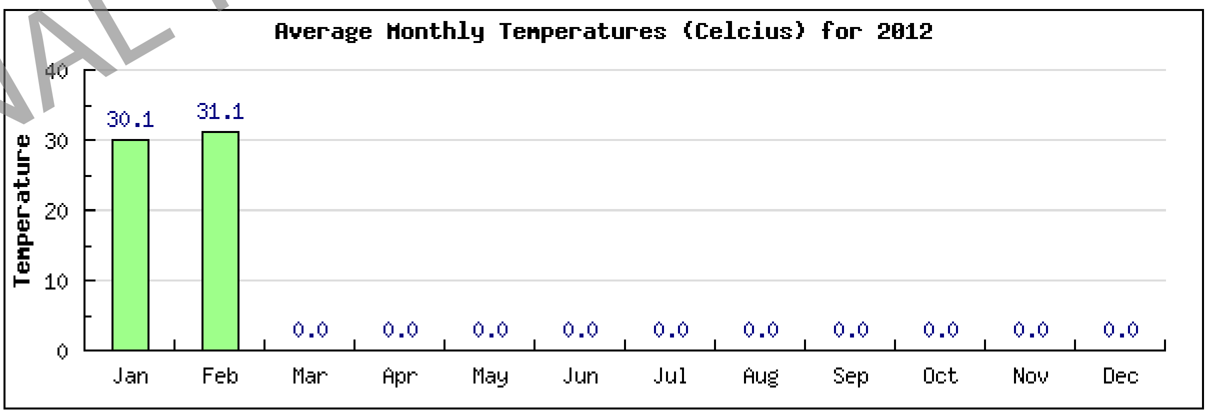


Figure 14: Buhuka Flats – Temperature 2012 (iWeathar 2014).

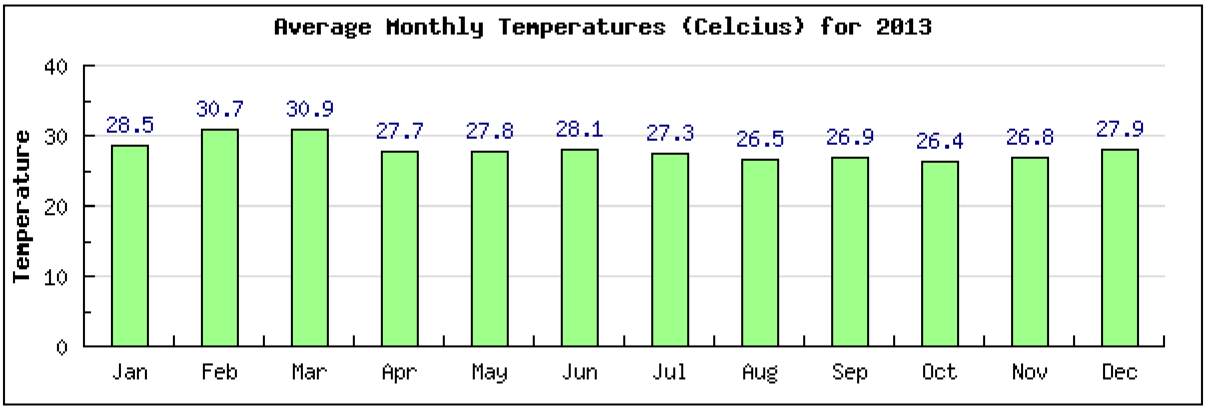


Figure 15: Buhuka Flats – Temperature 2013 (iWeathar 2014).

3.7.3 Rainfall

Monthly rainfall for the Buhuka Flats is provided in Figure 16 to Figure 19.

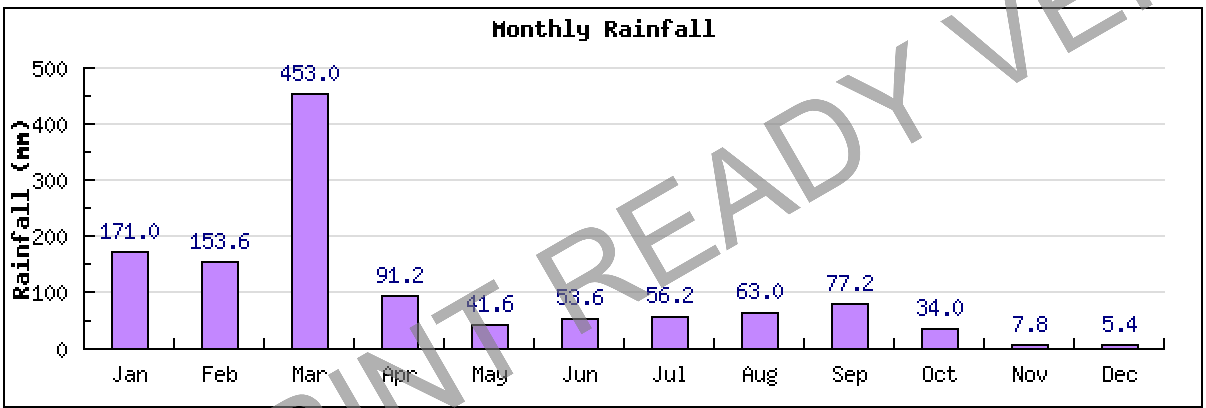


Figure 16: Buhuka Flats – Rainfall 2010 (iWeathar 2014).

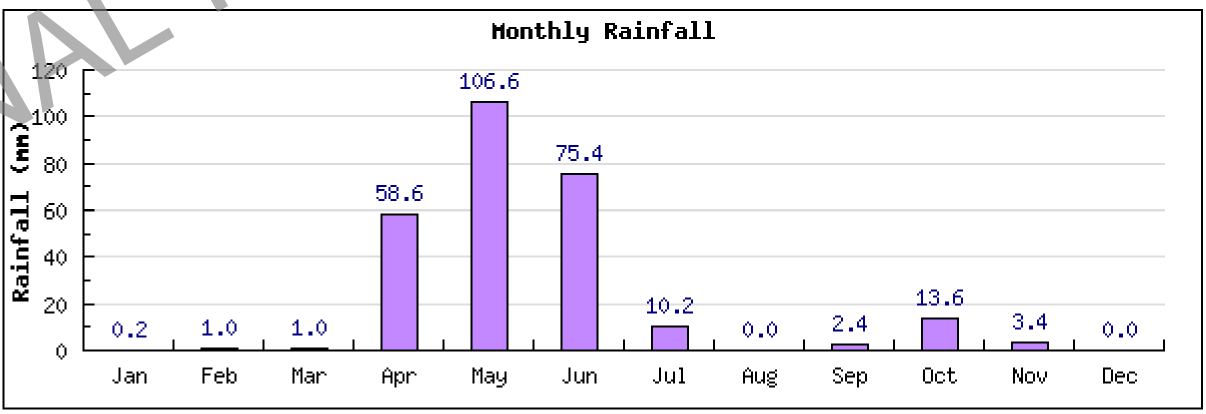


Figure 17: Buhuka Flats – Rainfall 2011 (iWeathar 2014).

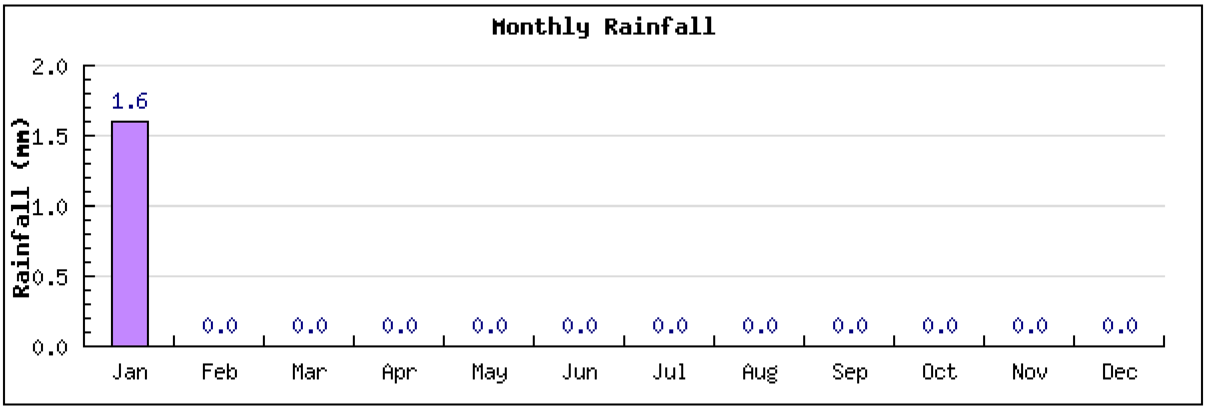


Figure 18: Buhuka Flats – Rainfall 2012 (iWeathar 2014).

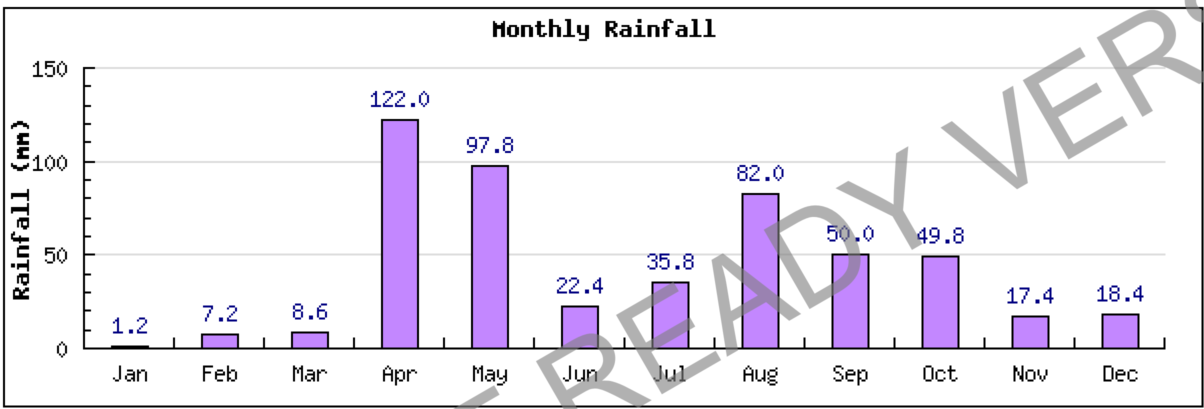


Figure 19: Buhuka Flats – Rainfall 2013 (iWeathar 2014).

3.8 Modelled meteorology

The Penn State University (PSU) / National Centre for Atmospheric Research (NCAR) meso-scale model is a limited-area, non-hydrostatic or hydrostatic (Version 2 only), terrain-following sigma-coordinate model designed to simulate or predict meso-scale and regional-scale atmospheric circulation. It has been developed at PSU and NCAR as a community meso-scale model and is continuously being improved by contributions from users at several universities and government laboratories. The Fifth-Generation PSU / NCAR Meso-scale Model is known as MM5 (PSU/NCAR 2014).

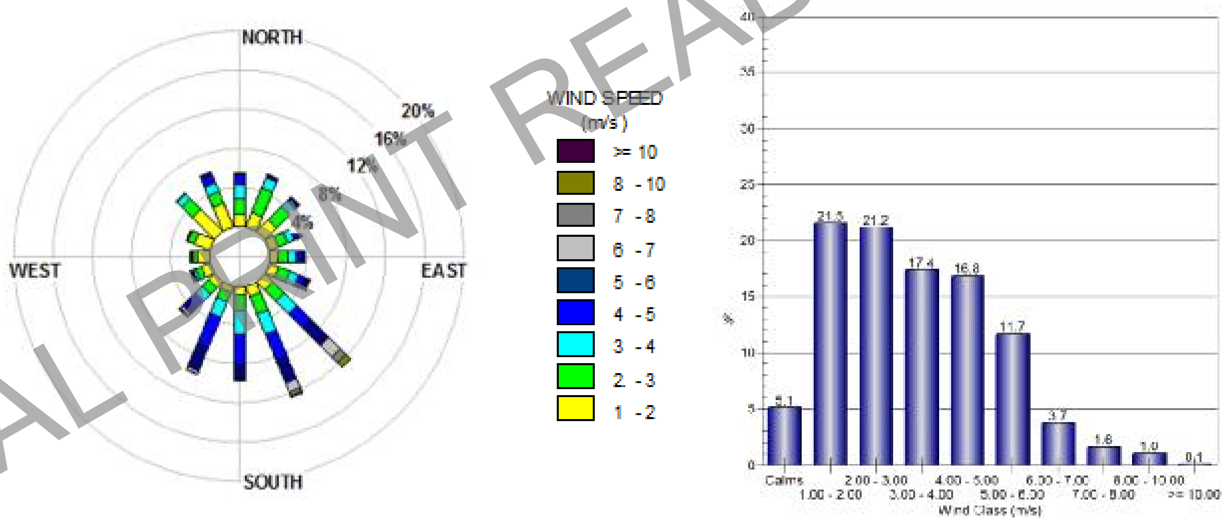
MM5 data for the Buhuka Flats for period 01 January 2011 to the 31 December 2013 was obtained for the purposes of this study, the data is assumed and expected to be representative of the actual meteorological conditions in EA3A.

3.8.1 Wind Roses

Predominant winds blew from the two sectors: SE to SSW (46% of the time); and NW (6% of the time). The average wind speed was 2.90m/s with 10% clams (Figure 20). Figure 21 shows diurnal variations in wind field, and Figure 22 seasonal variations.

Buhuka Flats (2011 to 2016)

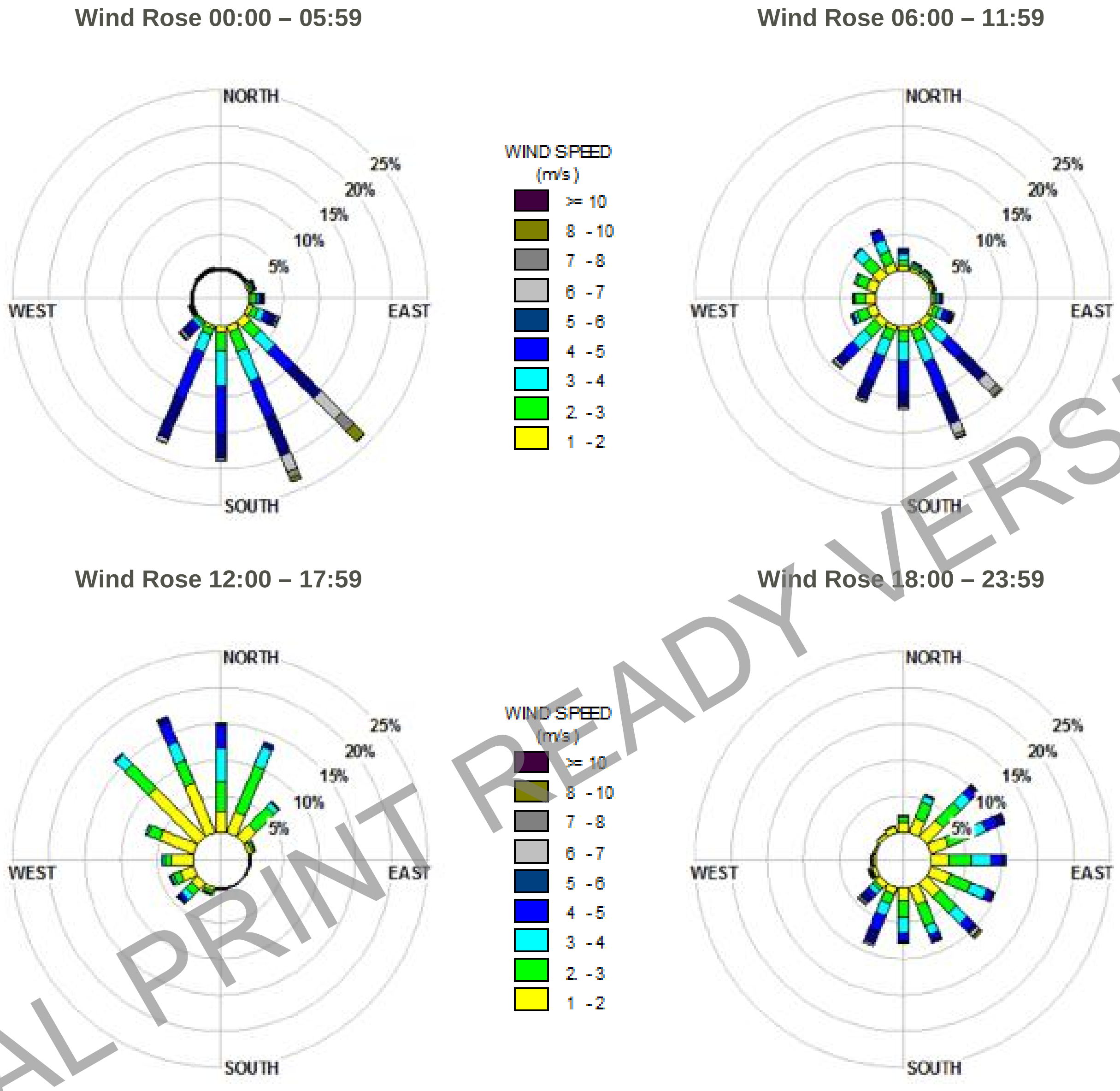
Wind Rose **Wind Classes**



Month	Wind Speed	Dominant Sector		Dominant Sector		Calms	Missing Data
2011-2016	3.2 m/s	SE-SSW	46%	NNW	6%	5.1%	0.0%

Figure 20: Period Wind Rose – Buhuka Flats 2011 - 2016.

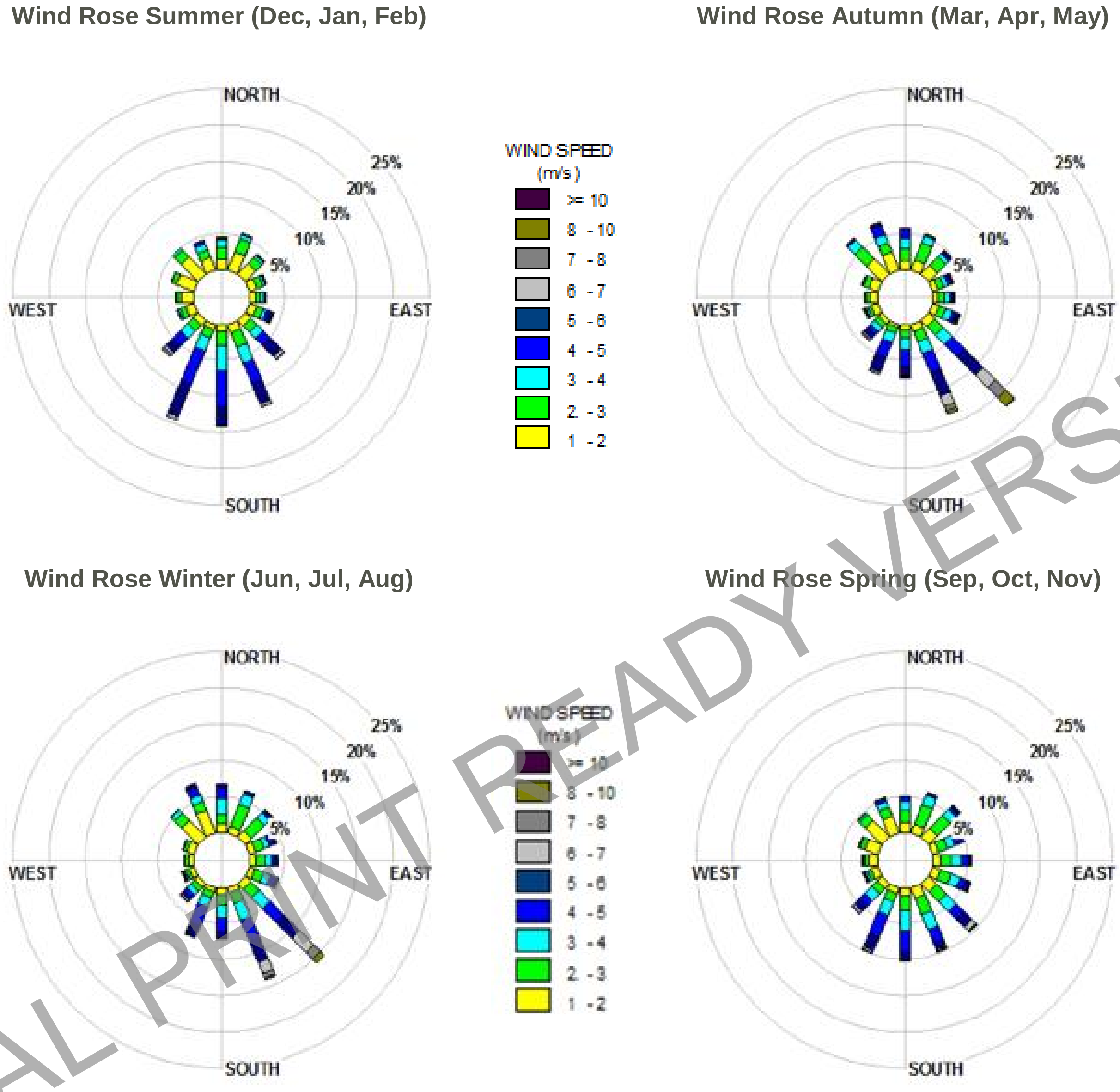
Buhuka Flats (2011 to 2016)



Time	Wind Speed	Dominant Sector		Dominant Sector		Calms	Missing Data
00-05	4.4 m/s	SE-SSW	84%	0	0%	1.2%	0.0%
06-11	3.6 m/s	SE-SW	66%	NNW	6%	3.1%	0.0%
12-17	2.0 m/s	N-NE	44%	WNW-NNW	42%	8.8%	0.0%
18-23	2.6 m/s	NE-SSW	83%	0	0%	7.2%	0.0%

Figure 21: Diurnal Wind Roses – Buhuka Flats 2011 - 2016.

Buhuka Flats (2011 to 2016)



Season	Wind Speed	Dominant Sector		Dominant Sector		Calms	Missing Data
Summer	3.0 m/s	SE-SW	58%	0	0%	5.0%	0.0%
Autumn	3.4 m/s	SE-SSW	47%	NW-NNW	15%	5.2%	0.0%
Winter	3.3 m/s	NNW-NNE	21%	SE-SSW	46%	4.7%	0.0%
Spring	2.9 m/s	NNE-NE	13%	SE-SSW	41%	5.4%	0.0%

Figure 22: Seasonal Wind Roses – Buhuka Flats 2011 - 2016.

3.8.2 Meteorological Cross Check

The MM5 data and valid local data overlapped in 2011 (Figure 23). A comparison of the two data sets, with correction for calms, produced a correlation coefficient (r) of 0.65. The following general categories indicate a quick way of interpreting a calculated r value:

- 0.0 to 0.2 very weak to negligible correlation;
- 0.2 to 0.4 weak, low correlation (not very significant);
- 0.4 to 0.6 moderate correlation;
- 0.6 to 0.8 strong, high correlation; and,
- 0.8 to1.0 very strong correlation.

