# Appendices

# Appendix I – Land title exchange documents

ORIGINAL

# IRREVOCABLE POWER OF ATTORNEY

BY

GODSON C. IWEZOR, JONATHAN OLIKPE UMUNNA, EMMANUEL NWUJU, CHIGOZIE NWAOGWUGWU and OKECHUKWU OGBONNA for ourselves and as representatives of the Umunwankwonta kindred in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State

(DONORS)

TO

MAIN INFRASTRUCTURE LIMITED

(DONEE)

IN RESPECT OF: All that piece and parcel of land known as and called **'Ohia Orkwu Udara'** being, lying and situate at Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and measuring **132923.319 square meters** as more particularly delineated in the area verged 'Red' in the survey plan of No. **TAN/AB/107A/2013** and signed by Surveyor Nwaogwugwu; Tochukwu A.

**PREPARED BY:**

Sam Ogbu-Nwobodo, Esq.
VIGOR-LAW & CO.
Attorneys at Law
3 Adekunle Fajuyi Close
Asokoro, Abuja, FCT
Nigeria.
www.vigor-law.com

VLC
VIGOR-LAW & CO

# IRREVOCABLE POWER OF ATTORNEY

**BY**

**GODSON C. IWEZOR, JONATHAN OLIKPE UMUNNA, EMMANUEL NWUJU, CHIGOZIE NWAOGWUGWU** and **OKECHUKWU OGBONNA** for ourselves and as representatives of the Umunwankwonta kindred in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State

(DONORS)

**TO**

**MAIN INFRASTRUCTURE LIMITED**

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**PREPARED BY:**

Sam Ogbu-Nwobodo, Esq.
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Attorneys at Law
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Asokoro, Abuja, FCT
Nigeria.
www.vigor-law.com

VLC
VIGOR-LAW & CO

# IRREVOCABLE POWER OF ATTORNEY

This Deed of Irrevocable Power of Attorney is made this _____ day of _____ 2013;

BY US:

**GODSON C. IWEZOR, JONATHAN OLIKPE UMUNNA, EMMANUEL NWUJU, CHIGOZIE NWAOGWUGWU** and **OKECHUKWU OGBONNA** for ourselves and as representatives of the Umunwankwonta kindred in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State, hereinafter referred to as the **'Donors'** which expression wherever the context so applies shall include our heirs, assigns or successors-in-title;

TO:

**MAIN INFRASTRUCTURE LIMITED**; a limited liability company incorporated in Nigeria under the Companies and Allied Matters Act with its office at No. 20 Dares-Salem Crescent, Wuse II Abuja, hereinafter referred to as the **'Donee'** which expression wherever the context so applies shall include its heirs, assigns or successors-in-title.

## WHEREAS

(i) The 'Donors' are the beneficial owners by customary inheritance of Asa land and persons entitled to apply for Certificate of Occupancy over all that piece and parcel of land known as and called **'Ohia Orkwu Udara'** being, lying and situate at Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and measuring **132923.319 square meters** as more particularly delineated in the area verged 'Red' in the survey plan of No. **TAN/AB/107A/2013** and signed by Surveyor Nwaogwugwu; Tochukwu A, and therein expressed to be bounded by beacons **nos. SC/ABR 4923, 4924, 4925, 4926, 4927, 4928, 4929, 4930, 4931, 4932, 4933, 4934,** and **4935** hereinafter referred as the "Property".

(ii) The Donee is desirous of developing some Electric Power related Projects on the Property.

(iii) That upon valuable consideration, the 'Donors' have agreed to grant and do hereby grant to the "Donee" an Irrevocable Power of Attorney over the said 'Property'.

**NOW WITNESSES** that we; **GODSON C. IWEZOR, OLIKPE UMUNNA, EMMANUEL NWUJU, OKECHUKWU OGBONNA** and **CHIGOZIE NWAOGWUGWU** for ourselves and as representatives of Umunwankwonta kindred Family in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and being the beneficial owners by customary inheritance and persons entitled to apply for Right of Occupancy over the said 'property' do hereby Appoint and Constitute

**MAIN INFRASTRUCTURE LIMITED** of the aforesaid address to be our True and Lawful Attorney over the said 'property' and in the Donee's names to do **ALL** or **ANY** of the following ACTS, THINGS or **DEEDS**, that is to say:-

1. To administer, manage and superintend the management of all that our said 'property' with all the cash crops and trees planted thereat.
2. To commence, issue notices, prosecute, enforce, demand, answer, take-over, eject, defend or oppose all actions and other legal proceedings and demands touching on the said 'Property' and also if considers fit, to compromise, refer to arbitration, abandon, submit to judgment or become non-suited in any such action or proceeding as aforesaid.
3. To take possessions of, occupy and exercise all rights, privileges and payments over the said 'Property'.
4. **And** generally to act as our **ATTORNEY OR AGENT** in relation to the said 'Property' and in all other matters in which we may be interested or concerned and on our behalves, to execute and do all instrument, acts or things as fully and effectually in all respects as ourselves could do if present **PROVIDED** that the instruments, acts, or things shall relate and refer to the 'Property' aforesaid.
5. To assign, mortgage, charge, rent, sublet or otherwise part with possession of the said 'Property' or part thereof to anyone including itself and to apply the proceeds for any purpose within its absolute discretion.
6. To apply for through the recognized processes and obtain in the Donee's names a certificate/right of occupancy or Deed of Assignment for the said 'Property' or part thereof.
7. To erect or caused to be erected and or maintain any building[s], plants, equipments and improvements on the said 'Property' or part thereof in accordance with any approved plan of the relevant authority which the said 'Donee' considers necessary and suitable for its purpose.
8. To re-delegate the power[s] herein given to it ['Donee'] to any person including itself so that the legal principle of **'DELEGATUS NON POTEST DELEGARE'** shall not apply in this power of attorney.
9. **PROVIDED ALSO** that in consideration of the sum of **=N=32,500,000.00, [Thirty Two Million, Five Hundred Thousand Naira** only and payments shown in the attached receipt, **(Fidelity Bank Plc Manager's Cheque numbers 01255051, 01255052, 01255053, 01255054, all cheques made payable to Godson C. Iwezor, having been duely authorized to recieve same on behalf of the donors)**, and the performance of all the customary rites relating thereto now paid and completely performed by the 'Donee' to the 'Donors', [the receipt and performance whereof the 'Donors' hereby acknowledge], this power of attorney is hereby expressed to be **ABSOLUTELY IRREVOCABLE** by us or our successors-in-title.

10. **IT IS FURTHER** agreed that there will be no further payment of customary rite and annual rent whatsoever by the 'Donee' to the 'Donors' on this "Property".

11. The Donee will from time to time at its sole discreation engage in meaningfull Coperate Social Responsibility (CSR) projects aimed at the physical and human capital development of the donor's Community.

11. **IT IS ALSO AGREED THAT** the 'Donors' shall indemnify the 'Donee' and or it's successors-in-title against all losses and cost arising from any defect in the 'Donors' title.

12. **We** confirm and agree to confirm whatever the said 'Donee' shall legitimately do by virtue of these presents and agree to sign all other relevant documents and take actions all necessary for the perfection of the title herein transfered irrevocably by the ''Donors'' to the ''Donee''.

**IN WITNESS WHEREOF THE DONORS HAVE PLACED OUR HANDS AND SEALS AND THE COMMON SEAL OF THE DONEE IS HEREUNDER AFFIXED ON THE DATE WRITTEN ABOVE.**

**SIGNED SEALED AND DELIVERED BY THE WITHIN NAMED 'DONORS'**

(i) _____ [l.s]
GODSON C. IWEZOR

(ii) _____ [l.s]
JONATHAN OLIKPE UMUNNA

(iii) _____ [l.s]
EMMANUEL NWUJU

(iv) _____ [l.s]
CHIGOZIE NWAOGWUGWU

(v) _____ [l.s]
OKECHUKWU OGBONNA

IN THE PRESENCE OF:

1. Name: MR MOSES. C. EBERE
   Address: UMUNWANKWANTA ORSHU. OGUE
   Signature: M.C.E

2. Name: MR. FRIDAY AKATABI

Address: Umunwankwonta Ogba - Ogwe

Signature: F. AKATORY

3. Name: Okey Nnaji

Address: Plot 1, close 11, Rumuwoko Rd Off Ada-George Rd, Port Harcourt.

Signature:

THE COMMON SEAL OF THE
WITHIN NAMED 'DONEE'
IS HEREUNTO AFFIXED

IN THE PRESENCE OF:

1. Name: Engr. Sylvester C. Okolike

Address: 225 Agbani Road Enugu.

Position: [Director]

Signature:

2. Name: Theophilus Egbuji

Address: 32 Mbosi Rd Owerri Imo State.

Position: [Secretary]

Signature:

CHECKED
Commissioner of Stamp Duties

PLAN NO.

N/AB /107A/2013

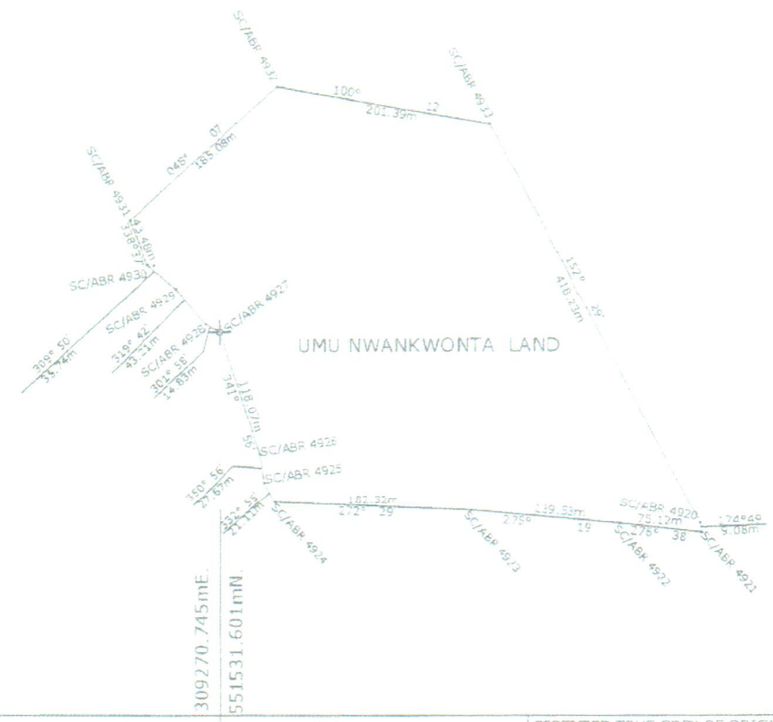
PLAN SHEWING LANDED PROPERTY
OF
**MAIN INFRASTURES LIMITED**
AT
OHIA UDARA ORGWU, OGWE
UKWA WEST LOCAL GOVT. AREA
ABIA STATE, NIGERIA
SCALE : 1/5000

m50 0 100 200 300m

ORIGIN : (UTM ZONE 32)

AREA =133408.746 SQ.Mtrs

U N




PLAN NO.

TAN/AB /107A/2013

EP. NO.
JRV/REC /2013

CERTIFIED TRUE COPY OF ORIGINAL PLAN
MADE BY ME ON 28/08 /2013


**SURV. NWAOGWUGWU,TOCHUKWU A.** M.Sc,AN S
MCSTEPH PROJECTS LIMITED
PLOT 1, CLOSE 11, RUMUEVORLU ROAD,
OFF ADA GEORGE ROAD,PORT HARCOURT,RIVERS STATE.

ORIGINAL

# IRREVOCABLE POWER OF ATTORNEY

BY

**TEMPLE A. NWARIE, ENYINNA ALOZIA STEVEN, AND OKORO CHARLES AKOMA, for themselves and as representatives of Umuwulu Kindred Family of Orgwu village, Ogwe Asa, in Ukwa West LGA Abia State.**

(DONORS)

TO

MAIN INFRASTRUCTURE LIMITED

(DONEE)

IN RESPECT OF: All that piece and parcel of land known as and called **'Ohia Orkwu Udara'** being, lying and situate at Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and measuring **89848.870 square meters** as more particularly delineated in the area verged 'Red' in the survey plan of No. **TAN/AB/107A/2013** and signed by Surveyor Nwaogwugwu; Tochukwu A.

**PREPARED BY:**

Sam Ogbu-Nwobodo, Esq.
**VIGOR-LAW & CO.**
Attorneys at Law
3 Adekunle Fajuyi Close
Asokoro, Abuja, FCT
Nigeria.
**www.vigor-law.com**

# IRREVOCABLE POWER OF ATTORNEY

BY

TEMPLE A. NWARIE, ENYINNA ALOZIA STEVEN, AND OKORO CHARLES AKOMA, for themselves and as representatives of Umuwulu Kindred Family of Orgwu village, Ogwe Asa, in Ukwa West LGA Abia State.

(DONORS)

TO

MAIN INFRASTRUCTURE LIMITED

(DONEE)

IN RESPECT OF: All that piece and parcel of land known as and called Ohia Orkwu Udara being lying and situate at Orgwu Village Ogwe Asa in Ukwa West Local Government Area of Abia State and measuring 89848.370 square meters as more particularly delineated in the area verged Red in the survey plan of No TAN/AB/107A/2013 and signed by Surveyor Nwaogwugwu Tochukwu A.

PREPARED BY:

Sam Ogolo-Nwobodo Esq.

Attorneys at Law
3 Adekunle Fajuyi Close
Asokoro, Abuja, FCT
Nigeria.

# IRREVOCABLE POWER OF ATTORNEY

This Deed of Irrevocable Power of Attorneyis made this _____ day of _____ 2013;

BY US:

**TEMPLE A. NWARIE, ENYINNA ALOZIE STEVEN,** and**OKORO CHARLES AKOMA,**for ourselves and as representatives of the Umuwulu kindred Family in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State, hereinafter referred to as the **'Donors'** which expression wherever the context so applies shall include our heirs, assigns or successors-in-title;

TO:

**MAIN INFRASTRUCTURE LIMITED;** a limited liability company incorporated in Nigeria under the Companies and Allied Matters Act with its office at No. 20 Dares-Salem Crescent, Wuse II Abuja, hereinafter referred to as the 'Donee' which expression wherever the context so applies shall include its heirs, assigns or successors-in-title.

AND THE DUTY THEREON HAS BEEN ASSESSED ACCORDINGLY

## WHEREAS

(i) The 'Donors' are the beneficial owners by customary inheritance of Asa land and persons entitled to apply for Certificate of Occupancy over all that piece and parcel of land known as and called **'Ohia Orkwu Udara'** being, lying and situate at Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and measuring 89848.870 square meters as more particularly delineated in the area verged 'Red' in the survey plan of No. **TAN/AB/107A/2013** and signed by Surveyor Nwaogwugwu; Tochukwu A,and therein expressed to be bounded by beacons nos. **SC/ABR 4914, 4915, 4916, 4917, 4918, 4919, 4920, 4933, 4934,** and **4935**, hereinafter referred as the "Property".