The MM5 data is therefore deemed representative of the local meteorology.

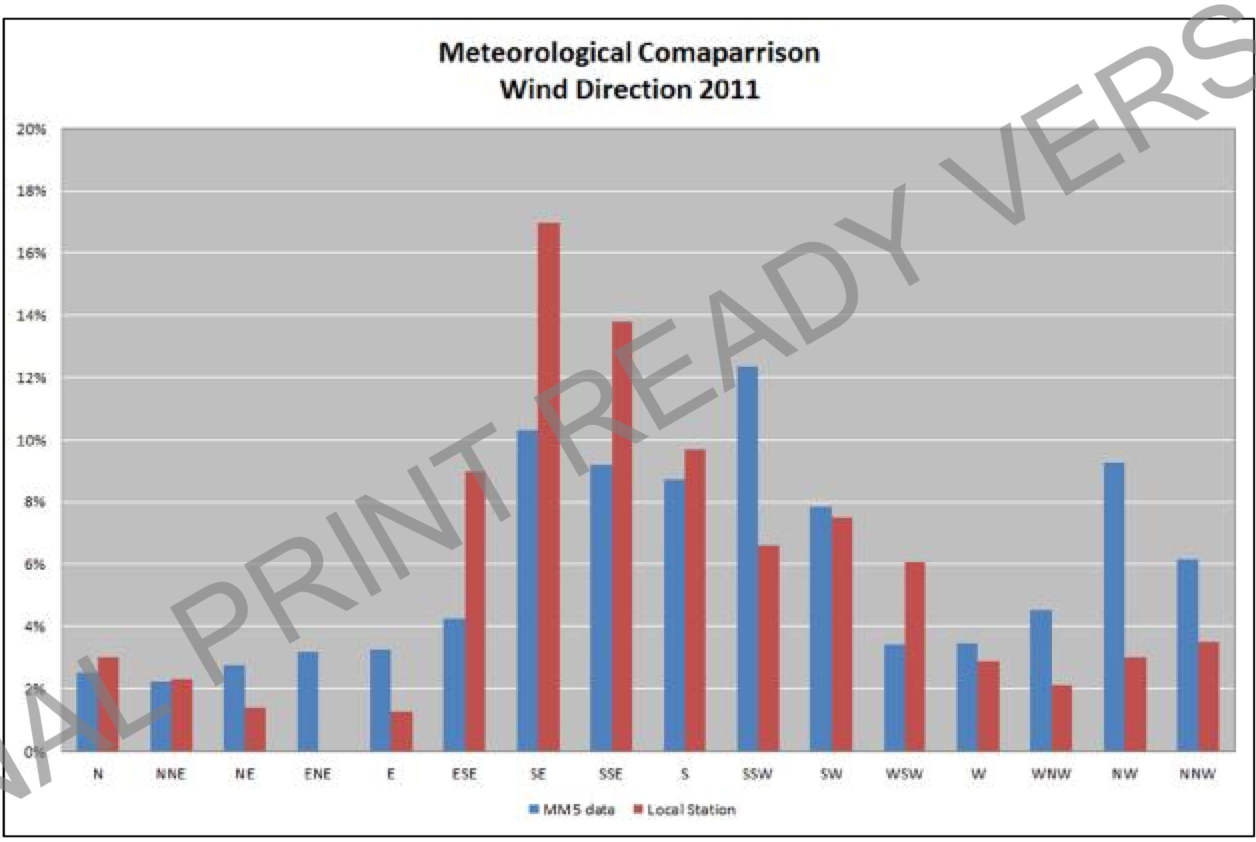


Figure 23: Meteorological cross check.

3.9 Ambient Air Quality Overview

Current air quality in EA3A was qualitatively assessed based on the local sources identified and the anticipated emissions thereof.

Potential sources of air pollution were identified to include:

- Agricultural activities;
- Mining activities;
- Oil Extraction and Refining;
- Domestic fuel burning;
- Biomass burning;
- Vehicle emissions (tailpipe and entrained emissions);
- Paved roads; and
- Unpaved roads.

3.9.1 Agricultural Activities

Land cover on the flats is predominantly grass and bush; subsistence farming is the dominant agricultural activity. The escarpment is covered by forest and bush land, it is often used as grazing area for livestock. The plateau contains a mixture of forest; bush land and farmland, there are both subsistence and commercial farms (tea).

Agricultural emissions are not anticipated to significantly influence the air quality in the area although particulate emissions may increase during the dry periods from fallow fields.

3.9.2 Mining Activities

The Albertine graben has a number of economic mineral resources, although there is not much detailed and accurate information on about the location and extent of the mineral deposits (NEMA 2010).

Mining activity within EA3A is limited and therefore not expected to have a significant on air quality.

3.9.3 Oil Extraction and Refining

Exploration and production activities so far indicate that the oil potential in EA3A is significant. The estimated scale of oil discoveries in the region as well as government policy on energy suggests the need for the construction of a fully-fledged oil refinery preferably within the Albertine graben. The preferred location of the refinery implies the need for construction of pipelines to transport crude and processed oil between production wells, processing facilities, refinery and markets (NEMA 2010).

Although there is currently no commercial oil extraction or refining in EA3A, indications are that there will most likely be in the near future. These activities can have a significant detrimental effect on air quality without appropriate mitigation measures. Potential air impacts that may occur as a result of the oil extraction and refining may be attributable to increased concentrations of:

- Criteria air pollutants (CAP), these include:
  - Sulphur Dioxide (SO_2);
  - Nitrogen Oxides (NO_X);
  - Carbon Monoxide (CO);

  - Particulate Matter (PM10, PM2.5 and TSP); and
  - Ozone (O_3).
- Toxic air contaminants (TAC), that cause or may cause cancer or other serious health effects, such as:
  - Hydrogen Sulphide;
  - Benzene;
  - Toluene;
  - Ethyl benzene;
  - Xylene; and
- Greenhouse gases (GHG), including:
  - Methane (CH4); and,
  - Carbon Dioxide.

3.9.4 Domestic Fuel Burning

The majority of the population in the Albertine graben use wood fuel as the most dominant source of energy. Kerosene or paraffin is used for lighting and less than 3% of all households have access to electricity supply. However, firewood has become scarce and most people have resorted to using charcoal which is often imported from elsewhere and is very expensive. At the moment, most of the Rift Valley area is not connected to the national grid. Individual companies involved in oil exploration have therefore had to invest in generators (NEMA 2010).

Domestic fuel burning of wood includes respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo (a) pyrene and formaldehyde. The main pollutants emitted from the combustion of paraffin are nitrogen dioxide, particulates, carbon monoxide and polycyclic aromatic hydrocarbons.

3.9.5 Biomass Burning

Biomass burning may be described as the incomplete combustion process of natural plant matter with carbon monoxide, methane and nitrogen dioxide being emitted during the process. During the combustion process, approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. In comparison to the nitrogen emissions, only small amount of sulphur dioxide and sulphate aerosols are emitted. With all biomass burning, visible smoke plumes are typically generated. These plumes are created by the aerosol content of the emissions and are often visible for many kilometres from the actual source of origin.

The extent of emissions liberated from biomass burning is controlled by several factors, including:

- The type of biomass material;
- The quantity of material available for combustion;
- The quality of the material available for combustion;
- The fire temperature; and
- Rate of fire progression through the biomass body.

General wild fires represent significant sources of combustion-related emissions associated with agricultural areas.

3.9.6 Vehicle emissions

Air pollution generated from vehicle engines (including motorised boats) may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly to the atmosphere as tail-pile emissions whereas, secondary pollutants are formed in the atmosphere as a result of atmospheric chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The primary pollutants emitted typically include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (including benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons), sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and particulates. Secondary pollutants formed in the atmosphere typically include nitrogen dioxide (NO_2), photochemical oxidants such as ozone, hydrocarbons, sulphur acid, sulphates, nitric acid, sulphates and nitrate aerosols.

The quantity of pollutants emitted by a vehicles depend on specific vehicle related factors such as vehicle weight, speed and age; fuel-related factors such as fuel type (petroleum or diesel), fuel formulation (oxygen, sulphur, benzene and lead replacement agents) and environmental factors such as altitude, humidity and temperature.

Given the population densities in the region, it is not anticipated that the contribution vehicle and boat exhaust emissions to air pollutant will be insignificant.

3.9.7 Wheel generated Dust on Unpaved Roads

When vehicles travel on unpaved roads; the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

Vehicle entrainment of particulates from unpaved roads is anticipated to be one of the dominant sources of particulate emissions in the region. Special attention in regards to mitigation of such emissions will have to be undertaken to prevent the deterioration of ambient air quality due to increased traffic.

3.9.8 Wheel Generated Dust on Paved Roads

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking lot; these emissions are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and re-suspension of loose material on the road surface. In general terms, re-suspended particulate emissions from paved roads originate from, and result in the depletion of, the loose material present on the surface (i.e., the surface loading). In turn, that surface loading is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and track-out from unpaved roads and staging areas. Various field studies have found that public streets and highways, as well as roadways at industrial facilities, can be major sources of the atmospheric particulate matter within an area.

Because the total coverage of tarmac road infrastructure in the area is limited vehicle entrainment of particulates from paved roads is anticipated to insignificant.

3.9.9 Summary of the Regional Air Quality

Based on the available information and the data analysed, it is anticipated that the regional air quality in the proposed project area is good, although may deteriorate periodically as a result of biomass burning.

3.10 Health Effects of Exposures to Various Pollutants

3.10.1 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a reddish-brown gas that can irritate the eyes, nose and throat and cause shortness of breath.

3.10.2 Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas that smells like burnt matches. It can be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defences, and worsening respiratory and cardiovascular disease.

3.10.3 Particulates (TSP, PM_{10}, $PM_{2.5}$ and dust fallout)

Atmospheric particulate matter also known as particulates or particulate matter (PM), are tiny pieces of solid or liquid matter associated with the earth's atmosphere. They are suspended in the atmosphere as atmospheric aerosol. Sources of particulate matter can be man-made or natural. They can adversely affect human health and also have impacts on climate and precipitation. Subtypes of atmospheric particle matter include total suspended particulates (TSP), respirable suspended particle (RSP; particles with diameter of 10µm or less), fine particles (diameter of 2.5 µm or less), ultrafine particles, and soot.

3.10.4 Hydrogen Sulphide (H_2S)

Hydrogen sulphide is considered a broad-spectrum poison, meaning that it can poison several different systems in the body, although the nervous system is most affected. The toxicity of H_2S is comparable with that of hydrogen cyanide or carbon monoxide. It forms a complex bond with iron in the mitochondrial cytochrome enzymes, thus preventing cellular respiration.

Exposure to H_2S has the following effects:

- 0.00047ppm or 0.47ppb is the odour threshold;
- 10ppm is the United States Occupational Safety Health Administration (OSHA) permissible exposure limit (PEL) (8 hour time-weighted average);
- 10–20ppm is the borderline concentration for eye irritation;
- 20ppm is the acceptable ceiling concentration established by OSHA;
- 50ppm is the acceptable maximum peak above the ceiling concentration for an 8 hour shift, with a maximum duration of 10 minutes;
- 50–100ppm leads to eye damage;
- At 100–150ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger;
- 320–530ppm leads to pulmonary oedema with the possibility of death;
- 530–1000ppm causes strong stimulation of the central nervous system and rapid breathing, leading to loss of breathing;
- 800ppm is the lethal concentration for 50% of humans for 5 minutes exposure (LC50); and,
- Concentrations over 1000 ppm cause immediate collapse with loss of breathing, even after inhalation of a single breath. Cortical pseudo laminar necrosis; degeneration of the basal ganglia and cerebral oedema have also been shown (WHO, 2000).

3.10.5 Volatile Organic Compounds (VOC's)

Volatile organic compounds (VOCs) are organic chemicals that have a high vapour pressure at ordinary room temperature. Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air. Harmful VOCs typically are not acutely toxic, but have compounding long-term health effects.

3.10.6 Summary

A summary of the health effects resulting from acute and chronic exposures to various is presented in Table 10 below.

Table 10: Acute and chronic health effects associated with exposure to the primary pollutants of concern.

Pollutant	Acute exposure	Chronic exposure
Carbon Monoxide	Severe hypoxia , can lead to death Headaches, nausea & vomiting Muscular weakness Shortness of breath	Neurological deficits and damage
Particulate matter	Airway allergic inflammatory reactions & a wide range of respiratory problems Increase in medication usage related to asthma, nasal congestion and sinuses problems Adverse effects on the cardiovascular system Increase in hospital admissions Increase in mortality	Increase in lung problems with lower respiratory symptoms Reduction in lung function in children and adults Increase in chronic obstructive pulmonary disease Reduction in life expectancy Reduction in lung function development
Sulphur dioxide	Reduction in lung function Respiratory symptoms (wheeze and cough) Increase in hospital admissions Increase in mortality	Increase in respiratory symptoms Reduction in lung function, especially in asthmatics and children Reduction in life expectancy Increase in mortality
Nitrogen dioxide	Effects on pulmonary function, especially in asthmatics Increase in airway allergic inflammatory reactions Increase in hospital admissions Increase in mortality	Reduction in lung function Increased probability of respiratory symptoms Reduction in life expectancy Increase in mortality
Benzene	Adverse effects on the cardiovascular system and central nervous system Increase in mortality	Neurological damage Damage to cardiovascular systems Reduction in life expectancy Increased prevalence of carcinomas in the community Increase in mortality

4.0 IMPACT ASSESSMENT

4.1 Development Description and Proposed Infrastructures

Figure 24: Project main infrastructure.

The Kingfisher oilfield comprises of four onshore well pads where all the development wells will be drilled. Among those four well pads, three currently exist and require upgrade to meet requirements for oil production. The well-fluids shall be transported to a Central Processing Facility (CPF) via flowlines from individual well pads. The well-fluids shall be processed in the CPF to separate formation water and associated gas from the oil phase. The stabilized crude will be transferred about 50km through a pipeline to Kabaale, where the refinery will be located.

For the field development, CNOOC will build a range of producing and supporting facilities to achieve 40,000 barrels of oil per day. The subsurface construction will include a total of 40 wells (27 production wells and 13 injection wells); and the surface construction will include well-pads, production flow lines and water injection flow lines, an oil feederpipeline, a central processing facility, a lake water extraction station, camps, a jetty, an airstrip and access roads among others. The proposed main infrastructures for the Kingfisher Project are described in the sections below and illustrated in Figure 24.

For the first year of development, the field production target is to reach 20,000 BOPD, and it is planned to use the two re-completed existing wells plus 5 producers (two of them will be inject water one year later) and 1 injector. At the start of the second year the target was raised to 30,000 BOPD, during which a re-completed existing well, further 5 producers (one of them will inject water one year later) and 1 injector will be added. Then, with 5 producers and 2 injectors coming on stream, the third year target was set at 40,000 BOPD and maintained as a plateau. Thereafter, another 18 wells will be brought into production to sustain plateau.

The annual produced oil and water volumes over 25 years for the base case development scenario are illustrated in Figure 25 below.

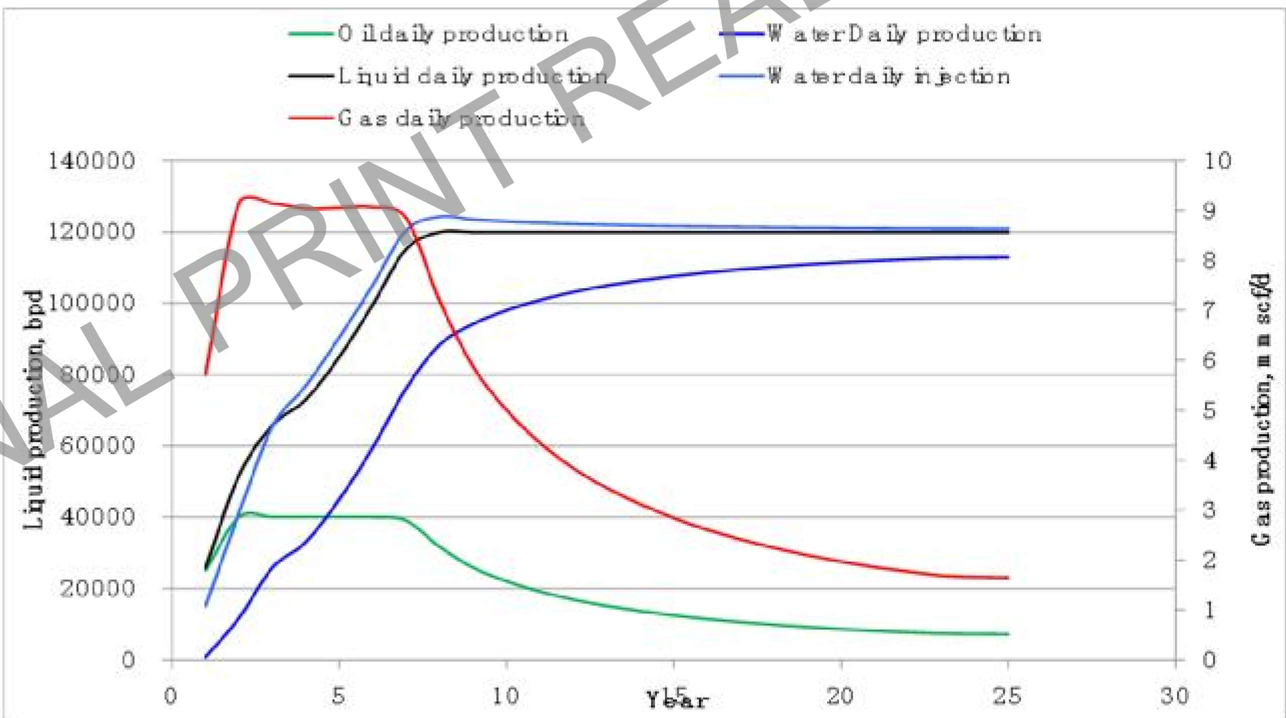


Figure 25: Production profiles for the Kingfisher oil field.

The 40,000 BOPD plateau can be sustained for almost 6 years, before increasing water cut renders the wells incapable of sustaining the target oil rates. Total fluid off-take reaches a maximum 120,000BLPD in the tenth year.

The total lifespan of Kingfisher field is 25 years.

4.1.1 Well pads for drilling and production

A base case development scenario of 40 wells has been identified. The final development will at least consist of 27 production wells and 13 water injection wells. It is proposed that all the wells will be drilled and completed from onshore utilizing the four well pads including three (3) existing exploration well pads. It should be noted that the onshore well count includes the three existing and suspended wells (Kingfisher-1, Kingfisher-2 and Kingfisher-3) which will be recompleted as production wells.

4.1.1.1 Well pad locations

Well pad coordinates (existing and proposed) are presented in Table 11; the locations of the pads are indicated in Figure 24.

Table 11: Existing and proposed well pads co-ordinates.

Description	X (UTM 36 N m])	Y (UTM 36 N [m])	Z (Elevation [m])	Size (m)
Well Pad 1 (existing)	248581	137907	624	Approximately 200 x 100
Well Pad 2 (existing	249548	138818	631	
Well Pad 3 (existing)	247512	136116	626	
Well Pad 4A	250265	139737	638	

4.1.1.2 Well pads for drilling

All 30 wells are proposed to be drilled from five onshore well pads: Pad 1, Pad 2, Pad 3, and Pad 4A. Amongst those well pads, Pad 1, Pad 2 and Pad 3 are already existing pads. A typical pad for drilling will be approximately 200m by 100m in size, these will be fenced facilities.

Figure 26: Example of the type of rig to be used. Photo indicated exploration drilling on Buhuka Flats.

During the drilling phase, a typical well pad will include a rig and auxiliary facilities such as such as drill wastes pits, a fuel tank storage area, a drilling fluids preparation area, mud tank, flare pits for emergency use, control rooms and fence. All five well pads including the three existing well pads will be constructed and / or upgraded to meet development well drilling requirements.

4.1.1.3 Well drilling

All the wells will generally be drilled using synthetic based muds from the pads down to the turning point and then directed towards the subsurface target as indicated in Figure 27. The wells will be drilled to a depth of more than 2000m, below Lake Albert.

There are currently three exploration/appraisal wells on Kingfisher which have been suspended following the well tests conducted. These wells were drilled as deviated wells out under the lake to intersect their reservoir targets from three drilling pads which were constructed on the shore of Lake Albert.

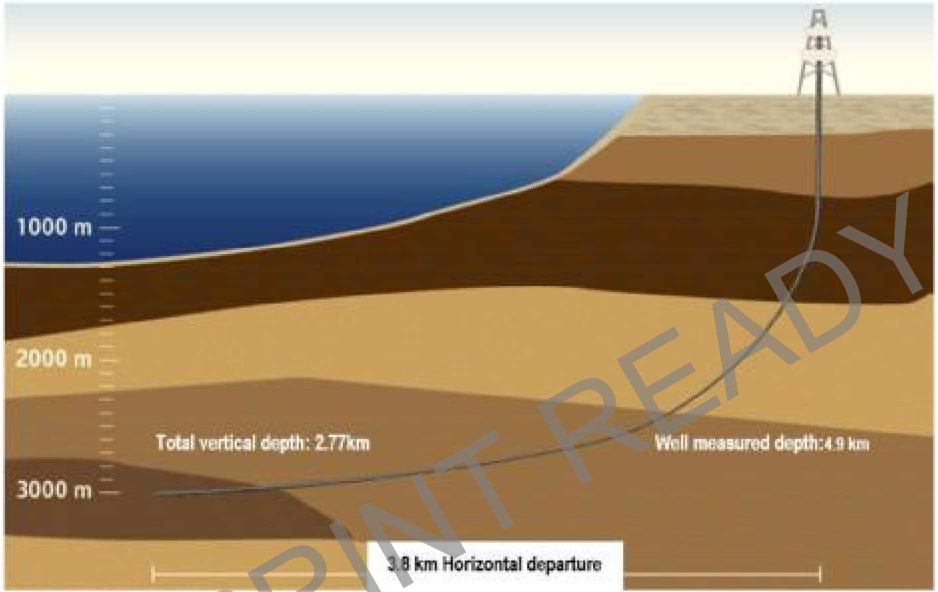


Figure 27: An illustration of directional drilling.

The following rig specifications or similar can be used as a basis during the tendering phase for a capability to drill the aforementioned wells:

- Mast: 450mt;
- Draw works: 2000HP, mechanical and electrical breaking systems with regenerative breaking;
- Top Drive: 450mt, >46,300ft.lbs, 150 rpm;
- Mud Pumps: 3 x 1,600 HP;
- Tank System: 600m^3 active, kill mud 20m^3;
- Pressure Control: minimum 5,000 psi BOP with 2,000 psi annular, mud gas separator;
- Power Pack: diesel generators, 6,000KW; and
- Drilling pipe: 5-1/2" or 5-7/8".