(ii) The Donee is desirous of developing some Electric Power related Projects on the Property

(iii) That upon valuable consideration, the 'Donors' have agreed to grant and do hereby grant to the "Donee" an Irrevocable Power of Attorney over the said 'Property'.

Commissioner
FULLY STAMPED

**NOW WITNESSES** that we; **TEMPLE A. NWARIE, ENYINNA ALOZIE STEVEN,** and**OKORO CHARLES AKOMA** for ourselves and as representatives of UmuwuluKindred Family in Orgwu village, Ogwe, Asa in Ukwa West Local Government Area of Abia State and being the beneficial owners by customary inheritance and persons entitled to apply for Right of Occupancy over the said 'property' do hereby Appoint and Constitute **MAIN INFRASTRUCTURE LIMITED** of the aforesaid address to be our True and Lawful Attorney over the said 'property'

and in the Donee's names to do **ALL** or **ANY** of the following ACTS, THINGS or DEEDS, that is to say:-

1. To administer, manage and superintend the management of all that our said 'property' with all the cash crops and trees planted thereat.
2. To commence, issue notices, prosecute, enforce, demand, answer, take-over, eject, defend or oppose all actions and other legal proceedings and demands touching on the said 'Property' and also if considers fit, to compromise, refer to arbitration, abandon, submit to judgment or become non-suited in any such action or proceeding as aforesaid.
3. To take possessions of, occupy and exercise all rights, privileges and payments over the said 'Property'.
4. And generally to act as our **ATTORNEY OR AGENT** in relation to the said 'Property' and in all other matters in which we may be interested or concerned and on our behalves, to execute and do all instrument, acts or things as fully and effectually in all respects as ourselves could do if present **PROVIDED** that the instruments, acts, or things shall relate and refer to the 'Property' aforesaid.
5. To assign, mortgage, charge, rent, sublet or otherwise part with possession of the said 'Property' or part thereof to anyone including itself and to apply the proceeds for any purpose within its absolute discretion.
6. To apply for through the recognized processes and obtain in the Donee's names a certificate/right of occupancy or Deed of Assignment for the said 'Property' or part thereof.
7. To erect or caused to be erected and or maintain any building[s], plants, equipments and improvements on the said 'Property' or part thereof in accordance with any approved plan of the relevant authority which the said 'Donee' considers necessary and suitable for its purpose.
8. To re-delegate the power[s] herein given to it ['Donee'] to any person including itself so that the legal principle of **'DELEGATUS NON POTEST DELEGARE'** shall not apply in this power of attorney.
9. **PROVIDED ALSO** that in consideration of the sum of **=N=19,500,000.00, [Nineteen Million, Five Hundred Thousand Nairaonly** and payments shown in the attached receipt, **(Fidelity Bank Plc Manager's Cheque numbers01255055 and 01255056, all cheques made payable to Enyinna Alozie steven, having been duely authorized to recieve same on behalf of the donors)**, and the performance of all the customary rites relating thereto now paid and completely performed by the 'Donee' to the 'Donors', [the receipt and performance whereof the 'Donors' hereby acknowledge], this power of attorney is hereby expressed to be **ABSOLUTELY IRREVOCABLE** by us or our successors-in-title.

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**IN WITNESS WHEREOF THE DONORS HAVE PLACED OUR HANDS AND SEALS AND THE COMMON SEAL OF THE DONEE IS HEREUNDER AFFIXED ON THE DATE WRITTEN ABOVE.**

SIGNED SEALED AND DELIVERED
BY THE WITHIN NAMED 'DONORS' (i) _____ [l.s]
**TEMPLE A. NWARIE,**

(ii) _____ [l.s]
**ENYINNA ALOZIE STEVEN**

(iii) _____ [l.s]
**OKORO CHARLES AKOMA**
237 Sule Rd Ifako
Lagos

IN THE PRESENCE OF:

1. Name: **OCHIEZE NWARIE, (Consenting Witness)**
   Address: _____
   Signature: _____

2. Name: OSONDU Alasie
   Address: OGBE Asa
   Signature: _____

3. Name: IKE OSAJINDI
   Address: 50 Kings park Ave. Abj

Signature: _____

THE COMMON SEAL OF THE
WITHIN NAMED 'DONEE'
IS HEREUNTO AFFIXED

IN THE PRESENCE OF:

1. Name: Engr. Sylvester C. Okwuhke
   Address: 225 Agbani Road Enugu.
   Position: [Director]
   Signature: _____

2. Name: Theophilus Egbuji
   Address: 32 Mbaisi Rd Owerri Imo State
   Position: [Secretary]
   Signature: _____

CHECKED
Commissioner of Stamp Duties

PLAN NO.

AN/AB /107/2013

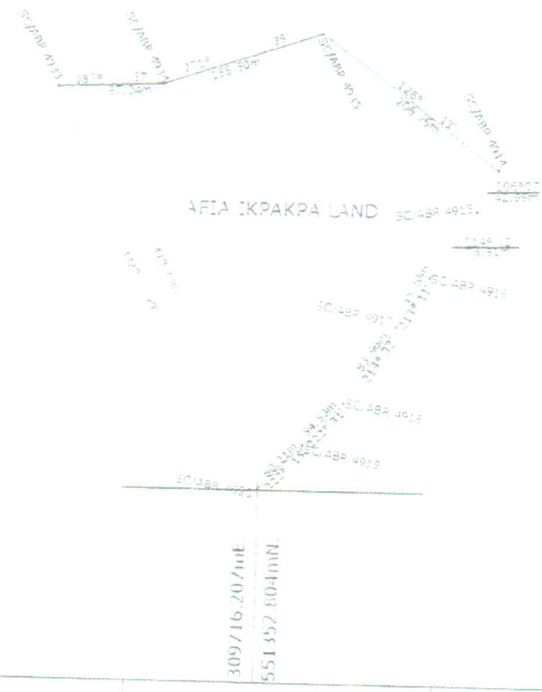
PLAN SHEWING LANDED PROPERTY
OF
**MAIN INFRASTURES LIMITED**
AT
OHIA UDARA ORGWU, OGWE
UKWA WEST LOCAL GOVT. AREA
ABIA STATE, NIGERIA
SCALE : 1/5000

m 50 0 100 200 300m

U N

ORIGIN : [illegible]

AREA = 89848.870 SQ.Mtrs




PLAN NO.

TAN/AB /107/2013

DEP. NO.
SURV/REC /2013

CERTIFIED TRUE COPY OF ORIGINAL PLAN
MADE BY ME ON 28/08/2013

**SURV. NWAOGWUGWU,TOCHUKWU A.** M.Sc.ANIS
MCSTEPH PROJECTS LIMITED
PLOT 1, CLOSE 11, RUMUEVORLU ROAD,
OFF ADA GEORGE ROAD,PORT HARCOURT,RIVERS STATE.

# Appendix II - Field Methodologies

# FIELD METHODOLOGIES

## 1.0 General

An inter-disciplinary approach involving data acquisition on climate/air quality, noise, soil, vegetation, groundwater, health and socio-economics was adopted for the OMA power plant EIA field sampling. Each of the environmental components was sampled in line with FMENV guidelines and standards.

The detailed methodologies for data acquisition for each environmental component are discussed in sections below:

## 1.1 Climate/Meteorology

Data acquired for this study was gotten via field work measurement (microclimatic data) for a period of 8 hours and long term data (macroclimatic data) from the Nigerian Meteorological Agency. The measurements of the various meteorological parameters were carried out using an Acurite Scientific Weather Station and a combined Wind vane and Anemometer as summarized in **Table 1**.

### 1.1.1 Topology

The topography represents the features of the study area such as the position of roads as well as the general landscape. The location maps were studied by team members and based on the maps; sampling stations were established across the study area.

The study area was traversed by foot. The distribution and pattern of the physical features defining the terrain in the project area was used as common approach to landscape description and assessment. Physiographic or land system approach was used to identify the units forming the terrain.

## 1.2 Air Quality/Noise

Air quality measurements were taken using Ambient Air quality & Gaseous point source emission analyzer in the upwind downwind directions. Four sampling stations (AQ1 – AQ4) were established in the study area with one control (AQ5) established away from the proposed plant site. The sampling stations were established

**Table 1: Instrumentation and Method of Observation**

| Climatic Variable | Instrumentation | Record Availability | |
|---|---|---|---|
| | | Onsite | Synoptic |
| Air temperature, Atmospheric Pressure Relative humidity | A multi-parameter digital barometer, Hygrometer and Thermometer used to measure temperature in $^{o}$C, Absolute pressure in Pa and relative humidity as %. Model: Acurite weather station | √ | √ |
| Wind direction and Wind speed | A combined Wind Vane and Anemometer was used in determining wind direction and speed. The wind speeds were measured in m/s.<br><br>Model: Acurite | √ | √ |
| Rainfall | Rain Gauge | | √ |

**Table 2: Measurement Methods for Air Quality Parameters**

| *Equipment* | Model | Capability |
|---|---|---|
| Ambient Air quality & Gaseous point source emission analyzer | Aeroqual series 205 | Gas analyser automatically extracts atmospheric air sent through the analyser gas sensors for the determination of gases of interest ($SO_2$, VOC, $NO_2$, CO, $H_2S$). |
| Suspended Particulate Matter (SPM) | Kanomax piezobalance dust monitor model 3521 | A dust monitor that automatically extracts atmospheric air sent through the analyser sensor for the determination of SPM. |
| Noise | TESTO 815<br><br>Sound meter | Sound level meter with measuring range of 30 – 130 dB (A), accuracy of ±1.5 dB (A). The average reading over a period of two minutes was taken to be the Noise-level at each point. |

based on upwind and downwind wind directions. Six readings were taken at each sampling stations at one hourly interval. **Plate 1** shows air quality measurement.

Ambient noise was measured using Sound meter model TESTO 815. Measurements were taken at the same stations where air quality measurements were taken. At each point, measurements were taken for fifteen (15) minutes, the range of the noise level was noted and the true mean computed. The results are shown in **Appendix III**. **Plate 2** shows noise measurement during the field survey.

**Plate 1: Air Quality Measurement using hand-held Digital Meter**

**Plate 2: Noise Measurement using a noise meter**

### *1.3 Vegetation/Ecology*

Desk study: Research and review of literature on the project was undertaken in the following areas:

- Land use;
- Biodiversity, including wildlife resources; and
- Vegetation and habitats.

Literature sources included but not limited to the following:

- Abia State and Federal Government publications
- Journal articles and university academic research (dissertations)
- Internet sources including the following:
  i. www.cbd.int/doc/world/ng/ng-nbap-01-en.boc (Nigeria National Biodiversity Plan, 2010, 104pp).
  ii. www.birdlife.org/datazone/userfiles/file/IBAs/AfricaCntryPDFs/Nigeria.pdf (Important Bird Areas in Africa and Associated Islands: Priority Areas for Conservation, Newbury and Cambridge, UK, Birdlife Conservation Series No.11)

Vegetation was sampled along five (5) transects (Veg. 1 – Veg. 5) as shown on the sampling map (Appendix I). The geographical coordinates of sampling locations were determined using GPS. Vegetation was studied in sampling quadrats measuring 20 m x 20 m. For each sampling

point, information on habitat, vegetation structure and species was recorded. Habitat data included vegetation description, latitude, longitude and signs of wildlife. Plant species were categorized into trees (4m or more), shrubs (0.5m to 4m) and herbs (less than 0.5m). Dendrometric parameters recorded included height (m), diameter (cm) and number of trees. A pair of binoculars (Model: Helios Fieldmaster 8x40) was employed to aid field identification of trees. Tree species diversity were calculated as the Shannon-Wiener ($H^1$) index and the abundance of herbaceous species expressed in semi-quantitative terms (dominant, frequent, occasional, rare) (Pryor, 1981). On this basis, a species having a wide distribution with many stands would be classified as a common, abundant, widespread species. Alternatively, a species may have a similarly wide distribution but with very few stands and would be classified as an infrequent, restricted or occasional species. Species of limited geographic distribution and with a few stands are classified as rare. Unidentified plants were taken in a plant press for verification/identification later in the University of Calabar reference herbarium. Plant species were identified using the works of Hutchinson and Dalziel (1963, 1968). Features of ecological interest were documented with a Canon IXUS 210 digital camera.

Plants were also observed for any disease symptoms/conditions. Samples of diseased plants were taken in polythene bags (where field identification of disease – causing agents could not be ascertained) for subsequent laboratory analysis to establish the identity of organism(s) associated with specific disease symptoms. Such diseased plants were examined microscopically and cultured on Agar plates using the surface spreading plate technique. Fungal and bacterial pathogens were identified microscopically using such features as cultural morphology and pigmentation.

### *Wildlife*

Observations were made at each sampling location for evidence of vertebrate wildlife. Hideouts such as crevices, leaf litters, logs etc were probed with props to rout out any hidden animals. Tree canopies were observed for birds and other arboreal animals such as squirrels and snakes. The indirect count method was employed, particularly for animals that do not readily offer themselves for observation. This method utilizes evidence of animal presence or occupation for evaluation of any given species without physically seeing them. Such evidence includes the presence of burrows, droppings, footprints, feathers, carcass, tracks sloughed skin,

devoured fruits and calls of different animals (**Plate 3**). The technique employed included looking for faecal droppings, foot marks, calls of different animals and sighting (direct observation). This was complemented by a review of existing wildlife literature for the area. Animals were identified using the field guides and keys of Kingdom (1997) and Happold (1987).

**Plate 3: Wildlife indicators in the area**

Invertebrate surveys were not done due to the following reasons:

a) Most of the study area was secondary forest or land undergoing regeneration following farming activities. Most of the study area was not farmland but vegetation that is considered as the 'oil palm variant', indicating areas that were under continuous cultivation for long periods.
b) There is no gas flaring activity within 5 km radius of project boundaries. Large numbers of insects are usually attracted to flares and get destroyed by the scorching heat. Loss of large numbers of insects could affect pollination success of crops. For agricultural projects or projects located gas flares invertebrate surveys (mostly arthropods) are usually carried out.
c) Nocturnal surveys were not carried out during the study as the security situation in the Niger Delta has been critical for over ten years. This makes such studies extremely risky and impracticable.

## 1.4 *Soil Studies*

Composite soil samples were collected at two depth, 0-15cm (surface soils) and 15-30cm (subsurface soils) at 20 stations using a soil auger (**Plate 4**). Soil samples were also collected for Total Hydrocarbon (THC) using aluminum foils for surface and subsurface soils.

Soil samples collected were packed in labelled polyethylene bags (**Plate 5**). The samples collected were processed, sieved through a 2mm mesh before transportation to the laboratory for physico-chemical analysis A total of forty (40) composite soil samples were collected. Parameters analysed include; pH, EC, available P, organic carbon, total Nitrogen, exchangeable bases (Ca, K, Mg, Na), exchange acidity, bulk density and particle size distribution (sand, silt and clay fractions). Samples were also be analysed for heavy metals (Fe, Pb, Mn Cd, Ni V, Co, Cu, Zn and Cr) and Total Hydrocarbon (THC) contents. All the sampling points were geo-referenced, and the sampled bagged and labelled for routine laboratory analysis.