Normally it takes about 2~4 months to drill one well depending on measured depth and the deviation angel of the well. Well pad construction will be prior to the drilling operations.

4.1.1.4 *Well pads for oil production*

After well completion, the rig and the auxiliary facilities will be removed and feeder field pipeline will be installed to conduit the crude from the well to CPF. Some minor adjustments in the well configuration design may be adopted to factor in the infrastructural changes. Normally, each well pad comprises:

- Production and water injection manifolds;
- Production and test MPFM;
- Pig Launcher/Receiver;
- Chemical injection system;
- Closed drain system; and
- Technical room to accommodate instrumentation, telecom, and electricity devices etc.

A production manifold shall be installed at each well site to gather produced fluids from the production choke valve on each Christmas tree (well head) via the individual well flowline. A test manifold shall also be provided to allow well testing to occur without interrupting production. The individual well flowlines shall be provided with manual block valves to divert produced fluids from production to test manifolds.

A water injection manifold shall be installed at each well site to deliver high pressure water for injection to the water injection choke valve on the Christmas tree via individual well flowlines. The individual well flowlines shall be provided with a manual block valve and a flowmeter.

All individual well flowlines and manifolds shall be heat traced and insulated for heat conservation. Its design shall allow for drilling rig to move between different slots without shutting down production from the well pad. The well pads are designed as normally unmanned. Firefighting philosophy will also be defined for drilling and completion operations and work over operations and normal production on the well pads.

4.1.2 Flowlines

The well-fluids (mixture of gas, crude and water, etc.) from the Kingfisher Field will be sent to the CPF (as described above) via infield flowlines from individual well pads. The flowline inside diameters vary from 6" to 12" depending on detail design. The production flowlines, the water injection flowlines and the water intake flowline will be constructed using carbon steel to ISO 3183 (API 5L).

The flowlines schematic is shown in Figure 28 below.

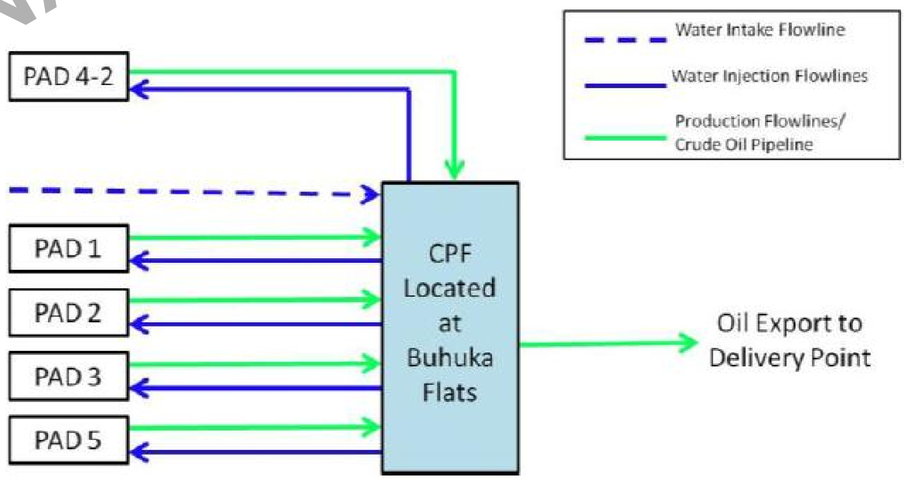


Figure 28: Flowlines schematics.

The flowlines shall be heat traced, possibly with Skin Effect Heat Tracing (SEHT), and insulated for heat conservation. The flow line shall be buried, and the buried depth shall be based on the standard requirements. An impressed current cathodic protection system shall be provided. The flowlines and cables shall be installed in a single trench, with each trench containing:

- Produced well fluids flowline. This shall be buried, trace heated, insulated, and piggable;
- Injection water flowline. This shall be buried, insulated, and piggable;
- Electricity power cable (unless overhead cable transmission is selected);
- Telecommunications FOC (Fibre Optic Cable).

It is envisaged that the power cable and FOC shall be bundled into a single umbilical (with redundancy for both services).

4.1.3 Central Processing Facility

The well-fluids from the Kingfisher field will be sent to a Central Processing Facility (CPF) on the Buhuka flats. The well-fluids will be processed in the CPF to separate formation water and associated gas from the oil phase. The oil will be stabilized, desalted and dehydrated to meet the product specification.

Associated gas will be separated at the CPF and utilized in priority for field requirements such as fuel gas for power generation, heating system and other utilities. The opportunities to utilize any excess associated gas that cannot be utilized within the CPF will be determined by Government of Uganda during the detail design of the CPF including:

- Supply of gas to other third party power producer integrated with all the developments in Lake Albert Area;
- Excess power export to other users; and
- Liquefied Petroleum Gas (LPG), or any other possibilities of gas utilization.

Produced water from separators is required to be treated in three stages of separation to achieve the injection water specifications. Produced water along with treated lake water from the CPF will be injected into the reservoir. Lake water will be pumped to the CPF via a dedicated flow line running from the Lake Albert intake facilities.

The equipment sparing requirements shall be confirmed during the detailed design for CPF.

4.1.3.1 CPF Location

The CPF will be located within the Buhuka Flats at the position as indicated in Figure 24 with the coordinates for the centre of the facility being E249, 819 and N137, 863 with the area of the CPF covering an area of 280,000m^2. A detailed baseline of the proposed location and factors in the determination of the exact location as well as analysis of alternatives will be undertaken in the ESIA and presented in the ESIS.

4.1.3.2 CPF Capacity

The processing facilities will be designed with the following capacities:

- Oil: 40,000 BOPD (1,991,878 tpa)
- Gas: 10.6 MMSCFD (63,224 tpa)
- Produced water: 110,600 BWPD
- Gross liquids: 120,000 BLPD

- Water Injection: 124,500 BWPD
- Make-up water: 40,000 BWPD

The facilities described here are designed for a stand-alone development of the Kingfisher field, and sized on the data currently available for this field. Actual capacities of the surface production facilities may be in practice different as they will be selected in a context of regional optimization of field developments in the area. Detailed capacity and design shall be included in ESIA.

4.1.3.3 Typical CPF Layout and main components

This section introduces the construction components of a typical CPF. The typical layout of the CPF is indicated in Figure 29.

Figure 29: Layout of the Central Processing Facility (CPF) in relation to other facilities

For a typical CPF, it shall include:

- A 2-stage production separation train;
- Associated gas compression;
- Electricity generation;
- Electrical switchgear and distribution equipment; Produced water and lake water treatment and pumping facilities;
- Produced oil and off-spec oil tankage;
- Diesel fuel tankage;
- Transmission pipeline pump station;
- Transmission pipeline pig launcher station;
- Flowline pig receivers station;
- Oil production manifold;
- Water injection manifolds;
- Chemical injection facilities;
- Safety Flare system;
- Open and closed drains systems;
- Station piping and valves;
- An Integrated Control Safety and Shutdown System (ICSS);
- Safety equipment at the plant shall include fire and gas detectors, fire water storage, a fire water ring main and hydrants and monitors, CO2 system, fire station equipped with fire engine(s) (if required), etc.;
- Plant air system;
- Inert gas system;
- Impressed current CP system;
- Equipment earthing system;
- Field instrumentation, including flow metering;
- An air-conditioned, manned control room;
- Area lighting;
- CCTV;
- Security structures, fencing and barriers;
- Maintenance workshop;
- Office and administrative Facilities; and,
- Laboratory.

4.1.3.4 Electricity Generation and Distribution System

Electricity shall be generated at the Kingfisher CPF. The electricity generation system at CPF shall comprise:

- Generators;
- MV switchgear;
- HV switchgear.

The electricity distribution system shall comprise:

- Transformers and switchgear at CPF to power CPF requirements and the pump station for the CPF-Kabaale export pipeline;
- Cables from CPF to each of the well pads, and transformers and switchgear at each well pad;
- A cable from CPF to the Water Extraction Pump Station, and a transformer and switchgear at the pump station;
- A cable from CPF to Kabaale with connections to each intermediate heating station and isolating block valve station along the route of the CPF-Kabaale pipeline. Each connection shall include a local transformer and switchgear;
- A cable from CPF to the Permanent Operators' Accommodation Camp; and
- A transformer, switchgear and distribution system at the Permanent Operators' Accommodation Camp.

4.1.3.5 Water Abstraction and Injection

The water injection requirements cannot be met by produced water reinjection alone; hence an additional source of water is required. A water intake system requirement and optimization study shall be carried out during the detail design. According to the nature condition of Lake Albert, the lake water intake system will be built at the lake edge. The preliminary location is at E249, 658.00 and N138, 950.00.

The water intake system shall comprise: A combined concrete water intake pump-house structure close to the shore line incorporating a pump basin, a silt collection basin and trash screen section and pump-house. The depth of the structure would be set to cover the range of design lake water levels and the pump basin depth set to ensure pump performance at the minimum lake level. Issues and suggested approach include, but are not limited to:

- A water transfer pipeline to transfer water from the intake pump station to the CPF water treatment facilities;
- Chemical injection package at the intake facility;
- Equipment earthing system at pump station;
- Field instrumentation at pump station;
- Area lighting at the pump station;
- CCTV at the pump station;
- Security fencing at the pump station.

Lake water shall be transferred to the CPF where it shall be de-aerated, filtered, chemically treated (if necessary), and mixed with produced water. The mixed water shall be heated and pumped to the well pad cluster sites for injection into the reservoir.

The water abstraction point is located near Pad 2.

4.1.3.6 Instrumentation and Control System

The Kingfisher Field Development instrumentation and control is segregated into onsite requirements, i.e. Central Processing Facility (CPF), pumping station & Kabaale facility and offsite requirements, i.e. Well pads, valve manifold and pigging stations, block valve station, flowlines and crude oil transmission pipeline.

Overall control of the Kingfisher oil production and transmission system shall be from the manned Central Control Room (CCR) at the CPF.

The Kingfisher Field development project shall be equipped with an Integrated Control & Safety System (ICSS) comprising:

- Process Control System (PCS);
- Emergency Shutdown system (ESD);
- Fire and Gas Detection System (FGS);
- Supervisory Control and Data acquisition system (SCADA);
- Human Machine Interface (HMI).

The ICSS equipment and Operator workstations installed in the CCR at the CPF shall enable the operator to monitor and control the SCADA, PCS, ESD and FGS. A subset of ICSS shall also be located in the Kabaale Tie-in to facilitate exchange of monitoring & control signals to CPF CCR.

Operator Work stations (OWS) shall enable monitoring and control of the entire CPF, and associated well pads, flowlines and manifolds. The OWS shall also display ESD system and FGS data and alarms, and provide access to the safety functions of the ESD & FGS.

An Instrument Equipment Room (IER) adjacent to the CCR shall house all the system and marshalling cabinets and some mechanical package Unit Control Panels (UCP), e.g. Compressor UCP. Under normal operating conditions the operator shall monitor and control the packages from the ICSS operator stations in the CCR.

The primary source of process information shall be provided by field instrumentation capable of measuring all physical process parameters. Sufficient instrumentation shall be provided to allow all necessary control and safety functions to be carried out.

The ICSS shall have a seamless integration of all instrument systems to serve plant monitoring, control, safety and operations of the facilities, including those off-sites. As a minimum the following systems shall be interfaced:

- Crude oil Metering at CPF and Kabaale;
- Machine Monitoring System (MMS);
- Pipeline Leak Monitoring System (PLMS);
- Electrical Switchgear/ Motor Control Centre;
- Unit Control Panels (UCPs);
- 3rd Party package Units.

The control and monitoring facilities shall be distributed across a number of different locations:

- RTUs at remote Gathering Facilities (Well pads);
- CCR/ LERs at the CPF;

- RTU at pipeline Block Valve Station;
- RTUs and Heat tracing controllers at Intermediate Power Feed Stations along the Transmission Pipeline;
- RTU at Kabaale.

4.1.4 Feeder Pipeline

A buried crude oil pipeline about 50km long with a width of approximately 12”~14” (and requiring a servitude of approximately 30m[3]) with Block Valve Station (BVS) on the escarpment is proposed for the oil feedfrom CPF to the delivery point. The block valve proposed to be installed at the top of the escarpment for the following reasons:

- If the oil pipeline is damaged between the BVS and the CPF there is potential for the whole of the contents of the pipeline to backflow down the escarpment to the leak point. The block valve, which can be remotely operated from the CPF, shall significantly reduce the amount of oil that could emanate from such a leak.
- Given the pressure head created by the escarpment, the pressure rating of the section of the pipeline between CPF and the BVS is significantly higher than the pressure rating of the pipeline downstream of the BVS. The block therefore forms a natural break point between the two pressure ratings.

In addition to the BVS at the top of the escarpment, one further BVS shall be provided with located on the CPF to Kabaale pipeline. The proposed route of the pipeline is shown in Figure 30.

The crude oil pipeline will be insulated with a minimum thickness of PUF insulation (or similar material) and a skin-effect heat tracing system (SEHT) to achieve and maintain flowing temperatures at or above pour point plus 5 degrees Celsius (5°C). The oil feeder pipelinewill be constructed using carbon steel to ISO 3183 (API 5L). This material is suitable for this service of transporting sales quality crude oil.

A power cable running parallel to the crude oil pipeline will provide power to the intermediate heating stations along the crude oil pipeline route. A fibre optic capability will also be provided as part of the SCADA system between the Central Control Room (CCR) in the CPF, the BVS and the delivery point.

Electricity shall be generated at the Kingfisher CPF. A high voltage transmission cable (buried and installed in the same trench as the oil feederpipeline) routes from Kingfisher CPF to Kingfisher Block Valve Station and on to Kabaale, with connections to each intermediate heating station and isolating block valve station along the route of the feederpipeline. Each connection shall include a local transformer and switchgear.

Pipeline Leak detection System (PLDS) will be provided for crude oil transmission line from CPF to the delivery point, which would be integral component of ICSS.

The SCADA system at the CPF will interface the remote controlled block valve station located along the crude oil pipeline to the delivery point. The SCADA system will also interface with the off-plot heat tracing power feed station controllers to enable the CCR operators to control and monitor the heat tracing temperature.

[3] This will be updated for optimization during the FEED design.

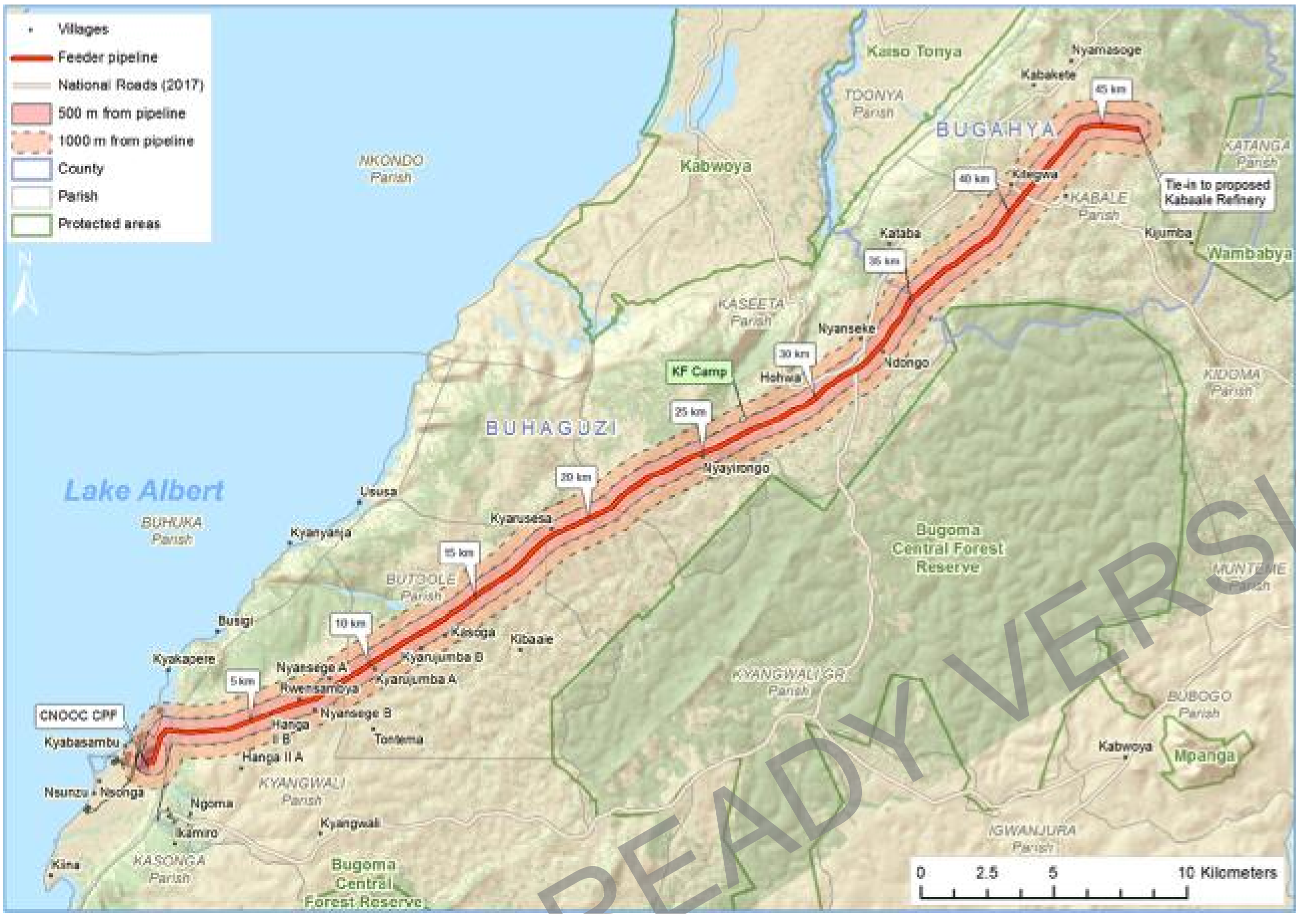


Figure 30: Location of the feeder pipeline

4.1.5 Supporting Infrastructures

4.1.5.1 Access roads

Escarpment Road - The Escarpment Road is a subject of a separate ESIA process; nonetheless, it is one of the components of the Kingfisher field development project. The proposed Escarpment road will start at the Ikamiro village on the escarpment top and ends around well pad 2 on the flat. From Ikamiro village to the base of the escarpment, there is no road and this is where access to the Kingfisher Area is required.

The total length of the proposed escarpment road is approximately7 kilometres long and 9 metres wide including shoulders. It is proposed that the road will be of a double base bituminous surface standard. Approximately 150 persons will be employed during the preparation and construction phase to include skilled and semiskilled labour. The supporting facilities of the road will include two construction camps, crusher plant and bitumen storage-area, spoil-areas; borrow pit and water abstraction points.

In field Roads -The proposed infield roads will subsequently provide access to the well pads, drilling and permanent camps and to the CPF. The location of the proposed infield/ access roads is presented in Figure 24. Since the road network is required in place way before the actual field development program to support pre-field development planning activities, a separate ESIA has been undertaken to ensure earlier approval of such important long lead infrastructure.

4.1.5.2 Airstrip

CNOOC has undertaken maintenance civil works on a light aircraft airstrip in Kyabasambu village. The existing airstrip obtained regulatory approval from an EIA prepared for Kingfisher-1 oil exploration well, and was subsequently constructed in 2006. Further upgrade of this airstrip may be considered during the kingfisher field development. The location of the proposed Airstrip is presented on Figure 24. A detailed description of proposed upgrade activities will be presented in the ESIS.

4.1.5.3 Camps and materials yard

All of the proposed camps and materials yards will be built outside of the lake protection zone, i.e. beyond 200 meters of the lakeshore.

4.1.5.3.1 Camps

Currently, there is an existing Bugoma drilling camp in Kingfisher that accommodates the crews undertaking field planning and rehabilitation of some field infrastructure ahead of the anticipated field development program. Kingfisher field construction and the production phase will however necessitate a number of various crews that will undertake among other activities, the construction and upgrade of the necessary infrastructure (pipeline, CPF, well sites among others), drilling, production and processing, management of crude feedalong the pipeline and other support service contractors. These activities are intensive and necessitate resident specialized crews to be accommodated in proximity to their work stations. Since however, the temporal occupation of the various crews is not uniform and only dependent on the lifespan of the particular project component, there is a consideration to have more than one camp for the project to include:

a) The drilling crew camp (drilling camp) – which is the existent current Bugoma camp located on a footprint measuring about 7 acres (185m x 185m) in Kyabasambu Village. The camp can accommodate a maximum of about 250 people.

   The permanent ooperators' aaccommodation Camp (production camp) - this will be similar to the drilling camp however with more permanent facilities. Based on initial estimates the camp would be sized for around 220 personnel (approximately 200m x 150m) and would include operational, maintenance, support, security and Well Work over personnel. The drilling crew workforce is not included as a separate camp will be provided as mentioned;

b) Two temporary construction camps will be required: One is dedicated to the CPF and in-field facilities. The site area is approximately 520m x 500m. The other is associated with the crude oil pipeline construction. The site area is approximately 250m x 150m. The estimate for the area size is preliminary and shall be final determined during detail design.

- The CPF and In-field Construction camp would be located on the Buhuka flats north of the CPF. The camp will comprise accommodation, messing and welfare facilities for the labour force undertaking the construction and commissioning work. An initial camp will be provided at the commencement of the project for the site enabling and early works, but would then be extended as the project progresses and the workforce increases.
- Another construction camp dedicated to the construction of the feeder pipelinefrom Kingfisher CPF to Kabaale would be provided. This construction camp would be significantly smaller than the main Kingfisher Construction camp. The exact location of the camp would be determined at a later stage of the project and would be dependent upon the selected construction sequence. Due to the relative short length of pipeline, a single accommodation and welfare facilities for the pipeline construction team would be provided, ideally around the mid-way point of the route. The pipeline accommodation camp would be fully self-sufficient comprising power generation, water treatment and sewage and waste disposal.

A typical camp shall have:

- Air-conditioned housing of varying grades with ablution facilities;
- Refectory messing facility (with food and drink storage facilities);
- Laundry facilities;
- Sick bay and first aid medical facility;
- Recreational & sports facilities (indoors and outdoors);
- Communications facilities;
- Area flood lighting;
- Camp office warehouse and maintenance facility;
- Electrical transformer, switchgear, and distribution system;
- Stand-by emergency diesel powered electrical generation;
- Potable water production and storage facilities;
- Sewage water treatment plant;
- Security gatehouses and fencing;
- Internal access roads, footpaths and parking areas.
- Fuel Station
- Vehicle maintenance house and washing bay
- Fire fight station, fire detection and fire-fighting system
- Waste storage and packing area
- Emergency Alarm system and PA system
- Smoking Area
- Training room
- POB and Accommodation management System and access control system.

A typical layout of workers' camp is shown below:

Figure 31: Layout for a typical workers' camp.

Another proposed consideration is to uphold and upgrade the camp used for the escarpment road construction at the escarpment top in Ikamiro village. The motivation for this proposal is because of its strategic position to effectively purpose as:

i) A security watch tower – the proposed camp on the escarpment is about 388m above the Kingfisher production field (Buhuka flats) giving a strategic watch height for the entire Kingfisher production area and beyond into the lake. This is important for security management especially that the production fields are on the shores of a cross border lake thus vulnerable to external intrusion.

ii) Evacuation base – In case of an evacuation emergency of security or catastrophic nature, this camp could provide a safe haven for the operating crews in the flat by virtue of its elevation above the flats. Evacuation would be easier especially that the camp will be connected to the flats by a paved escarpment road.

iii) VIP stopover – The camp would also act as a stopover for very important people visiting the kingfisher field to enable security and safety reassurance down in the production area.

A typical and proposed camp location and layout is presented in Figure 24 and Figure 31 respectively and will be confirmed during the ESIA. A more detailed assessment of the proposed camp sites will be undertaken during the ESIA.

4.1.5.3.2 Materials yards

Two material yards are proposed to be constructed in Kingfisher to separately accommodate the drilling and construction equipment and material supplies respectively.

One of the proposed materials yard to be located near to the northern edge of Bugoma Camp is intended to provide logistical support to operations of the proposed drilling operations. Another similar materials yard will be located near the CPF for production and EPC contractor camp. The yard will have a land requirement of approximately 200x200 meters, all levelled and compacted with murram. A detailed description of the components at the yard will be presented in the ESIS.

Construction of the storage yards will entail stripping away of the overburden, placing murram and compacting to create a firm flat surface suitable for supporting heavy equipment. The overburden will be stockpiled for future use during site restoration.

The layout for a typical materials yard is shown in Figure 32 below:

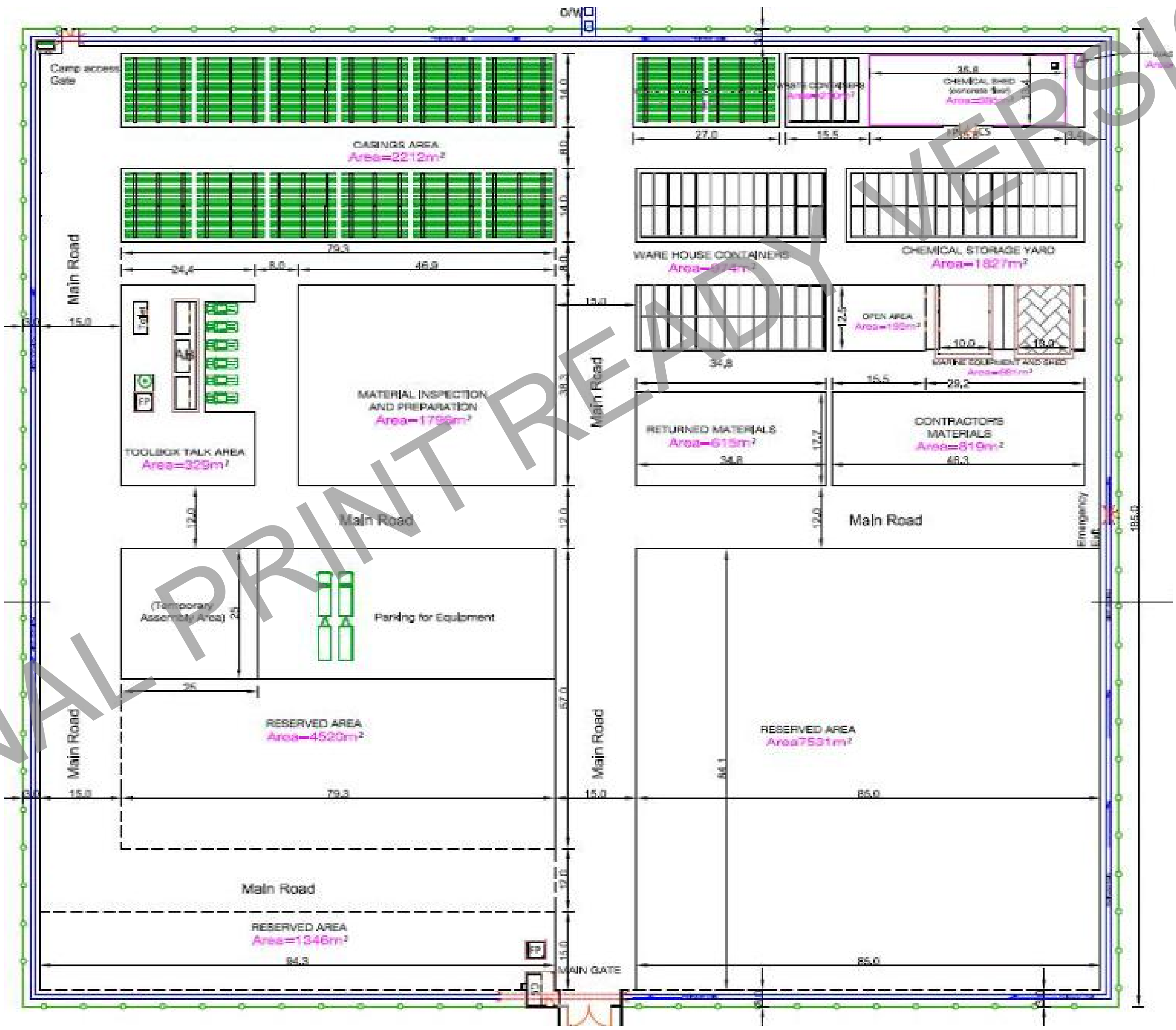


Figure 32: Layout for a typical materials yard.

The location of the material yards are also shown in Figure 24.

4.1.5.4 Jetty

CNOOC has rehabilitated (rehabilitation was permitted separately under a project brief)) the existing jetty adjacent to Bugoma drilling camp in Kyabasambu village to facilitate the movement of personnel, materials and equipment during the Kingfisher field development project. The jetty was constructed in 2006 by Heritage Oil & Gas (Uganda) Limited to facilitate Kingfisher-1 exploration well drilling operations. Since that time, no maintenance works had been undertaken on the jetty thus was dilapidated. Further upgrade that may be considered during the kingfisher field development will be described in the ESIS.

4.1.6 Proposed construction activities

All infrastructural developments listed above will entail construction activities that shall include in general:

a) Ground clearance and levelling of the specified sites

b) Excavation and laying of the foundations to host the installations

c) Installation of pertinent infrastructural components particular to the respective facility.

d) Linking of support infrastructure (access roads, water and power lines) to the respective facility.

Normally in the construction phase, bulldozers, excavators, dump trucks, vibrating roller, crane and other equipment and machines will be used. Construction materials including murram, sand, cement, steel and wooden post among others might be sourced outside of Kingfisher field.

Specific in-depth description and assessment of construction activities, number of equipment and personnel, and quantity of construction materials will be undertaken for the particular construction activities of the facilities in the ESIA.

4.1.7 Overview of the implementation phases of the project

This project will mainly involve three phases: Preparation phase, Construction phase, and Operation phase. During the preparation phase: a range of geophysical survey, planning and designing work will be done. During the construction phase, a range of well pads, wells, pipelines, central processing facilities, camps, airstrip, road, jetty, and other infrastructural support facilities will be constructed.

It should be noted that drilling operations of development wells shall continue after the onset of the first oil production. Therefore the construction phase and operation phase will overlap (Figure 33).

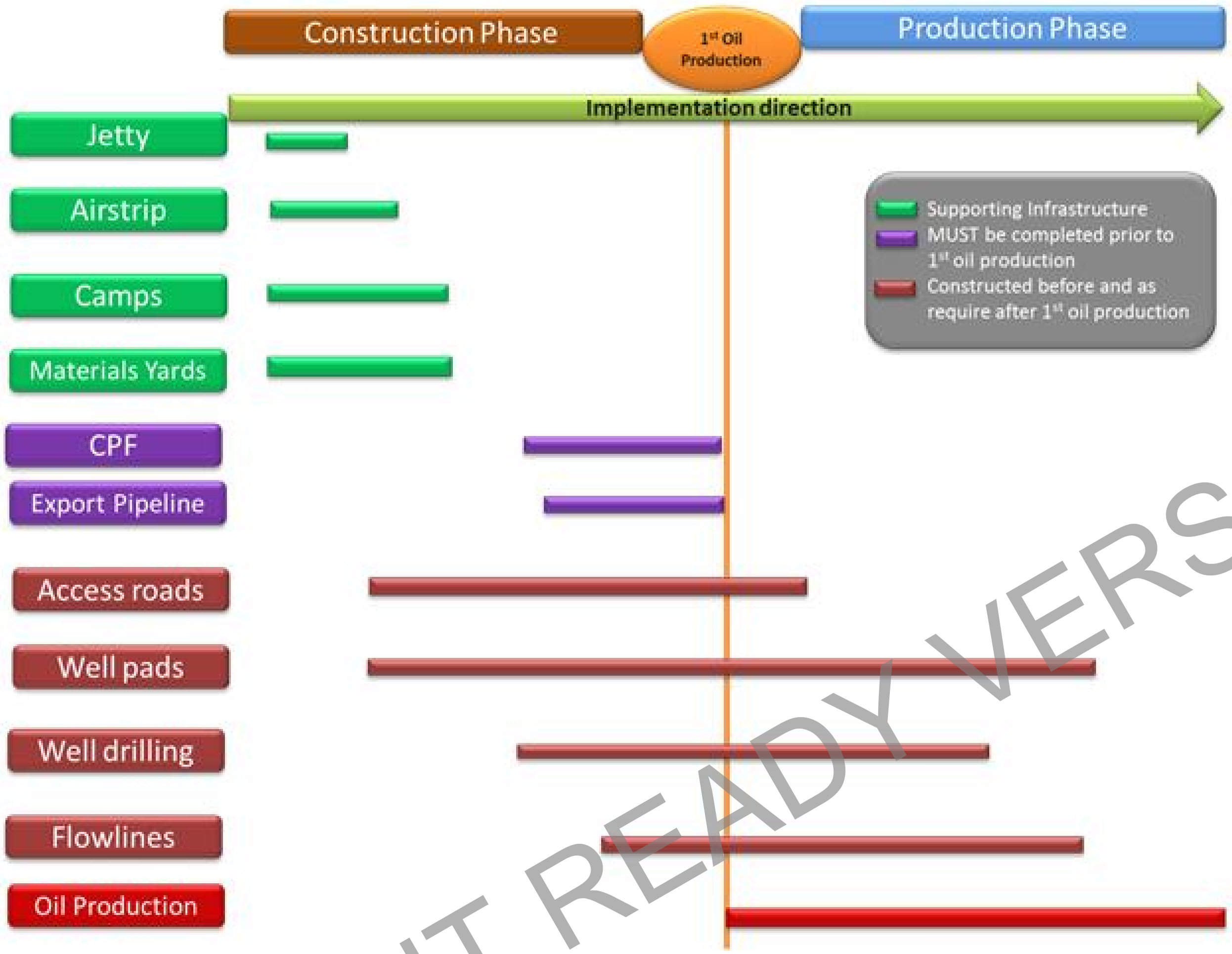


Figure 33: Project implementation.

4.1.8 Kingfisher Operations Overview

4.1.8.1 Overview of the process flow at the CPF

Well fluids from individual wells will be pumped using Electrical Submersible Pumps (ESPs) for artificial lift in order to meet the required flowing wellhead pressure and is collected in the production or the test manifolds.

To enable testing and metering of well fluids from individual wells, the well-fluids from a production well shall be diverted to the Test Manifold and then through a multi-phase flow meter before combining with the flow from the production manifolds.

Well fluids from the production and test manifolds are metered in multi-phase flow meters and sent to the CPF via flow lines. The flow lines will be heat traced, buried and insulated. SEHT in the flowlines ensures that the temperature in the flow lines does not fall below pour point temperature of maximum 45°C + 5°C design margin under normal flowing conditions. SEHT design will however ensure the possibility to operate at WAT + 5°C, in case of operational issues with operation at pour point + 5°C. SEHT design is also suitable to provide heating of the flow lines during start-up to 80°C in 24 hours to melt the entire wax. The flow lines are provided with pig launching/receiving facilities to enable the periodic pigging of the production flow lines.

Each well pad also consists of reception facility for the injection water flow line from the CPF to water injection wells. The flow lines from CPF terminate in a Water Injection Manifold. Connections are provided from the manifold to individual water injection wells. Stub connection has been provided for the future connection to a water disposal well, if the produced water quantity exceeds the water injection quantity. This connection is not required for the project. Connections are provided on the water injection flow lines for the installation of temporary pig launcher/receivers if it is desired to carry out pigging of these flow lines.

The chemical injection requirement will be confirmed by means of tests and based on crude oil production chemistry. Presently, defoamer, scale inhibitor and corrosion inhibitor injection have been considered in the production manifolds and test manifolds. Demulsifier is injected directly downhole via a downhole injection string at the ESP suction to destabilise emulsions. The chemical injection facilities are local to each well pad and requisite chemical storage and filling facilities will be available at the well pad.

In order to handle the oily drains from pipelines and equipment, each well pad is also provided with an underground closed drain drum and submersible pump. The drain drum level will be monitored and the drum should be periodically emptied into a mobile tanker.

It is anticipated that the wells will produce sand and sand screens will therefore be installed in the well. However, the ESPs will lift some sand to the surface. Therefore, the downstream equipment at CPF will be installed with on-line sand removal and disposal facilities.

4.1.8.2 Liquid-liquid separation and oil stabilisation

The flow lines from individual well pads will terminate into a common inlet manifold that supplies the well fluids to the 1st stage separator. The 1st stage separator is a three phase separator operating at 8.0barg.

The 1st stage separator separates the vapour, oil and water from the well fluid to ensure that the water content in the oil phase from the separator has a maximum of 25% water-cut. Vapour from the separator will be sent on pressure control to mix with the flash gas compressor discharge. The separated produced water will be sent to the produced water treatment unit.

The separated oil-water mixture from the 1st stage separator will be sent on level control to 2nd stage feed/Oil Exchanger where it will be heated regenerative with stabilized crude, and 2nd stage separator feed heater where it is heated by heating medium.

The crude-water mixture is heated up to 95°C in the above two exchangers and sent to the 2nd stage separator. The 2nd stage separator is a 3 phase separator operating at about 0.5 bars and 95°C to stabilise the crude sufficiently for storage and export. Oil from the 2nd stage separator is pumped to the electrostatic separator on level control. Water from the 2nd Stage Separator is pumped on level control to the produced water treatment unit. Flash gas from 2nd stage separator is sent to the flash gas compressor inlet cooler.

All the three separators will be fitted with sand removal facilities that include water jetting de-sanding nozzles. Depending on the extent of sand, the sand jetting is required to be either continuous or periodic.

The electrostatic separator is a liquid filled vessel operating at 95°C and provided with electrostatic terminals. The purpose of the electrostatic separator is to achieve the crude oil specification of BS&W content of less than 0.5vol% and salt content of 25ptb. The stabilised crude from the electrostatic separator is cooled by 2nd stage separator feed in the 2nd stage separator feed/Oil exchanger and then by air in the oil cooler to 68°C to remain above the pour point and wax appearance temperature. On-spec stabilised crude is sent to the on-spec storage tank. If the crude oil specifications of RVP and BS&W are not met (recorded by analysers), the crude will be automatically diverted to the off-spec crude tank.

The Process schematic of CPF is presented in Figure 34, the crude oil process is presented Figure 35.

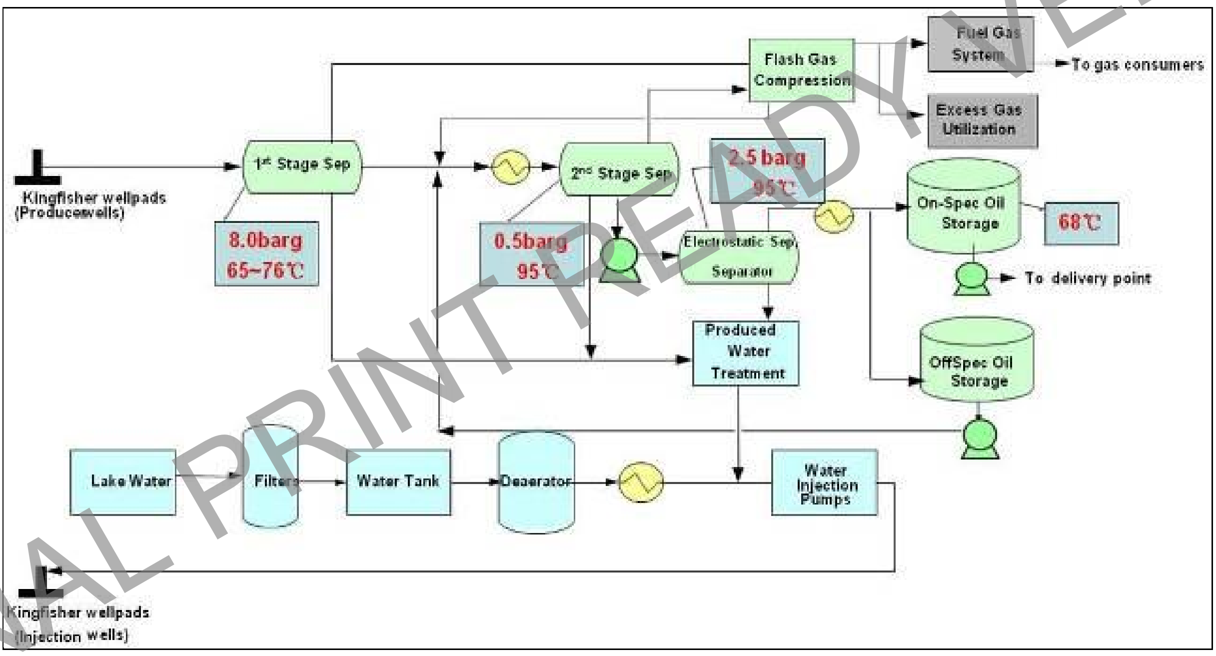


Figure 34: Typical process flow diagram of the CPF (only for illustration purpose).

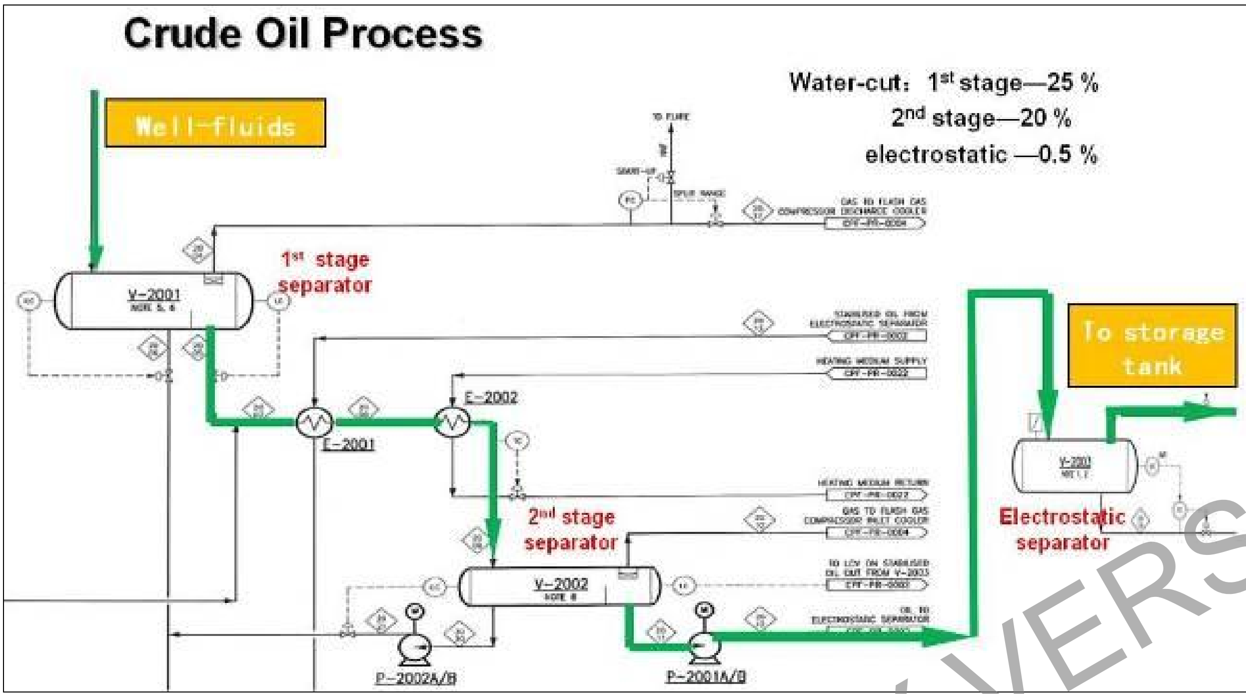


Figure 35: Typical crude oil process (only for illustration purpose).

4.1.8.3 Flash gas compression

Flash gas compressor is single stage reciprocating compressor. Flash gas from the 2nd stage separator is cooled in flash gas compressor inlet cooler and is sent to the flash gas compressor suction drum where the condensate is knocked out and vapour is sent to the flash gas compressor. Flash gas from the 1st stage separator is mixed with the flash gas compressor discharge, upstream of the flash gas compressor discharge cooler. Recycle condensate from the fuel gas compression system also joins the lash gas compressor discharge and is fed to the Flash Gas Compressor Discharge Cooler where it is cooled to 60°C and is sent to the flash gas compressor discharge drum to separate any condensate. If the temperature of the total gas/condensate upstream of the flash gas compressor discharge cooler is <60°C, there is a provision to bypass the air-cooler and send the stream directly to the flash gas compressor discharge drum. Condensate collected in the flash gas compressor discharge drum is sent on level control to the flash gas compressor suction drum. Compressed gas from the flash gas compressor discharge drum is sent to:

- The LP fuell gas supper heater to meet the superheat requirements of 30°C before sending LP fuel gas to consumers,
- The fuel gas ccompression system where the gas is compressed to 36 bars for use in the power generation gas turbines.
- Remaining gas, if any, is sent to the excess gas utilization package.
- Condensate collected in the flash gas compressor suction drum is pumped under level control and reprocessed along with the 2nd stage separator feed. There is a provision to divert the flash gas condensate to the Heating Medium Fired Heaters as a back-up to fuel gas.