For the determination of the soil parameters required for physico-chemical and biological characteristics, disturbed samples collected were air-dried. The methods adopted for the analysis were the standard analytical methods of analysis. Particle size analysis was done by the hydrometer method using Calgon as a dispersing agent. The sand fraction was separated into fine and coarse sand, and textural triangle was used in determining the textural classes of the soils (Grossman and Reinsch, 2002).

Undisturbed samples were collected using a core sampler from each of the locations at 15 cm interval. During the exercise, the core samplers were carefully driven into the soils using a geologic hammer and a hand trowel was used to remove the core to avoid disintegration. The samples were used for the following determination;

***Saturated hydraulic conductivity***

Saturated hydraulic conductivity was measured by the constant head perimeter method.
Calculation was done using the transposed Darcy's equation which states as follows:

**Plate 4**: **Soil sampling with an auger**

**Plate 5: Soil sample collection**

$Ks = QL/At\Delta H$ ……Eqn. (1)

Where Ks = saturated hydraulic conductivity ($cmh^{-1}$ )

Q = steady state volume of flow ($cm^3$)

L = length of soil column (cm)

A = cross sectional area of sample ($cm^2$)

t = time of flow (h)

$\Delta H$= hydraulic head difference

***Soil Moisture Constant***

The core samples were placed in a basin of water to saturate by capillarity for 24 hours prior to the installation of a constant head perimeter as reported by Edem and Edem, (2009). After the conduction of saturated hydraulic conductivity, the weight of those core samples were taken in grams, then after 3 days the weights (g) were taken again to determine moisture content at field capacity, then on the $10^{th}$ day the weights were also recorded to determine the permanent wilting coefficient. Available water content was calculated by subtracting the permanent wilting point from water at field capacity by using the formulae:

FC - PWP = AWC …….Eqn. (2)

Where FC = Field capacity (g) unit

PWP = Permanent wilting coefficient.

AWC = available water content (%)

***Bulk density***

The samples were re-saturated before oven-drying for bulk density determination, using this model,

BD = Ms/Vb …… Eqn. (3)

Where, BD = bulk density

Ms = mass of solid

Vb = bulk volume of the soil

## 1.5 Geotechnical Soil Investigation

The stratigraphy of the subsurface soil in the study area was investigated using the Percussion drilling technique. Three boreholes were drilled in the study area with a drilling bit of diameter size 6 inches and to an aquifer depth of 27m (90ft). Sample cuttings were taken at intervals from each borehole especially at points where lithologic changes were observed for laboratory soil testing of textural characteristics and lithosection design to help give a vivid picture of the subsurface. Standard Penetration Test (SPT) was taken in situ in BH2 and BH3. Undisturbed samples were taken with a corer at depths of 1.0 and 1.5m from BH2. All samples were preserved appropriately for further analysis.

***Bearing Capacity***

The bearing capacity (qf) of the sample was calculated from the triaxial test using Terzaghi's Equation:

$$qf = c.(Nc) + \gamma . D_f . (Nq) + ½ . \gamma . B(N\gamma)$$

Where qf= ultimate bearing capacity of the soil

C=Cu= Cohesion Intercept

Nc, Nq, Nɤ = Bearing Capacity Factors

Df= Depth of footing

B= width of footing

Factor of safety= 3

## 1.6 Hydrgeology/Ground water studies

Groundwater flow direction in the study area was determined using the three boreholes BH1, BH2 and BH3 drilled within the land space for the proposed power plant. The boreholes were located in a triangular manner and were drilled to depths of about 28m each**.** The depth to water (static water level) in each borehole was measured with a Fisher Model WLT electric water level indicator. The depth to water (SWL) of each borehole was subtracted from the elevation of the borehole to obtain the total water head at that point. A triangle was drawn on the map with the boreholes and their respective total head values at the apices of the triangle

from which the direction of flow for ground water was found. The wells were screened and cased, cemented and capped (**Plate 7**). The use of PVC pipes for casing and screening was to prevent infiltration and contamination of the groundwater. The wells were developed by flushing for a period of about two hours and allowed to equilibrate before water samples were collected.

**Plate 7: Casing of a Bore Hole**

# Appendix III – Baseline Data

# SECTION I

# Air Quality & Noise measurements; Groundwater, Soil Characteristics and Vegetation of the Study Area

**Table 1a: Air quality and Noise Measurements (Dry season)**

| Parameters | FMENV Limits | AQ 1 | AQ 2 | AQ 3 | AQ 4 | AQ 5 | AQ 6 | AQ 7 | AQ 8 | AQ 9 | AQ 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature ($^oC$) | N/A | 28.4 | 30.2 | 29.4 | 28.5 | 29.6 | 32.0 | 29.6 | 31.3 | 30.4 | 29.5 |
| R/ Humidity (%) | N/A | 52.3 | 56.2 | 57.0 | 49.7 | 57.0 | 53.4 | 58.1 | 55.2 | 60.3 | 53.8 |
| Atm. Pressure (mbar) | N/A | 1013 | 1000 | 1011 | 1011 | 1011 | 1006 | 1006 | 1008 | 1012 | 1010 |
| $NO_x$ (ppm) | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 |
| $SO_2$ (ppm) | 0.10 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.01 | 0.02 | 0.03 | 0.01 |
| VOC (ppm) | N/A | 3.6 | 3.5 | 4.3 | 5.0 | 3.9 | 4.8 | 3.6 | 4.3 | 6.2 | 5.6 |
| $H_2S$ (ppm) | 0.08 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| $NH_3$ (ppm) | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| CO (ppm) | N/A | 2.5 | 2.5 | 2.4 | 2.6 | 2.1 | 3.2 | 3.0 | 2.3 | 2.2 | 3.1 |
| SPM ($\mu g/m^3$) | 600 | 122 | 75 | 160 | 162 | 95 | 76 | 118 | 65 | 86 | 59 |
| Wind direction | N/A | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| Wind speed (m/s) | N/A | 2.7 | 2.5 | 3.3 | 2.4 | 2.8 | 2.5 | 3.5 | 2.6 | 2.4 | 2.6 |
| Average Noise (dBA) | 80-100 | 47.2 | 41.6 | 43.8 | 46.2 | 42.6 | 42.4 | 39.5 | 43.7 | 44.0 | 38.6 |
| **Heavy metals ($\mu g/m^3$)** | | | | | | | | | | | |
| Cadmium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Iron | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Copper | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Manganese | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sodium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Nickel | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