The flash gas compression is presented in Figure 36.

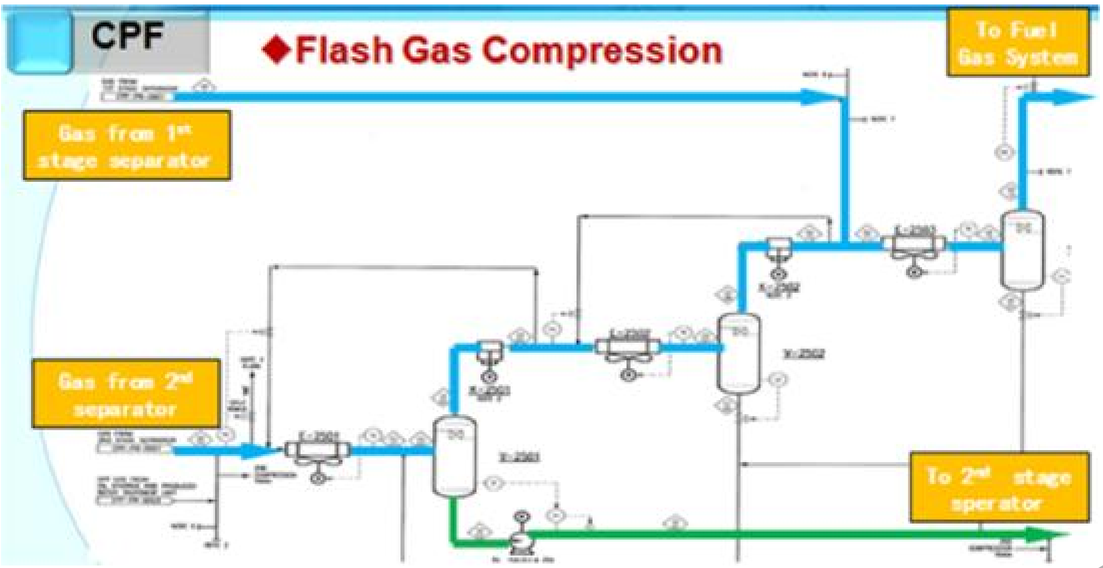


Figure 36: Flow chart of flash gas compression (only for illustration purpose).

4.1.8.4 Oil storage and export

Stabilised oil from the oil cooler will be analysed by online analysers for RVP and BS&W. On-spec crude oil is stored in the floating-roof on-spec oil storage tanks. If the crude oil is off-spec owing to high RVP or BS&W it can be diverted automatically to the off-spec storage. Heat loss from the tanks to the ambient surroundings will be recuperated by means of heating medium coils inside the tanks. The temperature in the tank will be maintained at 68oC by using internal heating medium coils.

On-spec crude oil will be pumped by two pumps in series. Crude oil will be metered in the fiscal metering package that is located on booster pump discharge. The crude from the booster pumps provides sufficient NPSH at the suction of the crude oil transmission pumps. The stabilized crude is pumped by means of crude oil transmission pumps on flow control to Kabaale via the feeder pipeline.

SEHT is provided on the crude oil feeder pipeline to maintain the temperature above pour point + 5°C. Although the normal operating philosophy is to operate at pour point + 5°C, SEHT design will be suitable to operate at WAT + 5°C, if there are operational issues with operation at lower temperatures.

Off-spec oil storage tank is a conical roof tank with fuel gas blanketing and a vapour recovery system to compress the off-gas from tank using Off-spec Oil storage tank blower. The compressed off-gas is sent to the 1st stage flash gas compressor suction drum to be compressed and used as fuel gas. Off-spec crude oil is recycled to the 2nd stage separator on flow control with tank low level override. Nitrogen will be required as backup for tank pressure maintenance during start-ups. Heat loss from the tanks to the ambient surroundings will be recuperated by means of heating medium coils inside the tanks. The temperature in the tank will be maintained at 68°C by using internal heating medium coils. The crude oil storage and feedis presented in Figure 37.

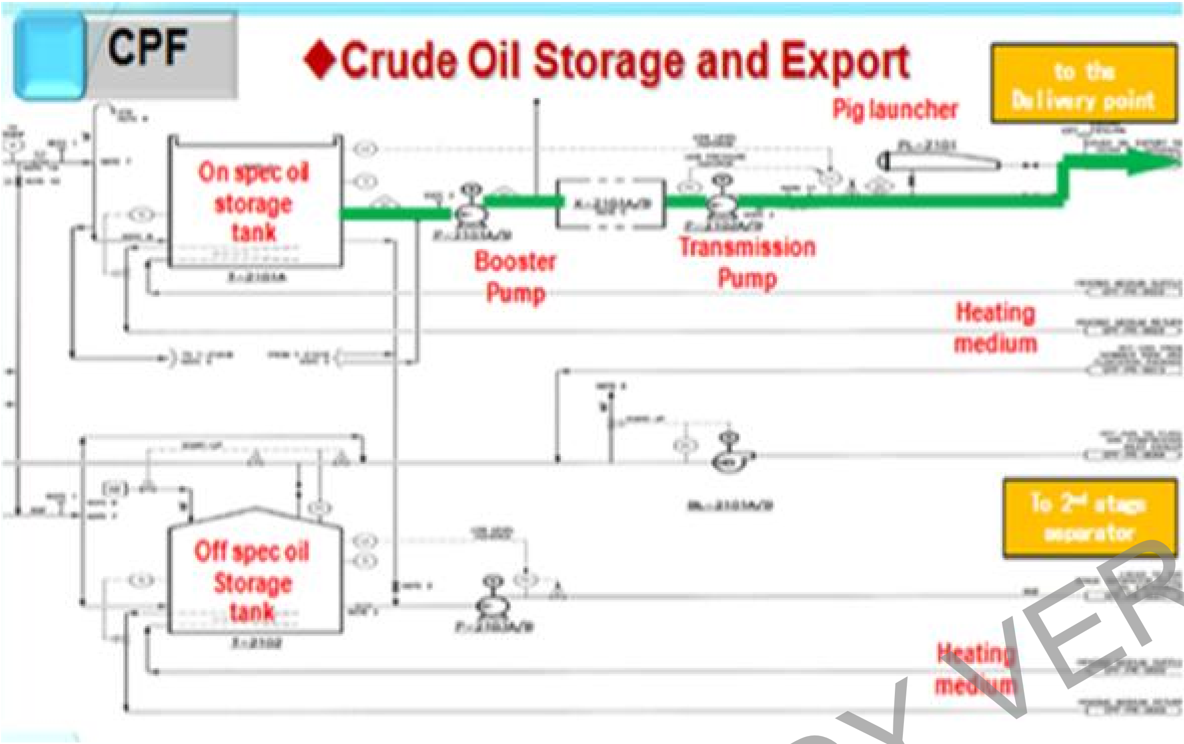


Figure 37: Flow chart of crude oil storage and feed supply (only for illustration purpose).

4.2 Air Emission Inventory

The main sources of air emissions (continuous or no continuous) resulting from oil and gas development activities include:

- Combustion sources from power and heat generation, and the use of compressors, pumps, and reciprocating engines (boilers, turbines, and other engines);
- Emissions resulting from flaring and venting of hydrocarbons; and,
- Fugitive emissions.

Principal pollutants from these sources typically include nitrogen oxides (NO_X), sulphur oxides (SO_X), carbon monoxide (CO), and particulates (TSP, PM_{10}, $PM_{2.5}$ and dust fallout). Additional pollutants can include: hydrogen sulphide (H_2S); volatile organic compounds (VOC's); methane and ethane; benzene, ethylbenzene, toluene, and xylenes (BTEX); glycols; and polycyclic aromatic hydrocarbons (PAHs) (IFC, 2007).

The following scenarios were considered:

- Construction,
- Operation including abnormal conditions (start-up, upset conditions and shutdown); and,
- Decommissioning.

The emission inventory is based on the following inputs:

- Construction and operations will overlap;
- Production of:
  - Oil at 40 000 BPD (1 991 878 tpa); and,
  - Gas at 229 scf/bbl (72 887 tpa).
- Natural gas produced will be consumed in combustion processes;
  - 56% will be used for power generation (16 MW output), the remainder (44%) flared; and
  - The natural gas contains no sulphur (Table 12);
- Diesel fuel sulphur content is 500 ppm;
- Engine:
  - Thermal efficiencies are 30%; and,
  - Fuel air ratios 1:10.

Table 12: Composition of the natural gas.

Compound	Mole %
C1	73.85%
C3	11.65%
C2	5.94%
nC4	3.79%
nC5	1.41%
iC5	1.31%
iC4	1.28%
H2O	0.27%
CO2	0.22%
C6	0.17%
M Cyclo C5	0.04%
N2	0.03%
Cyclo C6	0.02%
C7	0.01%
Other	0.01%
Total	100.00%

Notes:

- *The natural gas produced does not contain sulphurous; or,*
- *BTEX compounds (benzene, ethylbenzene, toluene, and xylenes).*

Emissions from engines were calculated using US-EPA and / or EA-NPI uncontrolled emission factors or worst case scenario factors, significant reductions in both NO_X and CO emissions (75% to 95%) can be achieved with post-combustion control technologies. Post-combustion control technologies applicable to these sources include selective catalytic reduction (SCR), non-selective catalytic reduction (NSCR), and catalytic oxidation (CO oxidation catalyst). (US-EPA, 2000).

Table 13: Physical parameters for emission sources.

Description	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Well Pad 1	4	0.5	50.0	423
Well Pad 2	4	0.5	50.0	423
Well Pad 3	4	0.5	50.0	423
Well Pad 4A	4	0.5	50.0	423
CPF Fugitive	2	1.0	1.0	373
CPF Vent	14	5.0	0.0	373
CPF Flare	28	9.0	0.5	623
CPF Generators	17	3.0	5.5	623
CPF Heaters	17	2.4	0.0	623

Table 14: Locations of emission sources.

Description	X (UTM 36 N m])	Y (UTM 36 N [m])	Z (Elevation [m])
Well Pad 1	248581	137907	624
Well Pad 2	249548	138818	631
Well Pad 3	247512	136116	626
Well Pad 4A	250265	139737	638
CPF Fugitive	249899	137929	636
CPF Vent	249877	137887	635
CPF Flare	249988	138052	636
CPF Generators	249875	137758	643
CPF Heaters	249851	137764	642

4.2.1 Construction

Table 15: Emissions from drilling (6000kW power pack).

Substance	tpa	g/s	mg/Nm³	mg/Nm³
Total VOC	4	0.128	20	13
CO	35	1.113	176	113
NO_X	83	2.633	**415**	268
PM_{10}	4	0.142	22	14
$PM_{2.5}$	4	0.139	22	14
SO_2	3	0.082	13	8

Notes:

- *The emissions are based on emission factors for stationary large (greater than 450 kW) diesel engines* (EA-NPI, 2008)*;*
- *Uncontrolled NO_X emissions will not meet IFC guidelines (200 mg/Nm^3), the application of control technologies will however (reduction of 75-95%) meet this requirement; and,*
- *The Sulphur content of the diesel was assumed to be 500 ppm.*

Construction emissions are associated with land clearing and construction, plus drilling on the well pads. Emissions from land clearing and construction activities will be transient. Drilling will only occur on one well pad at a time (Table 15).

4.2.2 Operation

Emissions for operations are provided in Table 16, Table 17. Drilling will only be undertaken on one well pad at a time, VOC's combustion emissions were assumed not to contain BTEX compounds (benzene, ethylbenzene, toluene, and xylenes), see Table 12 for the composition of the natural gas.

Table 16: Emissions from drilling (6000kW power pack).

Substance	tpa	g/s	mg/Nm³	mg/Nm³
Total VOC	4	0.128	20	13
CO	35	1.113	176	113
NO_X	83	2.633	**415**	268
PM_{10}	4	0.142	22	14
$PM_{2.5}$	4	0.139	22	14
SO_2	3	0.082	13	8

Notes:

- *The emissions are based on emission factors for stationary large (greater than 450 kW) diesel engines* (EA-NPI, 2008)*;*
- *Uncontrolled NO_X emissions will not meet IFC guidelines (200 mg/Nm³), the application of control technologies will however (reduction of 75-95%) meet this requirement; and,*
- *The Sulphur content of the diesel was assumed to be 500 ppm.*

Table 17: Emissions from power generation.

Substance	tpa	g/s	mg/Nm³	mg/m³
Total VOC	3	0.095	6	2
CO	117	3.699	218	96
NO_X	456	14.458	**853**	374
PM_{10}	3	0.086	5	2
$PM_{2.5}$	3	0.086	5	2
SO_2	0	N/A	N/A	N/A

Notes:

- *Results based on emission factors for uncontrolled gas turbines natural gas engines* (EA-NPI, 2008)*; and,*
- *Uncontrolled NO_X emissions will not meet IFC guidelines (200 mg/Nm³), the application of control technologies will however (reduction of 75-95%) meet this requirement.*

Table 18: Emissions from flaring.

Substance	tpa	g/s	mg/Nm³	mg/m³
Total VOC	413.2	13.102	773	339
CO	239.6	7.599	449	197
NO_X	41.3	1.310	77	34
$PM_{2.5}$	6.9	0.218	13	6
PM_{10}	6.9	0.218	13	6

Notes:

- *Results based on emission factors for flaring* (EA-NPI, 2013)*; and,*
- *Uncontrolled NO_X emissions will not meet IFC guidelines (200 mg/Nm³), the application of control technologies will however (reduction of 75-95%) meet this requirement.*

Table 19: Fugitive emissions from oil handling and storage.

Substance	tpa	g/s
Benzene	2	0.076
Ethylbenzene	0	0.008
n-Hexane	3	0.111
Methane	0	0.000
Toluene	2	0.050
Total VOC	14	0.442
Xylenes	2	0.055
Notes: *Results based on emission factors for oil and gas extraction and production* (EA-NPI, 2013)		

4.2.2.1 Abnormal Operations

Emissions associated with abnormal operations will be transient, these operations include:

- Start-up;
- Upset conditions;
- Venting; and,
- Shut-down.

4.2.3 Decommissioning

Atmospheric emissions from the project will stop at closure; therefore no adverse residual[4] air quality impacts are anticipated.

[4] Residual impacts are significant project-related impacts that might remain after on-site mitigation measures (avoidance, management controls, abatement, restoration, *etc.*) have been implemented.

4.3 Simulations Inputs

4.3.1 Modelling Domain

Dispersion of pollutants were modelled 1.5 m above ground level using on two Cartesian receptor grids with the following attributes:

Table 20: Receptor grids.

Maps	Site Domain	Site Grid
UTM Zone	36 N	36 N
Centre x (m)	248799	248799
Centre y (m)	137215	137215
Radius (km)	20	N/A
Length x (km)	40	6
Length y (km)	40	9
SW x (m)	228799	245799
SW y (m)	117215	132715
NE x (m)	268799	251799
NE y (m)	157215	141715
Resolution (m)	1000	100

4.3.2 Topography

The topography used for the modelled area was obtained from Shuttle Radar Topography Mission (SRTM) data sets. SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA – previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry.

4.3.3 Meteorology

Accurate dispersion simulations require meteorological data representative of the modelling domain. Data for the period January 2011 to December 2016 was acquired from the Pennsylvania State University / National Centre for Atmospheric Research PSU/NCAR meso-scale model (known as MM5). The MM5 model is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation.

4.4 Modelling Results

The following scenarios were simulated:

- Construction, and
- Operations.

Only results where maximum concentration approached 25% of the IFC guidelines are presented these include:

- Construction:
  - Drilling on well pad 1, NO_2 maximum hourly concentration (99th percentile) Figure 38;
  - Drilling on well pad 2, NO_2 maximum hourly concentration (99th percentile) Figure 39;
  - Drilling on well pad 3, NO_2 maximum hourly concentration (99th percentile) (Figure 40);
  - Drilling on well pad 4, NO_2 maximum hourly concentration (99th percentile) (Figure 41);
  - Drilling on well pad 1, NO_2 maximum annual concentration (Figure 42);
  - Drilling on well pad 2, NO_2 maximum annual concentration (Figure 43);
  - Drilling on well pad 3, NO_2 maximum annual concentration (Figure 44); and,
  - Drilling on well pad 4, NO_2 maximum annual concentration (Figure 45).
- Operations:
  - Drilling on well pad 1, NO_2 maximum hourly concentration (99th percentile) (Figure 46);
  - Drilling on well pad 2, NO_2 maximum hourly concentration (99th percentile) (Figure 47);
  - Drilling on well pad 3, NO_2 maximum hourly concentration (99th percentile) (Figure 48);
  - Drilling on well pad 4, NO_2 maximum hourly concentration (99th percentile) (Figure 49);
  - Drilling on well pad 1, NO_2 maximum annual concentration (Figure 50);
  - Drilling on well pad 2, NO_2 maximum annual concentration (Figure 51);
  - Drilling on well pad 3, NO_2 maximum annual concentration (Figure 52); and,
  - Drilling on well pad 4, NO_2 maximum annual concentration (Figure 53).

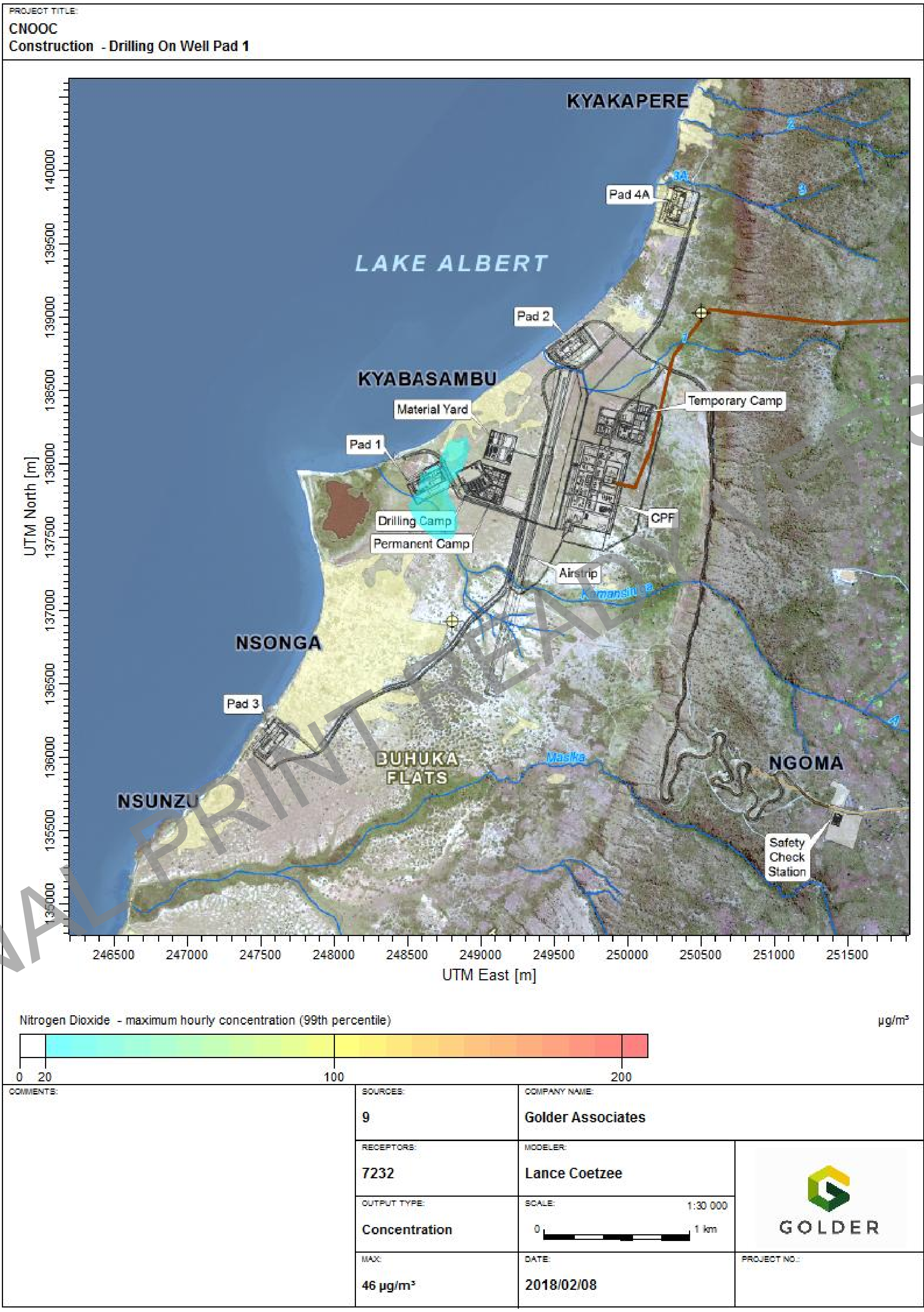


Figure 38: Construction - drilling on well pad 1, NO_2 maximum hourly concentration (99th percentile).