**Table 1b: Air quality and Noise Measurements (Wet season)**

| Parameters | FMENV Limits | AQ 1 | AQ 2 | AQ 3 | AQ 4 | AQ 5 | AQ 6 | AQ 7 | AQ 8 | AQ 9 | AQ 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature ($^oC$) | N/A | 27.2 | 27.2 | 26.8 | 27.0 | 27.6 | 28.0 | 27.5 | 27.3 | 27.0 | 27.1 |
| R/ Humidity (%) | N/A | 64.4 | 69.4 | 66.8 | 67.1 | 67.7 | 69.3 | 68.2 | 68.5 | 69.4 | 67.5 |
| Atm. Pressure (mbar) | N/A | 1010 | 1010 | 1010 | 1011 | 1012 | 1008 | 1007 | 1012 | 1010 | 1011 |
| $NO_x$ (ppm) | 0.06 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | <0.01 | 0.02 |
| $SO_2$ (ppm) | 0.10 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.04 | 0.02 | 0.01 |
| VOC (ppm) | N/A | 4.3 | 6.1 | 2.8 | 7.3 | 2.5 | 4.4 | 3.5 | 6.0 | 5.4 | 5.6 |
| $H_2S$ (ppm) | 0.08 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| $NH_3$ (ppm) | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| CO (ppm) | N/A | 1.9 | 2.4 | 1.3 | 2.0 | 1.8 | 2.2 | 1.8 | 1.6 | 1.4 | 2.0 |
| SPM ($\mu g/m^3$) | 600 | 13.6 | 15.2 | 9.1 | 16.3 | 17.8 | 14.0 | 12.2 | 15.7 | 11.6 | 20.2 |
| Wind direction | N/A | SW | SW | S | SW | SW | N | NE | SW | W | SW |
| Wind speed (m/s) | N/A | 2.1 | 2.3 | 1.8 | 2.0 | 2.4 | 2.1 | 1.7 | 2.3 | 2.3 | 1.6 |
| Average Noise (dBA) | 80-100 | 42.5 | 43.4 | 46.1 | 48.1 | 43.9 | 36.3 | 40.4 | 39.0 | 35.6 | 41.2 |
| **Heavy metals ($\mu g/m^3$)** | | | | | | | | | | | |
| Cadmium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Iron | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Copper | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Magnesium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Manganese | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sodium | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Nickel | N/A | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

**Table 2a: Physicochemical Characteristic of Ground Water (Dry Season)**

| Parameters | BH 1 | BH 2 | BH3 | BHC |
|---|---|---|---|---|
| Temp. ($^oC$) | 27.3 | 30.3 | 27.4 | 33.2 |
| pH | 7.02 | 6.45 | 6.48 | 5.03 |
| Turbidity (NTU) | 11.0 | 9.3 | 10.2 | 3.1 |
| Cond. (µS/cm) | 80.0 | 40.0 | 70.0 | 170.0 |
| Salinity as $Cl^-$(mg/l) | 30.2 | 10.5 | 29.4 | 45.1 |
| DO (mg/l) | 5.76 | 6.72 | 3.90 | 6.60 |
| TDS (mg/l) | 45.0 | 22.0 | 40.0 | 93.5 |
| TSS (mg/l) | 7.43 | 9.82 | 10.0 | 8.14 |
| COD (mg/l) | 4.00 | 2.00 | 10.00 | 4.00 |
| BOD (mg/l) | 4.74 | 3.78 | 6.60 | 3.90 |
| Nitrate (mg/l) | 1.20 | 0.99 | 0.96 | 1.06 |
| Sulphate (mg/l) | 28.1 | 14.1 | 21.7 | 1.41 |
| Phosphate (mg/l) | 1.15 | 0.11 | 0.83 | 0.13 |
| Sodium (mg/l) | 0.23 | 1.10 | 0.17 | 0.32 |
| Potassium (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Calcium (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Ammonium (mg/l) | 0.33 | 0.27 | 0.26 | 0.29 |
| T/Hardness (mg/l) | 15.2 | 16.0 | 18.2 | 26.0 |
| THC (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Oil & Grease (mg/l) | <0.01 | <0.01 | 0.01 | <0.01 |
| Arsenic(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Iron(mg/l) (mg/l) | 0.012 | <0.001 | 0.010 | <0.001 |
| Mercury(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Lead(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Zinc(mg/l) | <0.001 | <0.001 | 0.03 | 0.01 |
| Vanadium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Nickel(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| **Microbiology** | | | | |
| THBC (x $10^1$ cfu/ml) | 0.00 | 1.00 | 1.00 | 1.00 |
| HUB (x $10^1$ cfu/ml) | 0.00 | 0.00 | 2.00 | 0.00 |
| THFC (x $10^1$ cfu/ml) | 0.00 | 0.00 | 0.00 | 0.00 |
| HUF (x $10^1$ cfu/ml) | 0.00 | 0.00 | 0.00 | 0.00 |
| Coliform (x $10^1$ cfu/100ml) | 1.00 | 0.00 | 2.00 | 0.00 |

**Table 2b: Physicochemical Characteristic of Ground Water (Wet Season)**

| Parameters | BH 1 | BH 2 | BH3 | BHC |
|---|---|---|---|---|
| Temp. ($^oC$) | 26.5 | 26.7 | 26.3 | 26.8 |
| pH | 6.50 | 6.52 | 6.61 | 6.65 |
| Turbidity (NTU) | 5.3 | 2.4 | 4.8 | 3.6 |
| Cond. (µS/cm) | 42.1 | 36.3 | 38.1 | 40.2 |
| Salinity as $Cl^-$(mg/l) | 16.2 | 12.5 | 9.8 | 11.6 |
| DO (mg/l) | 5.2 | 5.8 | 5.6 | 6.1 |
| TDS (mg/l) | 20.4 | 15.3 | 16.4 | 21.5 |
| TSS (mg/l) | 2.6 | 2.0 | 3.1 | 2.7 |
| COD (mg/l) | 17.2 | 15.5 | 18.1 | 12.4 |
| BOD (mg/l) | 4.61 | 4.32 | 4.41 | 4.10 |
| Nitrate (mg/l) | 0.21 | 0.18 | 0.16 | 0.15 |
| Sulphate (mg/l) | 3.23 | 5.18 | 2.21 | 6.20 |
| Phosphate (mg/l) | 0.17 | 0.23 | 0.40 | 0.36 |
| Sodium (mg/l) | 1.21 | 2.20 | 1.42 | 1.30 |
| Potassium (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Calcium (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Ammonium (mg/l) | 0.07 | 0.13 | 0.15 | 0.21 |
| T/Hardness (mg/l) | 60.0 | 35.0 | 40.0 | 60.0 |
| THC (mg/l) | <0.01 | <0.01 | <0.01 | <0.01 |
| Oil & Grease (mg/l) | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper(mg/l) | 0.032 | 0.051 | 0.024 | 0.020 |
| Iron(mg/l) (mg/l) | 0.215 | 0.230 | 0.018 | 0.020 |
| Mercury(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Lead(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Zinc(mg/l) | 0.006 | 0.021 | 0.012 | 0.014 |
| Vanadium(mg/l) | <0.001 | <0.001 | <0.001 | <0.001 |
| Nickel(mg/l) | 0.24 | 0.17 | 0.26 | 0.19 |
| **Microbiology** | | | | |
| THBC (x $10^1$ cfu/ml) | 5.00 | 4.00 | 2.00 | 4.00 |
| HUB (x $10^1$ cfu/ml) | 0.00 | 0.00 | 0.00 | 0.00 |
| THFC (x $10^1$ cfu/ml) | 1.00 | 0.00 | 1.00 | 1.00 |
| HUF (x $10^1$ cfu/ml) | 0.00 | 0.00 | 0.00 | 0.00 |
| Coliform (x $10^1$ cfu/100ml) | 0.00 | 0.00 | 0.00 | 0.00 |

## Table 3a (i): Physical characteristics of soil (Dry season)

| Sampling points | BD g/cm$^3$ | Porosity cm$^3$cm$^{-3}$ | AMC % | Sand | Silt | Clay | Texture | BD g/cm$^3$ | Porosity cm$^3$cm$^{-3}$ | AMC % | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % | | | | | | | % | | | |
| | Surface soil | | | | | | | Sub surface soil | | | | | | |
| SS 1 | 1.44 | 0.4566 | 0.25 | 94.6 | 4.2 | 1.2 | Sandy | 1.51 | 0.4306 | 0.24 | 85.0 | 10.2 | 4.8 | Loamy Sand |
| SS 2 | 1.41 | 0.4796 | 0.28 | 81.3 | 10.6 | 8.1 | Loamy Sand | 1.23 | 0.5364 | 0.27 | 86.4 | 7.4 | 6.2 | Loamy Sand |
| SS 3 | 1.50 | 0.4340 | 0.31 | 93.2 | 3.2 | 3.6 | Sandy | 1.65 | 0.3771 | 0.21 | 88.6 | 6.7 | 4.7 | Loamy Sand |
| SS 4 | 1.42 | 0.4801 | 0.24 | 85.8 | 9.3 | 4.9 | Loamy Sand | 1.24 | 0.5322 | 0.33 | 85.2 | 9.2 | 5.6 | Loamy Sand |
| SS 5 | 1.50 | 0.4341 | 0.33 | 87.3 | 5.4 | 7.3 | Loamy Sand | 1.46 | 0.4494 | 0.32 | 84.9 | 10.2 | 4.9 | Loamy Sand |
| SS 6 | 1.62 | 0.3982 | 0.21 | 85.4 | 10.2 | 6.8 | Loamy Sand | 1.38 | 0.4793 | 0.25 | 91.8 | 4.2 | 4.0 | Sandy |
| SS 7 | 1.54 | 0.4189 | 0.27 | 91.5 | 4.5 | 4.0 | Sandy | 1.26 | 0.5259 | 0.29 | 87.2 | 6.6 | 6.2 | Loamy Sand |
| SS 8 | 1.52 | 0.4264 | 0.31 | 93.7 | 3.4 | 2.9 | Sandy | 1.50 | 0.4340 | 0.31 | 83.7 | 8.2 | 8.1 | Sandy |
| SS 9 | 1.39 | 0.4755 | 0.24 | 95.0 | 4.2 | 0.8 | Sandy | 1.33 | 0.4981 | 0.27 | 85.0 | 4.2 | 10.8 | Loamy Sand |
| SS 10 | 1.58 | 0.4011 | 0.26 | 83.0 | 6.1 | 10.9 | Loamy Sand | 1.42 | 0.4644 | 0.24 | 93.5 | 3.7 | 2.8 | Sandy |
| SS 11 | 1.43 | 0.4591 | 0.32 | 85.1 | 6.2 | 8.7 | Loamy Sand | 1.37 | 0.4832 | 0.26 | 91.7 | 4.4 | 3.9 | Sandy |
| SS 12 | 1.61 | 0.3974 | 0.23 | 85.8 | 8.0 | 6.2 | Loamy Sand | 1.35 | 0.4913 | 0.28 | 92.2 | 4.4 | 3.4 | Sandy |
| SS 13 | 1.57 | 0.4075 | 0.26 | 87.2 | 8.0 | 4.8 | Loamy Sand | 1.34 | 0.4943 | 0.32 | 86.3 | 8.9 | 4.8 | Loamy Sand |
| SS 14 | 1.66 | 0.3736 | 0.16 | 84.9 | 5.5 | 9.6 | Loamy Sand | 1.28 | 0.5175 | 0.25 | 85.6 | 8.0 | 6.4 | Loamy Sand |
| SS 15 | 1.40 | 0.4717 | 0.34 | 86.2 | 8.4 | 5.4 | Loamy Sand | 1.40 | 0.4724 | 0.31 | 84.3 | 10.9 | 4.8 | Loamy Sand |
| SS 16 | 1.52 | 0.4015 | 0.28 | 85.0 | 12.2 | 8.8 | Loamy Sand | 1.36 | 0.4872 | 0.24 | 87.0 | 8.2 | 4.2 | Loamy Sand |
| SS 17 | 1.60 | 0.3997 | 0.25 | 93.2 | 3.6 | 3.2 | Sandy | 1.51 | 0.4301 | 0.28 | 94.2 | 2.9 | 2.9 | Sandy |
| SS 18 | 1.43 | 0.4591 | 0.32 | 88.2 | 2.6 | 9.2 | Loamy Sand | 1.23 | 0.5367 | 0.31 | 86.4 | 9.0 | 4.6 | Loamy Sand |
| SS 19 | 1.47 | 0.4453 | 0.29 | 86.3 | 6.9 | 6.8 | Loamy Sand | 1.65 | 0.3776 | 0.27 | 87.2 | 8.4 | 4.4 | Loamy Sand |
| SS 20 | 1.50 | 0.4340 | 0.27 | 89.0 | 6.2 | 4.8 | Loamy Sand | 1.24 | 0.5325 | 0.24 | 87.0 | 8.2 | 4.2 | Loamy Sand |

P = porosity, BD = bulk density, AMC= available moisture content.

**Table 3a (ii): Chemical characteristics of soils (Dry season)**

| Sampling points | pH | EC µS/cm | Redox potential | SAR | Mg mg/kg | Na meq/100g | CEC meq/100g | Ammonium mg/kg | pH | EC µS/cm | Redox Potential | SAR | Mg mg/kg | Na meq/100g | CEC meq/100g | Ammonium mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | Sub surface soil | | | | | | | |
| SS 1 | 4.95 | 48 | 7.52 | 8.78 | 1.78 | 10.20 | 7.15 | 0.76 | 4.68 | 90 | 4.35 | 9.12 | 1.89 | 10.50 | 8.90 | 0.76 |
| SS 2 | 5.70 | 82 | 4.15 | 12.40 | 1.92 | 3.98 | 10.50 | 0.38 | 4.96 | 75 | 5.66 | 11.30 | 2.34 | 0.89 | 9.95 | 0.38 |
| SS 3 | 4.50 | 52 | 5.20 | 9.70 | 2.62 | 7.11 | 20.50 | 0.88 | 5.19 | 48 | 4.21 | 10.34 | 2.18 | 11.10 | 17.00 | 0.88 |
| SS 4 | 4.42 | 42 | 4.33 | 9.43 | 2.93 | 12.90 | 12.90 | 0.30 | 4.20 | 51 | 5.11 | 8.22 | 3.20 | 7.85 | 7.85 | 0.30 |
| SS 5 | 5.10 | 65 | 5.64 | 7.32 | 1.88 | 21.30 | 21.30 | 0.15 | 5.15 | 62 | 5.24 | 8.04 | 1.78 | 16.30 | 16.30 | 0.15 |
| SS 6 | 5.18 | 73 | 6.17 | 10.30 | 2.04 | 15.21 | 15.21 | 0.32 | 5.30 | 68 | 5.29 | 8.05 | 2.53 | 9.25 | 4.25 | 0.32 |
| SS 7 | 4.92 | 46 | 6.20 | 7.14 | 1.63 | 9.22 | 9.22 | 0.49 | 4.63 | 52 | 4.78 | 11.80 | 1.12 | 11.35 | 1.35 | 0.49 |
| SS 8 | 4.66 | 30 | 5.60 | 10.30 | 3.08 | 16.35 | 16.30 | 0.28 | 4.28 | 35 | 7.99 | 8.73 | 2.73 | 13.00 | 13.00 | 0.28 |
| SS 9 | 5.83 | 75 | 12.80 | 19.00 | 26.69 | 15.00 | 12.00 | 0.98 | 4.97 | 69 | 11.90 | 18.00 | 20.20 | 11.62 | 10.90 | 0.98 |
| SS10 | 5.20 | 32 | 8.00 | 17.20 | 32.00 | 20.16 | 20.50 | 0.32 | 5.55 | 21 | 6.10 | 20.20 | 28.00 | 12.00 | 15.80 | 0.32 |
| SS 11 | 4.15 | 45 | 10.50 | 17.20 | 26.00 | 9.95 | 17.50 | 0.50 | 4.12 | 29 | 10.30 | 15.20 | 23.00 | 10.90 | 16.20 | 0.50 |
| SS 12 | 4.92 | 27 | 7.80 | 14.20 | 21.00 | 13.00 | 14.80 | 0.38 | 4.98 | 20 | 6.57 | 11.06 | 26.00 | 14.20 | 14.60 | 0.38 |
| SS 13 | 4.12 | 48 | 6.65 | 16.30 | 27.20 | 13.30 | 13.20 | 0.38 | 4.16 | 39 | 2.95 | 18.00 | 27.20 | 12.08 | 16.00 | 0.38 |
| SS 14 | 5.21 | 23 | 3.89 | 14.20 | 31.20 | 18.00 | 15.80 | 0.20 | 5.01 | 52 | 4.89 | 13.20 | 25.00 | 16.80 | 17.30 | 0.20 |
| SS 15 | 4.99 | 47 | 5.28 | 14.90 | 23.00 | 16.80 | 12.20 | 0.49 | 5.31 | 42 | 5.70 | 12.50 | 28.10 | 17.20 | 11.90 | 0.49 |
| SS 16 | 5.21 | 68 | 5.82 | 17.20 | 23.30 | 15.00 | 13.50 | 0.81 | 4.81 | 49 | 5.11 | 14.20 | 24.20 | 13.20 | 12.80 | 0.81 |
| SS 17 | 5.55 | 38 | 2.32 | 11.06 | 29.00 | 16.20 | 10.50 | 0.65 | 4.15 | 29 | 3.95 | 16.30 | 22.30 | 14.00 | 9.85 | 0.65 |
| SS 18 | 4.12 | 45 | 5.07 | 19.80 | 23.00 | 11.50 | 11.90 | 0.35 | 4.92 | 39 | 6.05 | 18.00 | 28.20 | 12.80 | 12.20 | 0.35 |
| SS 19 | 4.98 | 34 | 6.65 | 14.20 | 26.30 | 13.50 | 10.20 | 0.53 | 4.12 | 32 | 8.2 | 13.20 | 29.20 | 12.00 | 13.10 | 0.53 |
| SS 20 | 4.16 | 49 | 10.2 | 14.90 | 25.00 | 13.00 | 1.30 | 0.65 | 4.00 | 46 | 7.52 | 13.20 | 23.90 | 12.60 | 16.00 | 0.65 |