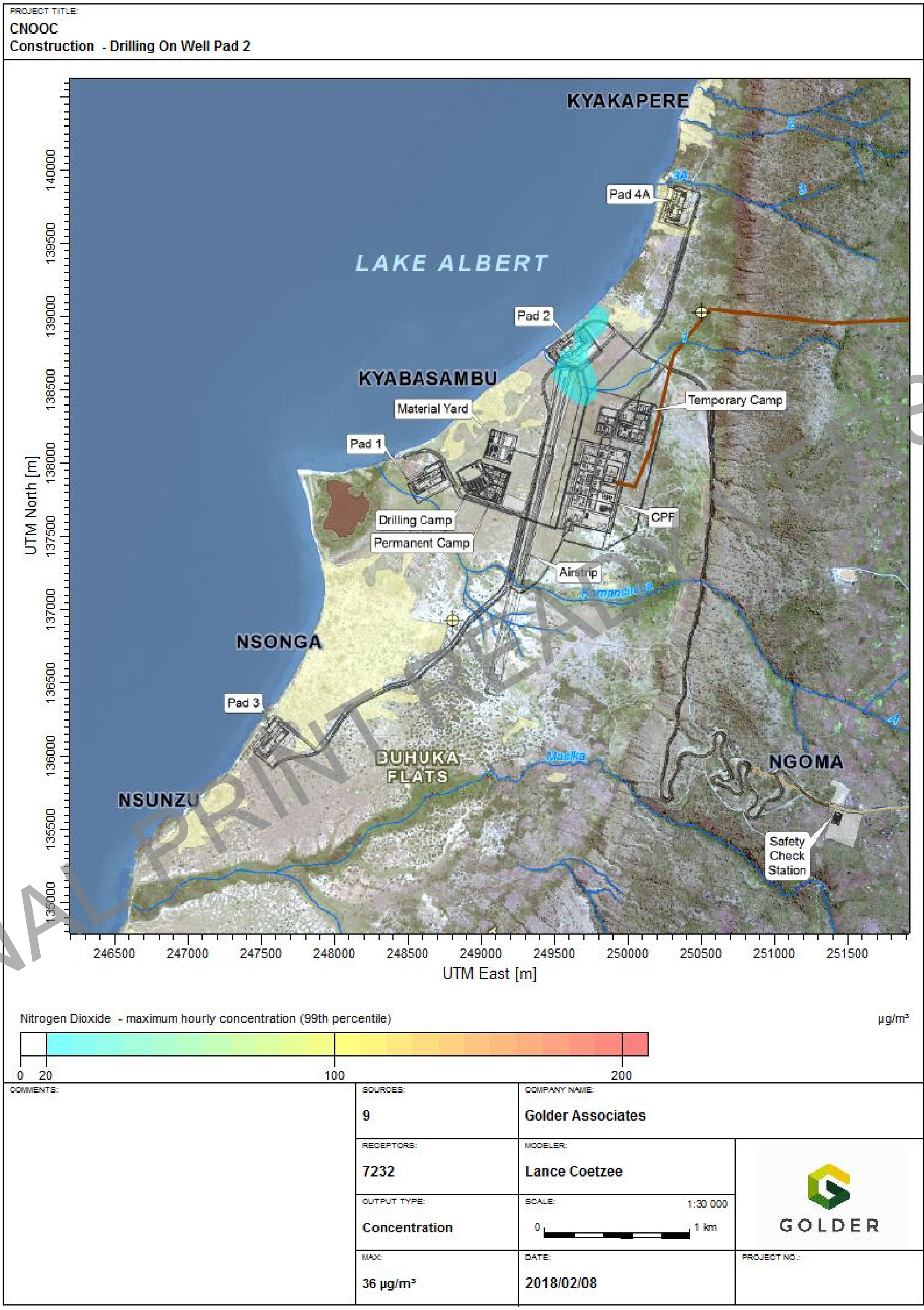


Figure 39: Construction - drilling on well pad 2, NO_2 maximum hourly concentration (99th percentile).

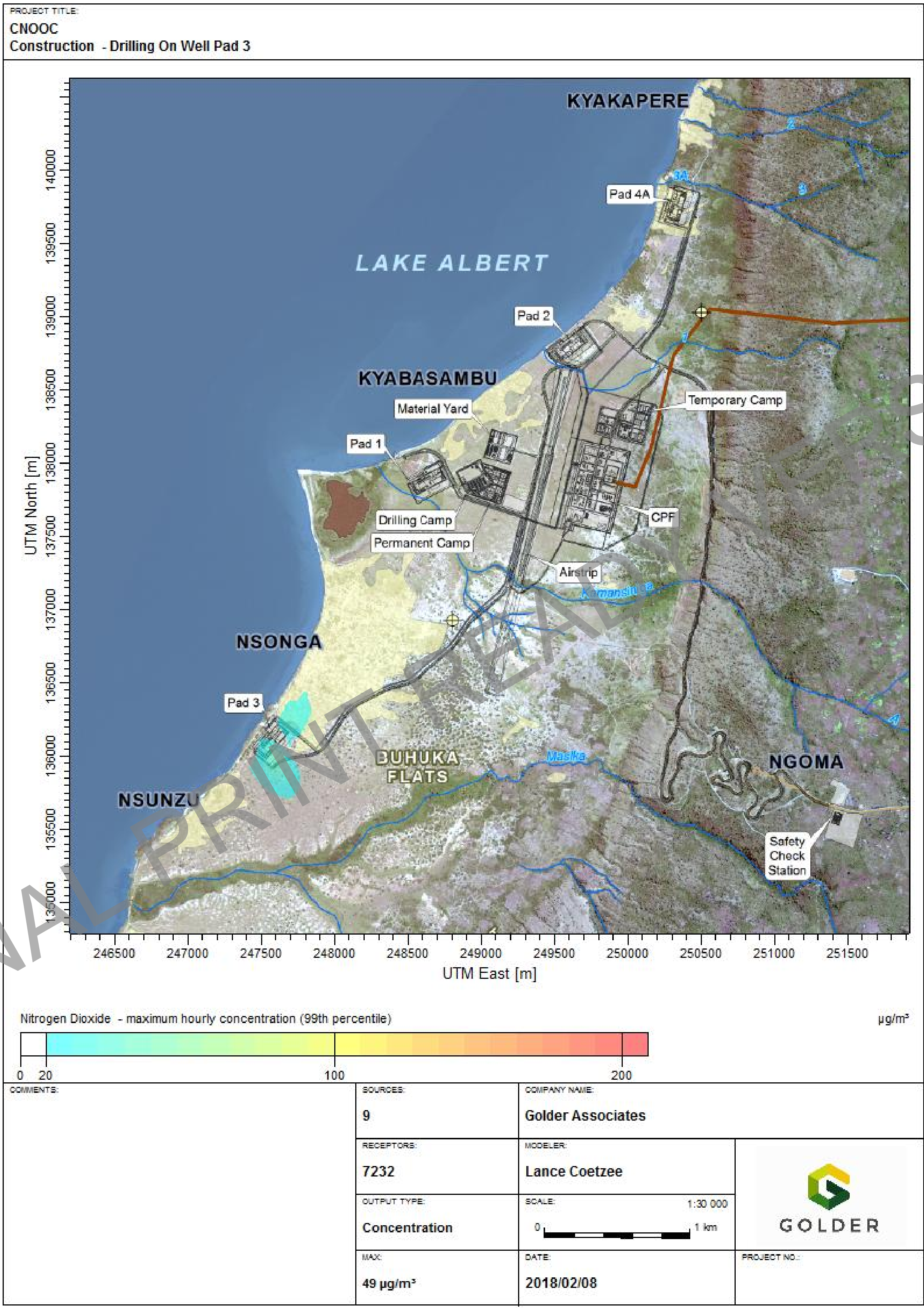
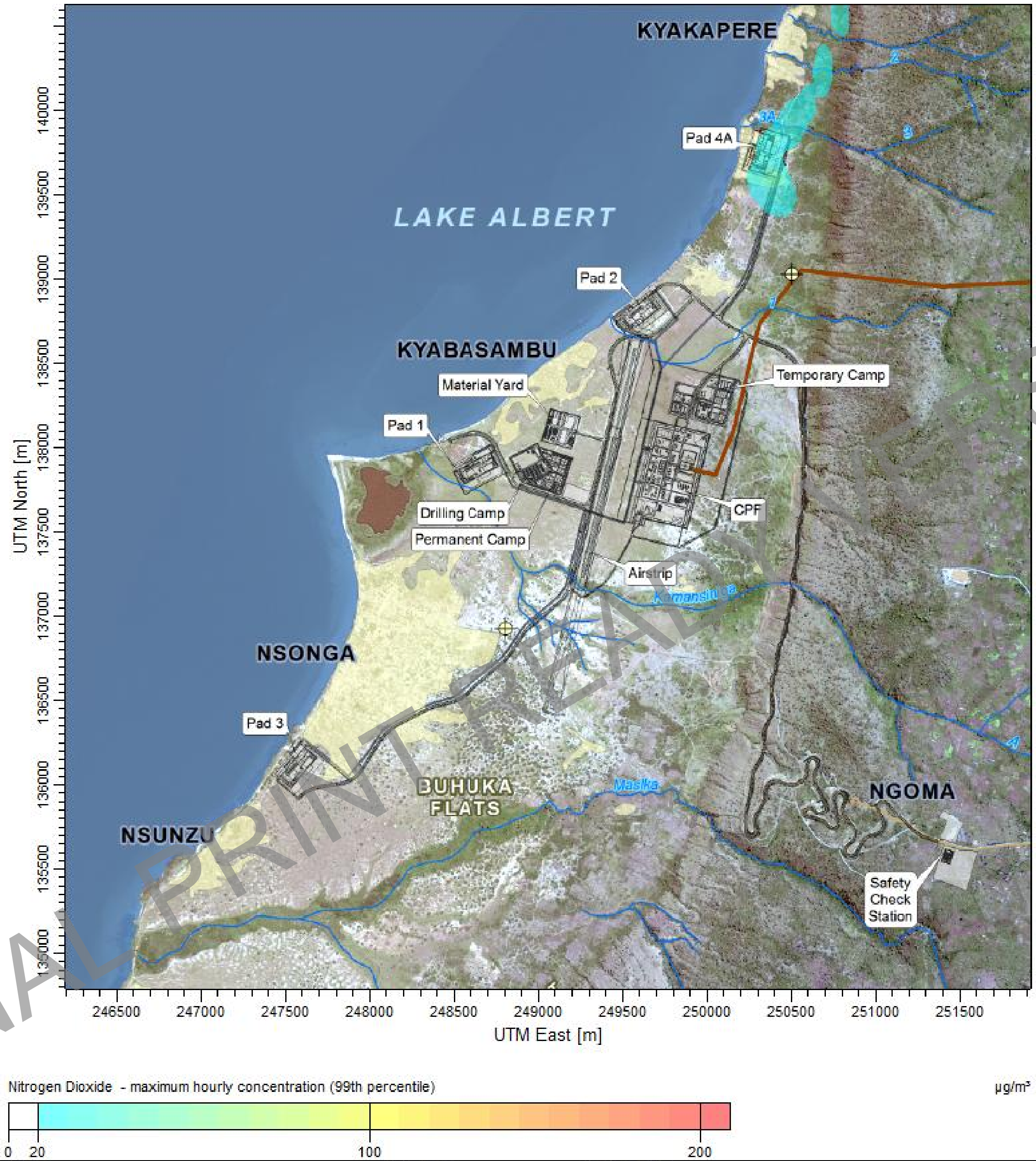


Figure 40: Construction - drilling on well pad 3, NO_2 maximum hourly concentration (99th percentile).

PROJECT TITLE:
CNOOC
Construction - Drilling On Well Pad 4



COMMENTS:	SOURCES: 9	COMPANY NAME: Golder Associates
	RECEPTORS: 7232	MODELER: Lance Coetzee
	OUTPUT TYPE: Concentration	SCALE: 1:30 000 (0 – 1 km)
	MAX: 59 µg/m³	DATE: 2018/02/08
		PROJECT NO.:

GOLDER

Figure 41: Construction - drilling on well pad 4, NO_2 maximum hourly concentration (99th percentile).

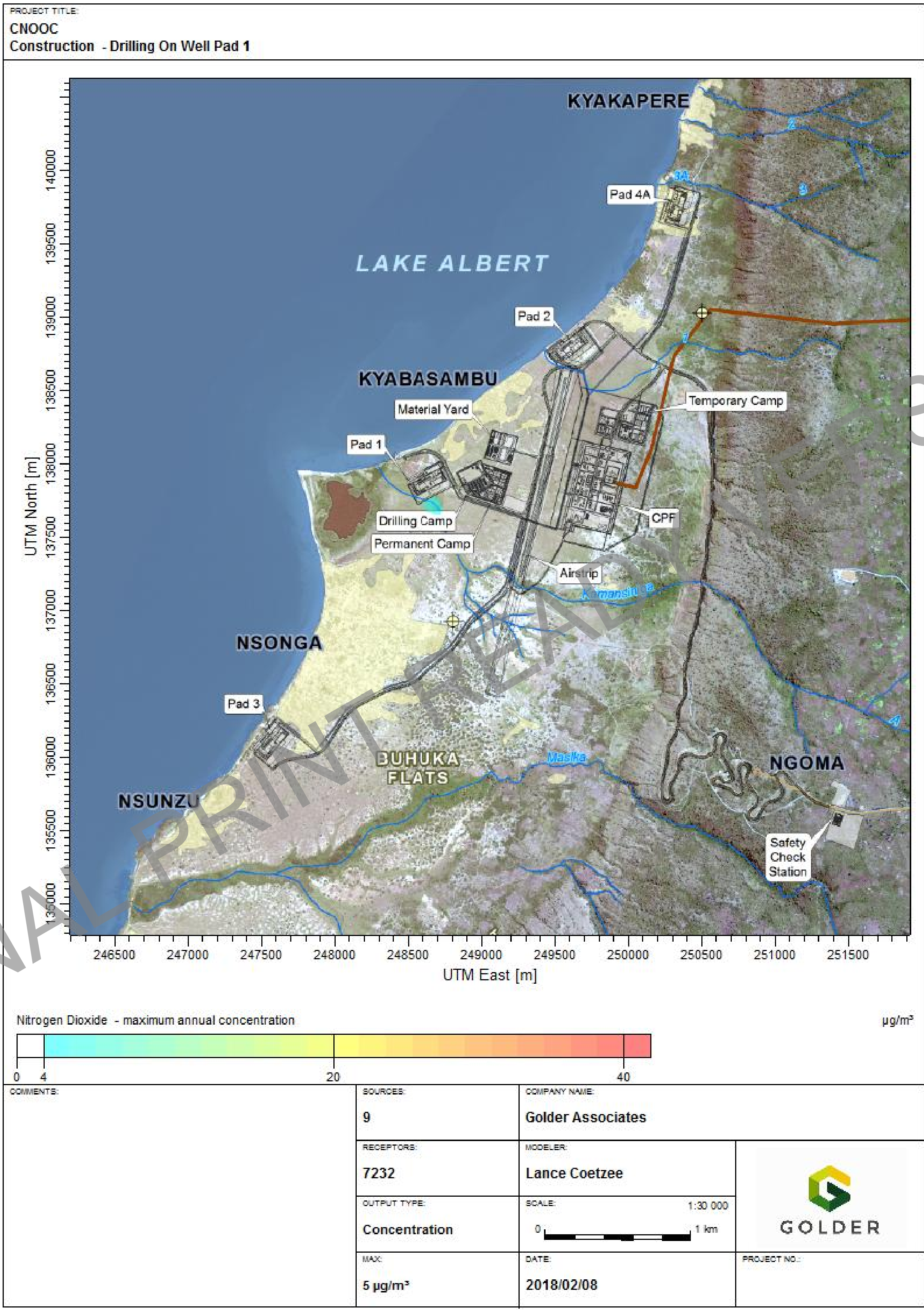


Figure 42: Construction - drilling on well pad 1, NO_2 maximum annual concentration.

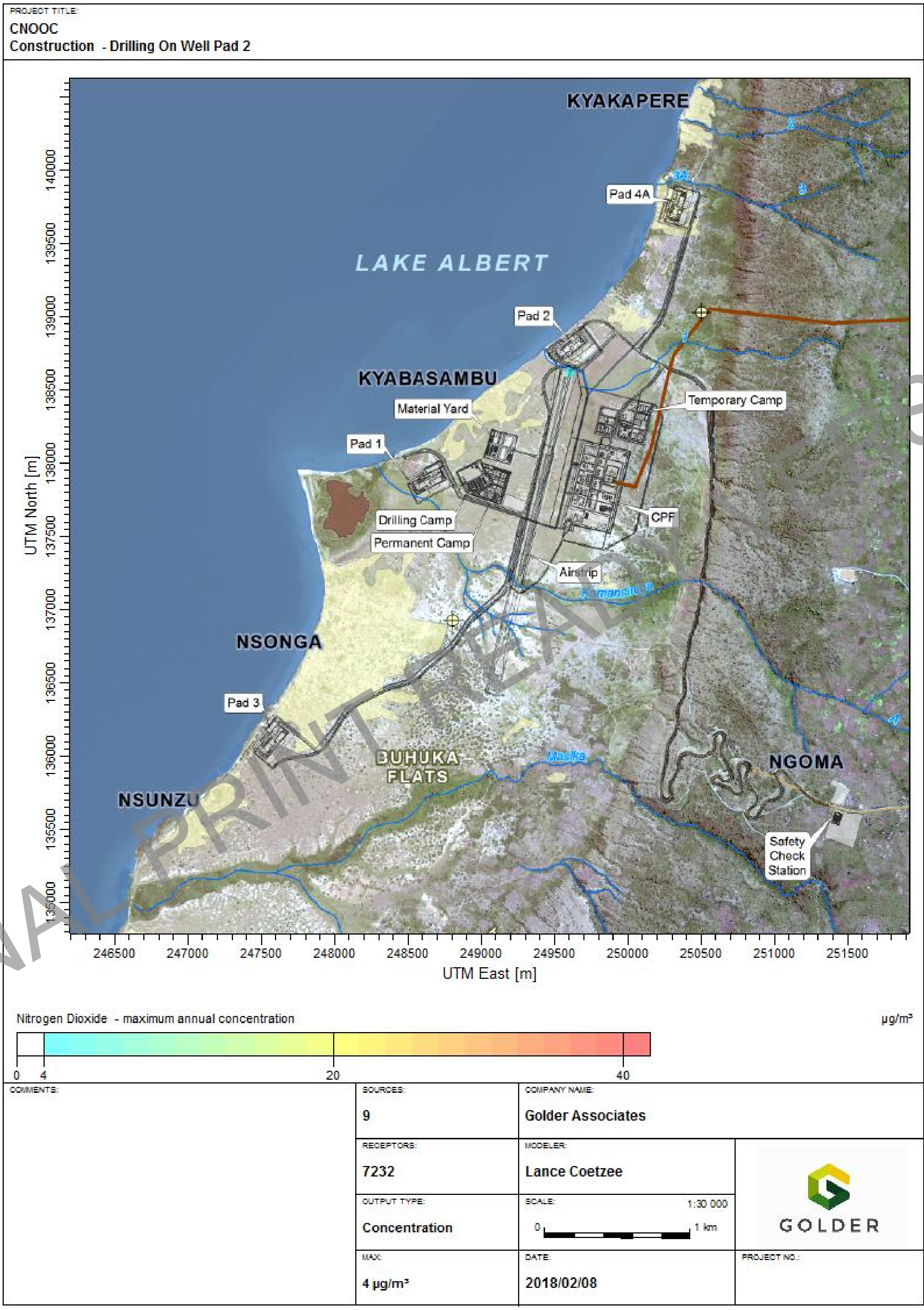
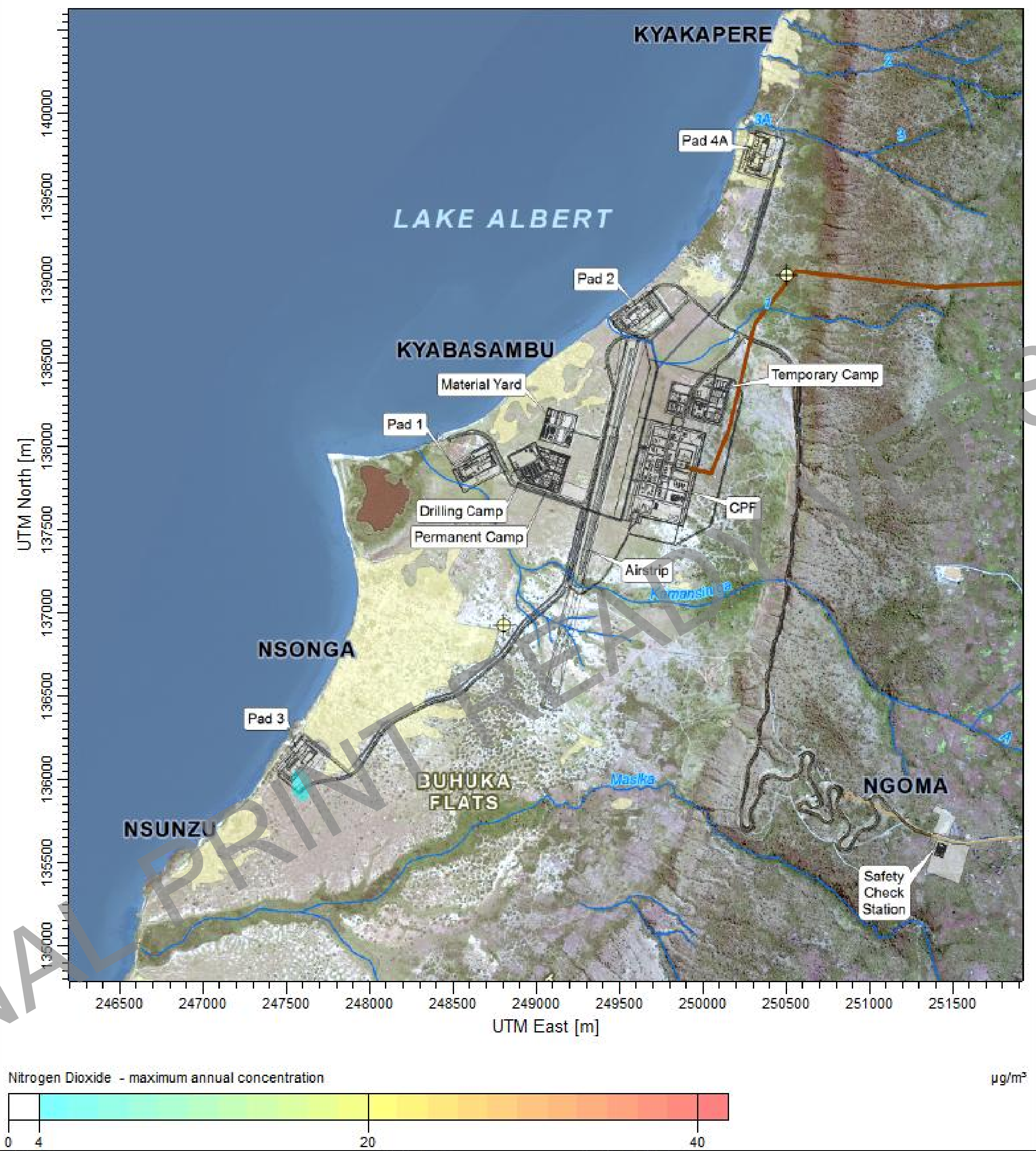


Figure 43: Construction - drilling on well pad 2, NO_2 maximum annual concentration.

PROJECT TITLE:
CNOOC
Construction - Drilling On Well Pad 3



COMMENTS:	SOURCES: 9	COMPANY NAME: Golder Associates	
	RECEPTORS: 7232	MODELER: Lance Coetzee	GOLDER
	OUTPUT TYPE: Concentration	SCALE: 1:30 000 (0 – 1 km)	
	MAX: 6 µg/m³	DATE: 2018/02/08	PROJECT NO.:

Figure 44: Construction - drilling on well pad 3, NO_2 maximum annual concentration.

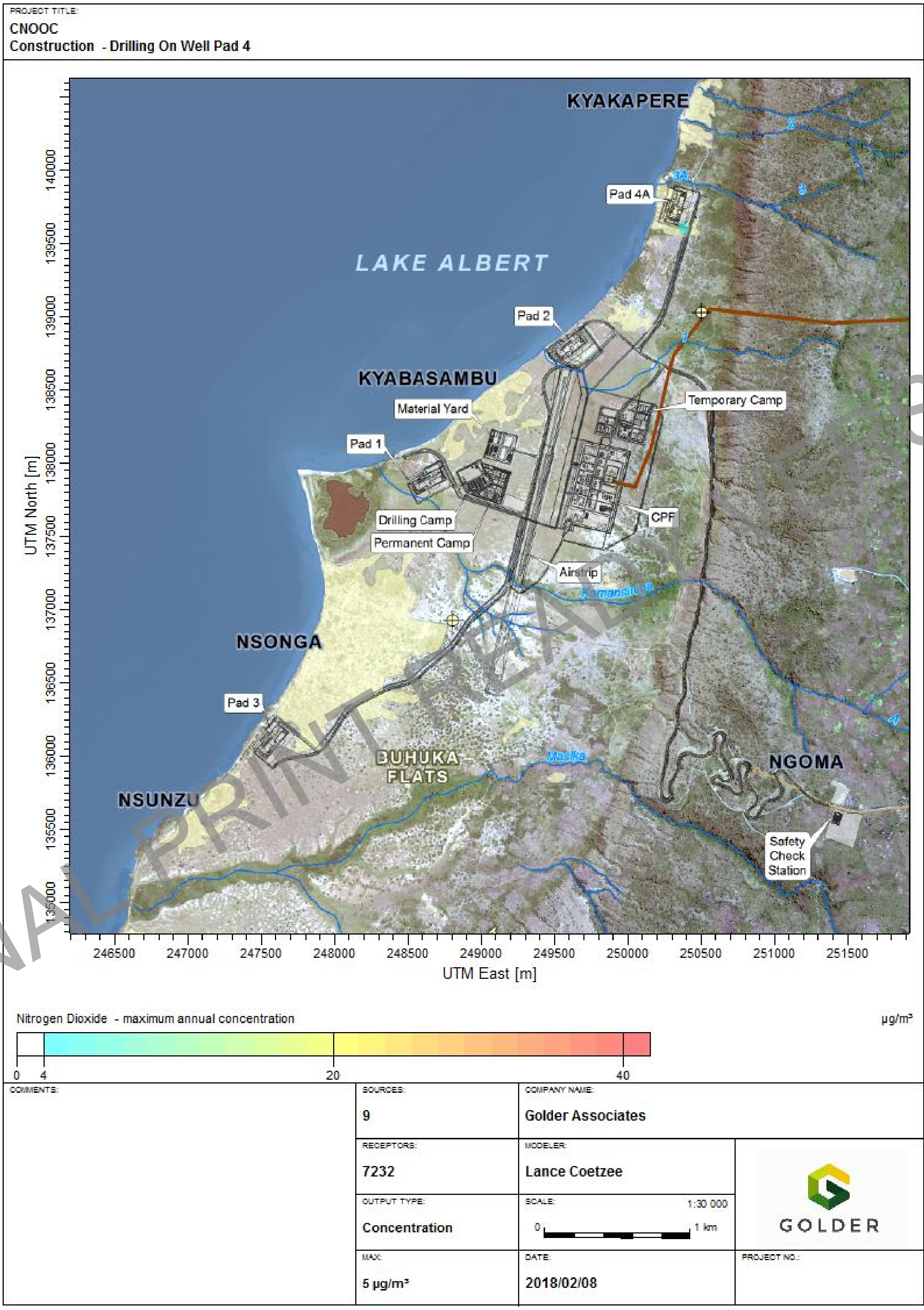


Figure 45: Construction - drilling on well pad 4, NO_2 maximum annual concentration.

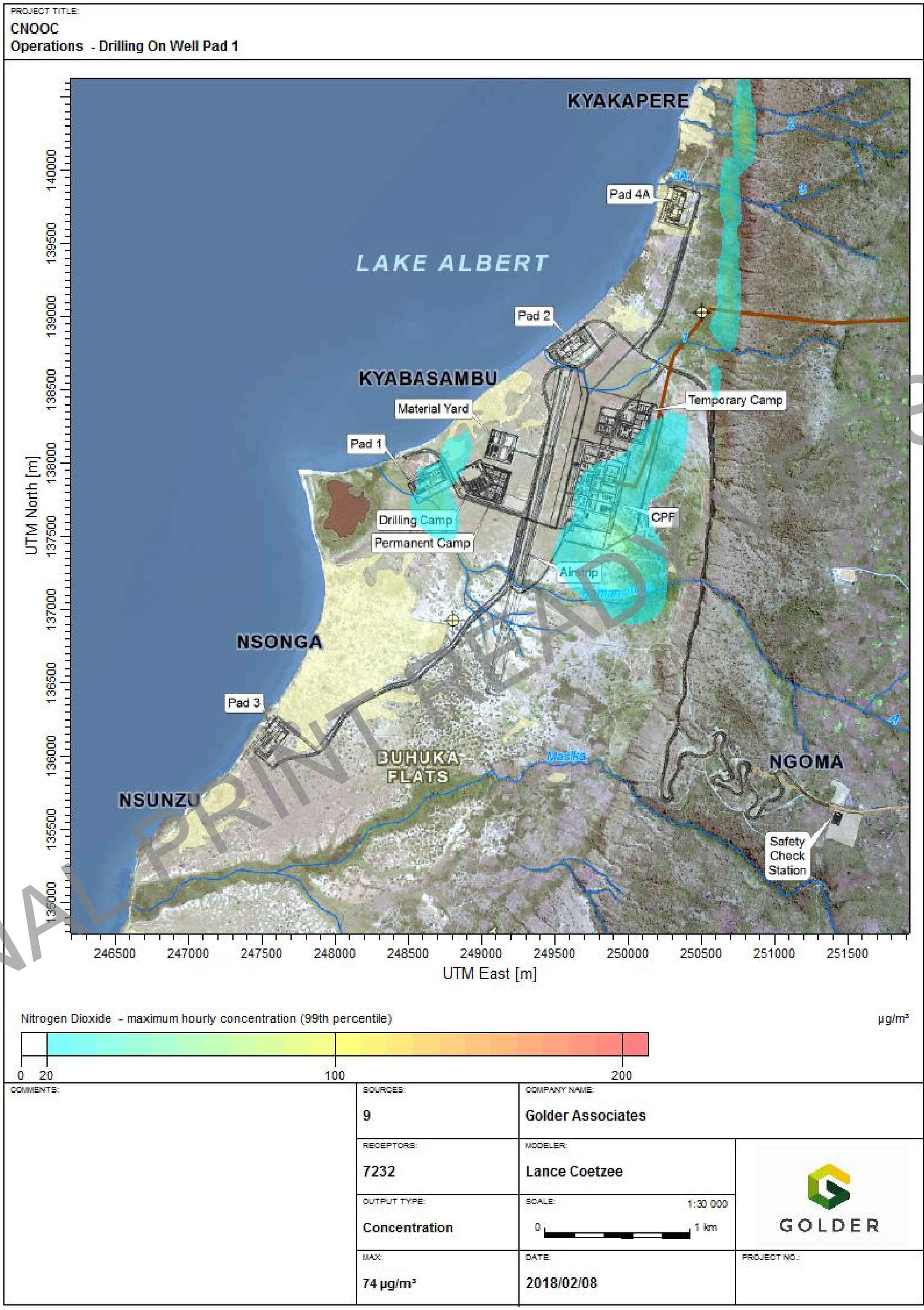


Figure 46: Operations - drilling on well pad 1, NO_2 maximum hourly concentration (99th percentile).

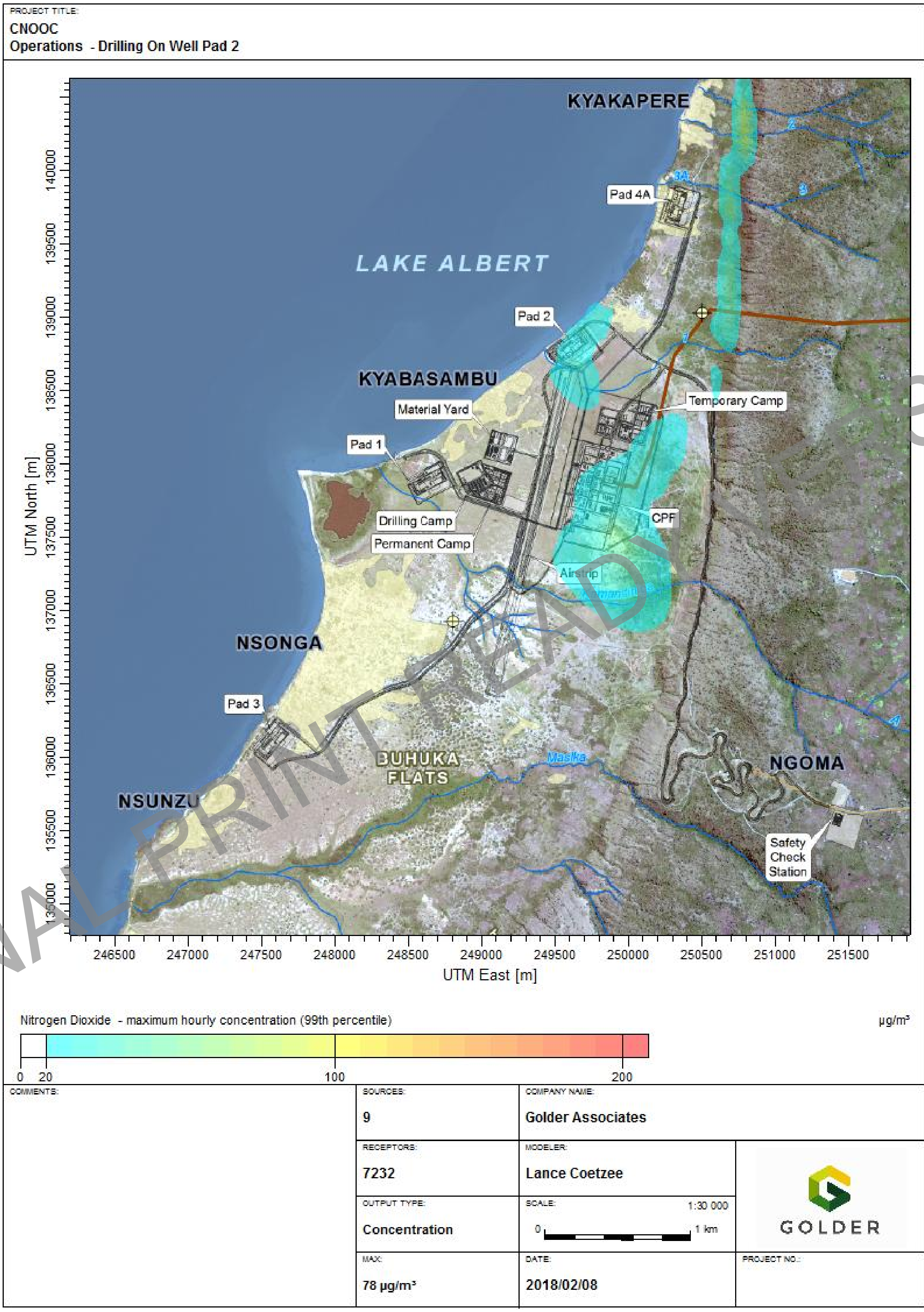


Figure 47: Operations - drilling on well pad 2, NO_2 maximum hourly concentration (99th percentile).

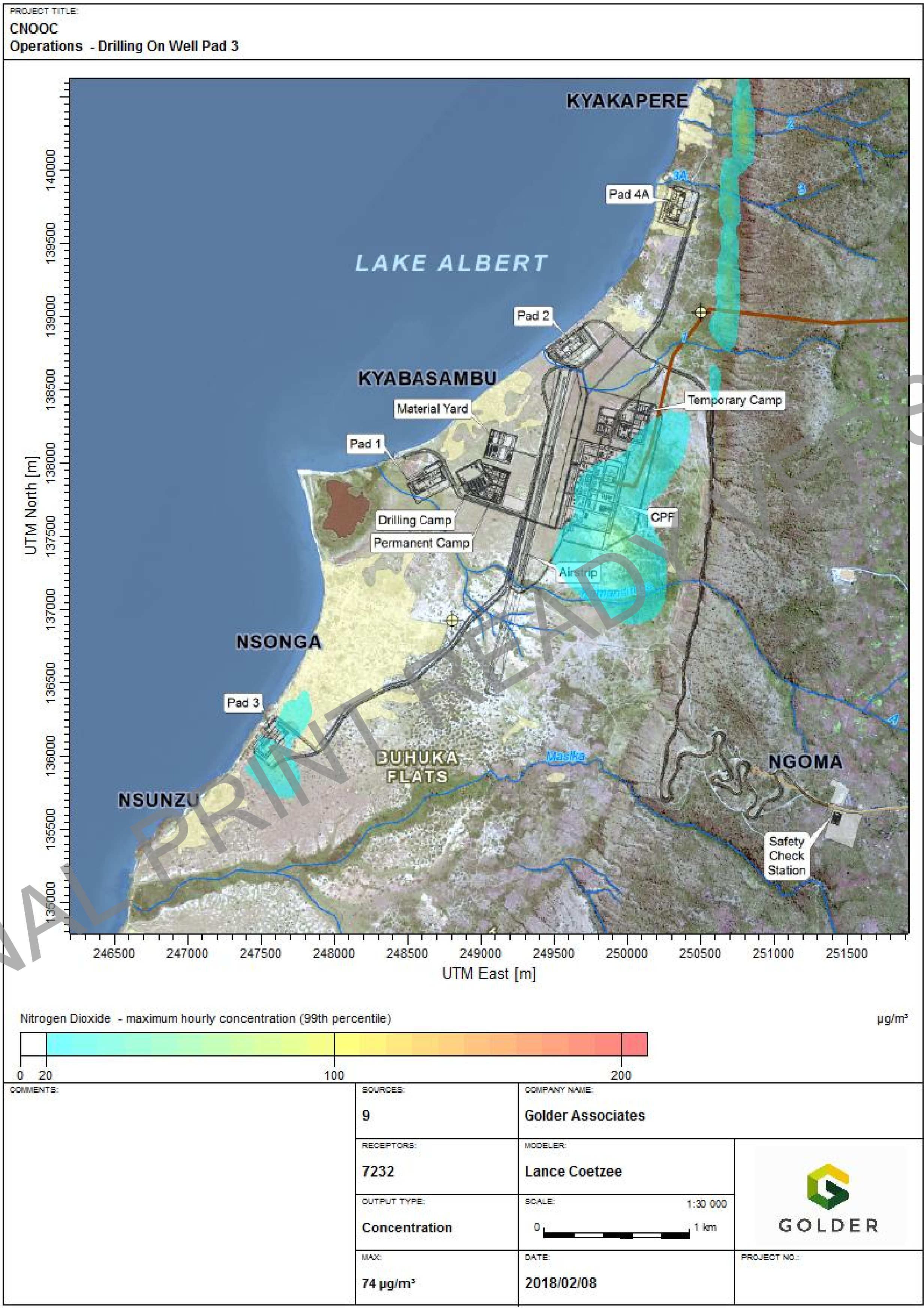


Figure 48: Operations - drilling on well pad 3, NO_2 maximum hourly concentration (99th percentile).

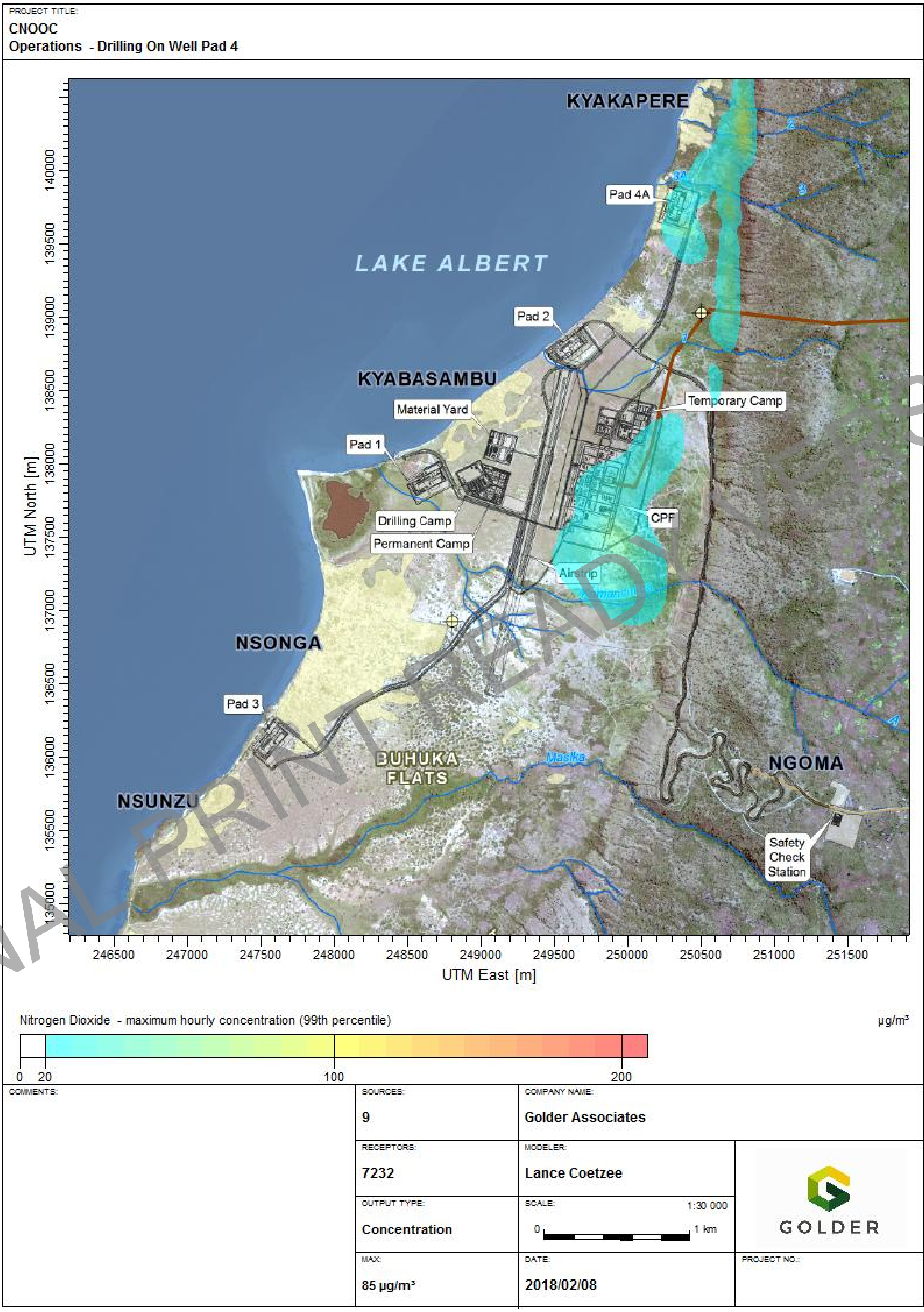
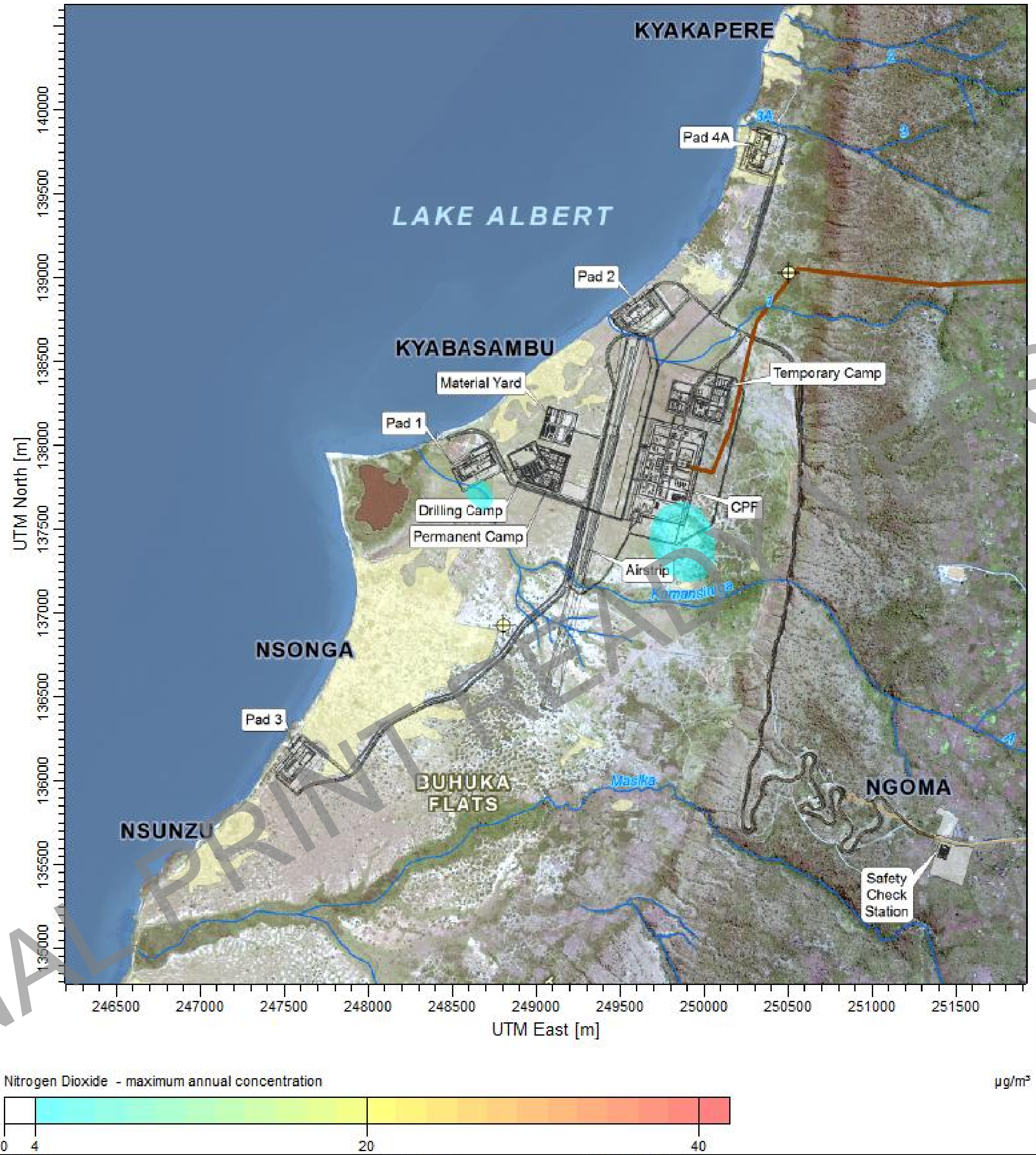


Figure 49: Operations - drilling on well pad 4, NO_2 maximum hourly concentration (99th percentile).

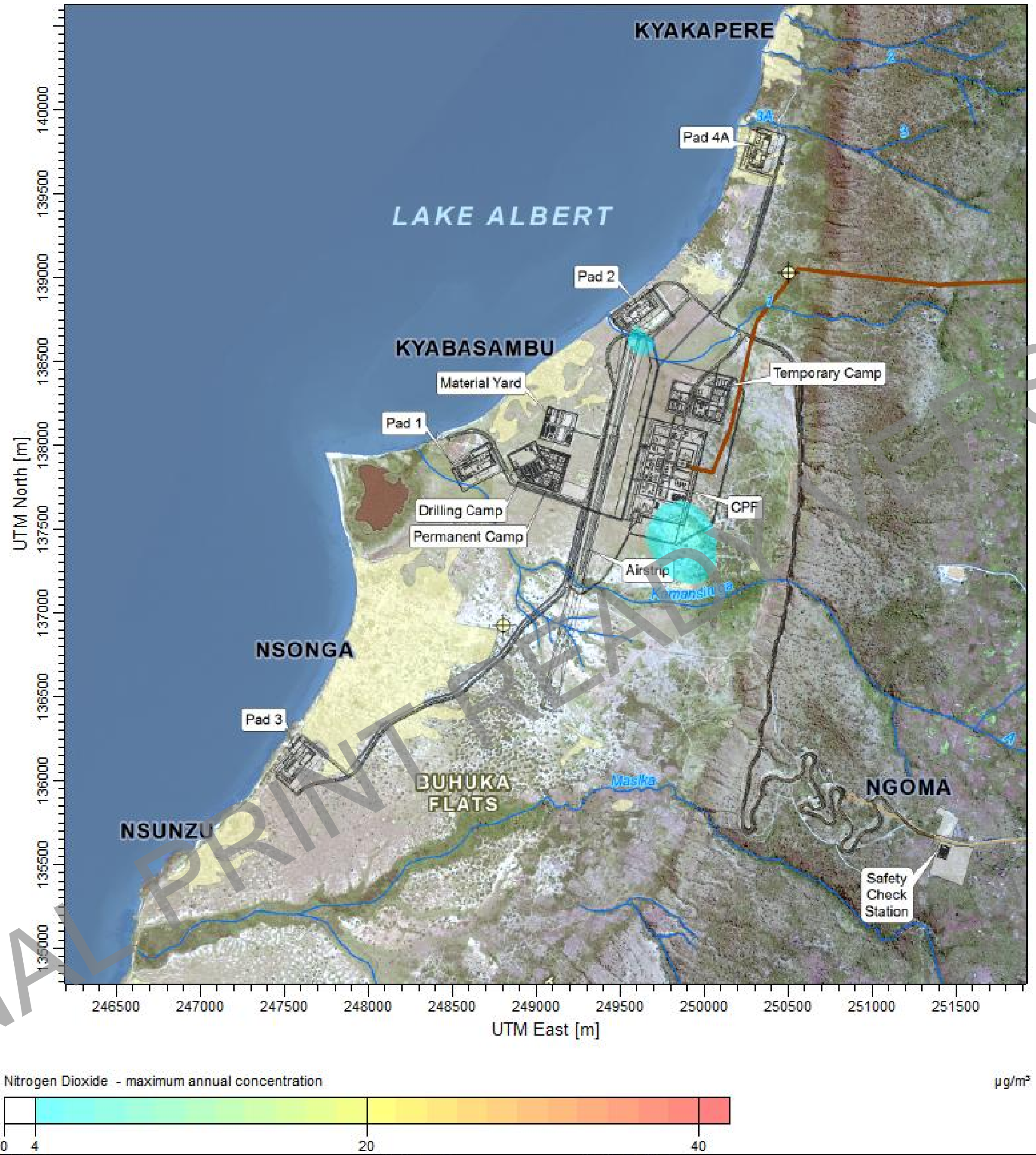
PROJECT TITLE:
CNOOC
Operations - Drilling On Well Pad 1



COMMENTS:	SOURCES: 9	COMPANY NAME: Golder Associates	
	RECEPTORS: 7232	MODELER: Lance Coetzee	GOLDER
	OUTPUT TYPE: Concentration	SCALE: 1:30 000 (0 – 1 km)	
	MAX: 7 µg/m³	DATE: 2018/02/08	PROJECT NO.:

Figure 50: Operations - drilling on well pad 1, NO_2 maximum annual concentration.

PROJECT TITLE:
CNOOC
Operations - Drilling On Well Pad 2



COMMENTS:	SOURCES: 9	COMPANY NAME: Golder Associates
	RECEPTORS: 7232	MODELER: Lance Coetzee
	OUTPUT TYPE: Concentration	SCALE: 1:30 000 (0 – 1 km)
	MAX: 7 µg/m³	DATE: 2018/02/08
		PROJECT NO.:

Figure 51: Operations - drilling on well pad 2, NO_2 maximum annual concentration.

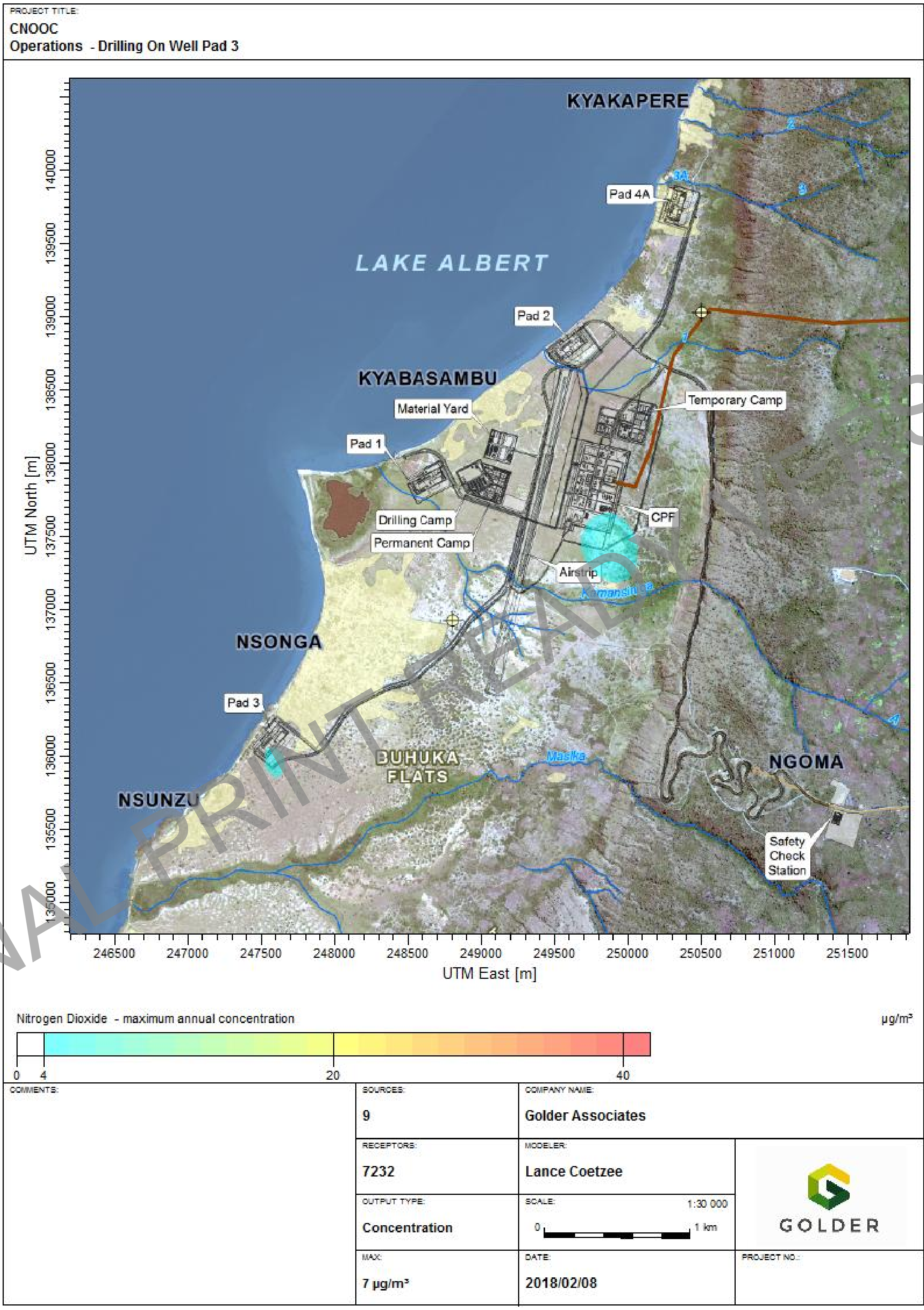
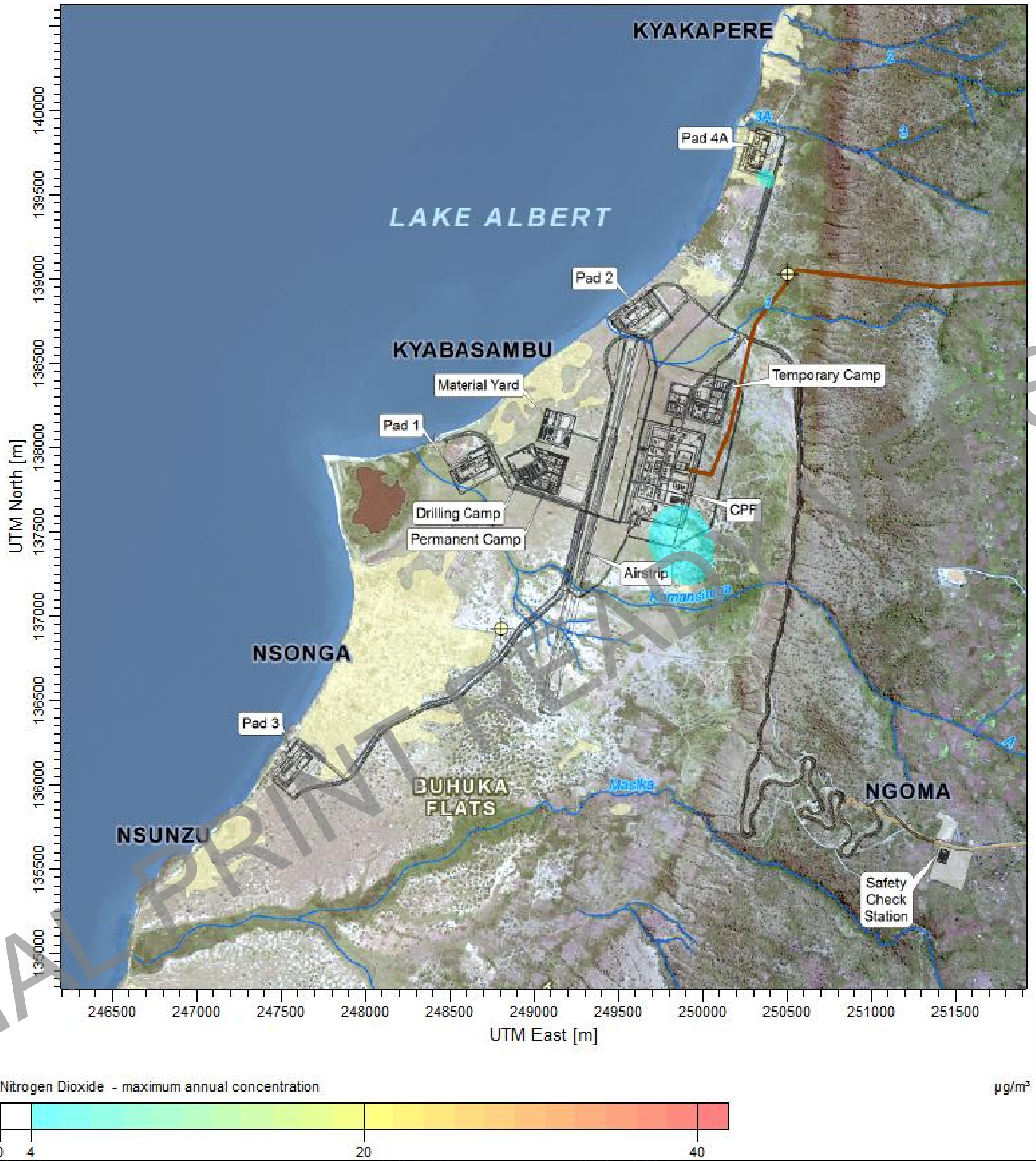


Figure 52: Operations - drilling on well pad 3, NO_2 maximum annual concentration.

PROJECT TITLE:
CNOOC
Operations - Drilling On Well Pad 4



COMMENTS:	SOURCES: 9	COMPANY NAME: Golder Associates	
	RECEPTORS: 7232	MODELER: Lance Coetzee	GOLDER
	OUTPUT TYPE: Concentration	SCALE: 1:30 000 (0 – 1 km)	
	MAX: 7 µg/m³	DATE: 2018/02/08	PROJECT NO.:

Figure 53: Operations - drilling on well pad 4, NO_2 maximum annual concentration.

4.5 Air Quality Impact Assessment

4.5.1 Project impact rating

Impacts ratings for this air quality impact assessment were based on the temporal intensities of various atmospheric pollutants experienced by various valued environmental and social components (VEC's). Sensitivity classifications for identified VEC's are provided in Table 21.

Table 21: Impact assessment criteria and rating scale – Air Quality

Criterion	Rating	Definition
Magnitude (the expected magnitude or size of the impact)	Negligible	Pollutant concentration ≤ 25% of guidelines.[5]
	Very Low	Pollutant concentration >25% and ≤ 50% of guidelines.
	Moderate	Pollutant concentration >50% and ≤ 100% of guidelines.
	Major	Pollutant concentration >100% of guidelines.
Sensitivity of Receptor (VEC)	Negligible	Infrastructure (no human exposure).
	Very Low	Infrastructure (worker occupational exposure).
	Moderate	Camps (worker medium-term exposure)
	Major	Villages (public long-term / repeated exposure)

Impact ratings for construction, operation and decommissioning are provided in Table 22, Table 23 and Table 24. In alignment with IFC requirements impacts as a result of the proposed project as well as existing impacts were assessed to provide cumulative impacts[6].

[5] As a general rule, the IFC General EHS Guideline suggests 25% percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed.

[6] A cumulative impact, in relation to an activity, is the impact of an activity that may not be significant in isolation, but may become significant when added to the existing and potential impacts arising from similar or other activities in the area.

Table 22: Air quality impact assessment rating for construction

Impact	Location	Project Impact			Cumulative Impact			Impact After Mitigation		
		Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance
Degradation of airshed due to increased particulate and / or trace gas concentrations as a result of the project.	Access Roads	3	4	12	4	4	16	2	4	8
	Airstrip	3	2	6	4	2	8	2	2	4
	CPF	3	2	6	4	2	8	2	2	4
	CPF Camps	3	3	9	4	3	12	2	3	6
	Escarpment Camp	3	3	9	4	3	12	2	3	6
	Escarpment Road	3	4	12	4	4	16	2	4	8
	Flow Lines	3	1	3	4	1	4	2	1	2
	Pipeline	3	1	3	4	1	4	2	1	2
	Well Pads	3	2	6	4	2	8	2	2	4
	Busigi	1	4	4	1	4	4	1	4	4
	Ilkamiro	1	4	4	1	4	4	1	4	4
	Kacunde	1	4	4	1	4	4	1	4	4
	Kiina	1	4	4	1	4	4	1	4	4
	Kyabasambu	2	4	8	2	4	8	2	4	8
	Kyakapere	2	4	8	2	4	8	2	4	8
	Kyenyanja	1	4	4	1	4	4	1	4	4
	Ngoma	1	4	4	1	4	4	1	4	4
	Nsonga	2	4	8	2	4	8	2	4	8
	Nsunzu	2	4	8	2	4	8	2	4	8
	Sangarao	1	4	4	1	4	4	1	4	4
	Senjonjo	1	4	4	1	4	4	1	4	4
	Ususa	1	4	4	1	4	4	1	4	4

Table 23: Air quality impact assessment rating for operations

Impact	Location	Project Impact			Cumulative Impact			Impact After Mitigation		
		Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance
Degradation of airshed due to increased particulate and / or trace gas concentrations as a result of the project.	Access Roads	2	4	8	3	4	12	2	4	8
	Airstrip	2	2	4	3	2	6	2	2	4
	CPF	2	2	4	3	2	6	2	2	4
	CPF Camps	2	3	6	3	3	9	2	3	6
	Escarpment Camp	2	3	6	3	3	9	2	3	6
	Escarpment Road	2	4	8	3	4	12	2	4	8
	Flow Lines	1	1	1	2	1	2	1	1	1
	Pipeline	1	1	1	2	1	2	1	1	1
	Well Pads	2	2	4	3	2	6	2	2	4
	Busigi	1	4	4	1	4	4	1	4	4
	Ilkamiro	1	4	4	1	4	4	1	4	4
	Kacunde	1	4	4	1	4	4	1	4	4
	Kiina	1	4	4	1	4	4	1	4	4
	Kyabasambu	2	4	8	3	4	12	2	4	8
	Kyakapere	2	4	8	3	4	12	2	4	8
	Kyenyanja	1	4	4	1	4	4	1	4	4
	Ngoma	1	4	4	1	4	4	1	4	4
	Nsonga	2	4	8	3	4	12	2	4	8
	Nsunzu	2	4	8	3	4	12	2	4	8
	Sangarao	1	4	4	1	4	4	1	4	4
	Senjonjo	1	4	4	1	4	4	1	4	4
	Ususa	1	4	4	1	4	4	1	4	4

Table 24: Air quality impact assessment rating for decommissioning

Impact	Location	Project Impact			Cumulative Impact			Impact After Mitigation		
		Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance	Magnitude	Sensitivity	Significance
Degradation of airshed due to increased particulate and / or trace gas concentrations as a result of the project.	Access Roads	1	4	4	1	4	4	1	4	4
	Airstrip	1	2	2	1	2	2	1	2	2
	CPF	1	2	2	1	2	2	1	2	2
	CPF Camps	1	3	3	1	3	3	1	3	3
	Escarpment Camp	1	3	3	1	3	3	1	3	3
	Escarpment Road	1	4	4	1	4	4	1	4	4
	Flow Lines	1	1	1	1	1	1	1	1	1
	Pipeline	1	1	1	1	1	1	1	1	1
	Well Pads	1	2	2	1	2	2	1	2	2
	Busigi	1	4	4	1	4	4	1	4	4
	Ilkamiro	1	4	4	1	4	4	1	4	4
	Kacunde	1	4	4	1	4	4	1	4	4
	Kiina	1	4	4	1	4	4	1	4	4
	Kyabasambu	1	4	4	1	4	4	1	4	4
	Kyakapere	1	4	4	1	4	4	1	4	4
	Kyenyanja	1	4	4	1	4	4	1	4	4
	Ngoma	1	4	4	1	4	4	1	4	4
	Nsonga	1	4	4	1	4	4	1	4	4
	Nsunzu	1	4	4	1	4	4	1	4	4
	Sangarao	1	4	4	1	4	4	1	4	4
	Senjonjo	1	4	4	1	4	4	1	4	4
	Ususa	1	4	4	1	4	4	1	4	4

4.5.2 Construction

Exceedances of the short term (daily) IFC PM_{10} and $PM_{2.5}$ guidelines are anticipated during construction (land clearing, preparation and construction). These impacts will be transient and can be effectively mitigated.

4.5.3 Operation

Simulations performed to assess NO_2, SO_2, PM_{10}, $PM_{2.5}$ and VOC dispersion as a result of emissions from the project predicted that IFC guidelines would not be exceeded.

VEC's most adversely affected include the villages of:

- Kyakapere;
- Kyabasambu;
- Nsonga; and,
- Nsunzu.

4.5.4 Decommissioning

Atmospheric emissions from the project will stop at closure; therefore no adverse residual[7] air quality impacts are anticipated.

4.6 Conclusions and Recommendations

Adverse air quality ratings predicted for construction activities are mainly as a result of both short-term and impacts of particulates, ands adverse air quality ratings predicted for operations mainly as a result of short and long term NO_2 impacts. Impacts from SO_2, H_2S and VOC's were predicted to be very low. Measure aimed at mitigation emissions from the project are provided in Table 25

[7] Residual impacts are significant project-related impacts that might remain after on-site mitigation measures (avoidance, management controls, abatement, restoration, *etc.*) have been implemented.

Table 25: Air quality management plan.

Phase	Impacts	Objective	Detailed Mitigation measures	Monitoring Mechanism	Target / Performance indicator	Responsibility
Construction / Operations	Impact of increase in ambient particulate concentrations due to vehicles, construction works, drilling, and, dust from exposed areas.	Avoid and/or reduce dust	- Wet suppression, wet misting during materials handling activities; - Wind speed reduction through sheltering or wind breaks for open exposed areas prone to wind erosion (where possible); - Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation; - Progressive rehabilitation and re-vegetation; - Reduction in unnecessary traffic volumes; - Wet suppression on all unpaved roads with water or a suitable dust palliative to achieve 50% control efficiency or better (note: water alone will only achieve a 75% control efficiency); - Park vehicles off travelled roadways; and - Rigorous speed control and the institution of traffic calming measures to reduce vehicle dust entrainment.	Ambient dust/particulate matter monitoring	Compliance with local and international regulations	Environmental Department
Construction / Operations	Impact of increase in ambient trace gas concentrations due to vehicles, construction works, power generation, and, drilling.	Minimise trace gas emissions	- Maintain and service all vehicles and diesel generators regularly to ensure that exhaust particulate and trace gas emissions are kept to a minimum with post combustion control measures; - Where possible, use low sulphur fuels to reduce SO_2 emissions - Maintain a site wide emissions inventory for the mining operation; - Re run the air dispersion model to quantify the mining operations ambient air quality impacts on the surrounding	Ambient trace gas monitoring	Compliance with local and international regulations	Environmental Department

Phase	Impacts	Objective	Detailed Mitigation measures	Monitoring Mechanism	Target / Performance indicator	Responsibility
			environment every 5 years or when a significant change to operations takes place; - Operate and maintain a site specific particulate monitoring and trace gas monitoring network; - The air quality monitoring network should undergo and annual audit and optimization study to ensure that the network is maintained in alignment with best practice and is relevant to the key emission sources on the ground; and - The emissions inventory and model should feed into future updates of the air quality management plan.			
Operations	Impact of increase in ambient trace gas concentration due to power generation, heating and flaring.	Minimise trace gas emissions	- Implement post combustion control measures on engines; control technologies applicable to these sources include selective catalytic reduction (SCR), non-selective catalytic reduction (NSCR), and catalytic oxidation (CO oxidation catalyst). - Implement annual emission testing.	Ambient air quality monitoring / emission testing	Compliance with local and international regulations	Environmental Department

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Signature Page

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