EC = Electrical conductivity, SAR = Sodium Adsorption Ratio, CEC = Cation Exchange Capacity

## Table 3a (iii): Heavy Metals concentration (mg/kg) in Soil (Dry season)

| Sampling points | Copper | Lead | Mercury | Iron | Zinc | Nickel | Vanadium | Chromium | Barium | cadmium | Copper | Lead | Mercury | Iron | Zinc | Nickel | Vanadium | Chromium | Barium | Cadmium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | | | Sub surface soil | | | | | | | | | |
| SS 1 | 8.00 | 0.20 | <0.01 | 23.00 | 5.12 | 1.21 | <0.001 | <0.01 | <0.001 | <0.01 | 7.25 | 0.08 | <0.01 | 24.00 | 7.12 | 1.23 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 2 | 7.10 | 0.12 | <0.01 | 23.00 | 6.10 | 1.35 | <0.001 | <0.01 | <0.001 | <0.01 | 6.43 | 0.70 | <0.01 | 22.00 | 6.12 | 1.28 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 3 | 5.89 | 0.20 | <0.01 | 26.00 | 7.01 | 1.52 | <0.001 | <0.01 | <0.001 | <0.01 | 8.12 | 0.13 | <0.01 | 27.00 | 8.04 | 1.61 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 4 | 5.97 | 0.15 | <0.01 | 22.00 | 6.00 | 1.38 | <0.001 | <0.01 | <0.001 | <0.01 | 4.82 | 0.18 | <0.01 | 21.00 | 4.82 | 1.29 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 5 | 6.43 | 0.14 | <0.01 | 21.00 | 6.43 | 1.62 | <0.001 | <0.01 | <0.001 | <0.01 | 6.25 | 0.40 | <0.01 | 19.00 | 6.25 | 1.60 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 6 | 7.04 | 0.20 | <0.01 | 19.00 | 7.04 | 1.52 | <0.001 | <0.01 | <0.001 | <0.01 | 0.82 | 0.12 | <0.01 | 22.00 | 0.82 | 1.48 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 7 | 4.42 | 0.32 | <0.01 | 26.00 | 4.42 | 1.34 | <0.001 | <0.01 | <0.001 | <0.01 | 4.35 | 0.19 | <0.01 | 20.00 | 4.35 | 1.68 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 8 | 6.35 | 0.15 | <0.01 | 23.00 | 6.25 | 1.57 | <0.001 | <0.01 | <0.001 | <0.01 | 7.21 | 0.05 | <0.01 | 26.00 | 7.21 | 1.26 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 9 | 6.25 | 0.22 | <0.01 | 28.00 | 4.53 | 1.81 | <0.001 | <0.01 | <0.001 | <0.01 | 6.76 | 0.12 | <0.01 | 25.00 | 5.95 | 2.29 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 10 | 4.22 | 0.18 | <0.01 | 27.00 | 4.33 | 1.78 | <0.001 | <0.01 | <0.001 | <0.01 | 5.28 | 0.13 | <0.01 | 28.00 | 3.82 | 2.20 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 11 | 4.55 | 0.32 | <0.01 | 29.00 | 6.12 | 2.18 | <0.001 | <0.01 | <0.001 | <0.01 | 5.15 | 0.23 | <0.01 | 28.00 | 6.05 | 2.16 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 12 | 4.74 | 0.14 | <0.01 | 27.00 | 8.01 | 1.92 | <0.001 | <0.01 | <0.001 | <0.01 | 4.81 | 0.23 | <0.01 | 26.00 | 7.22 | 1.72 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 13 | 3.31 | 0.22 | <0.01 | 27.00 | 4.33 | 2.99 | <0.001 | <0.01 | <0.001 | <0.01 | 3.63 | 0.19 | <0.01 | 26.00 | 4.25 | 1.15 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 14 | 5.62 | 0.28 | <0.01 | 27.00 | 1.98 | 1.52 | <0.001 | <0.01 | <0.001 | <0.01 | 4.70 | 0.17 | <0.01 | 26.00 | 5.21 | 1.22 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 15 | 5.04 | 0.43 | <0.01 | 28.00 | 6.27 | 1.01 | <0.001 | <0.01 | <0.001 | <0.01 | 6.72 | 0.35 | <0.01 | 26.00 | 4.71 | 1.92 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 16 | 4.71 | 0.17 | <0.01 | 26.00 | 6.22 | 1.62 | <0.001 | <0.01 | <0.001 | <0.01 | 6.22 | 0.43 | <0.01 | 21.00 | 5.66 | 1.70 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 17 | 4.82 | 0.35 | <0.01 | 22.00 | 5.82 | 1.61 | <0.001 | <0.01 | <0.001 | <0.01 | 4.44 | 0.17 | <0.01 | 23.00 | 6.28 | 1.25 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 18 | 5.62 | 0.21 | <0.01 | 18.00 | 6.12 | 2.08 | <0.001 | <0.01 | <0.001 | <0.01 | 7.49 | 0.12 | <0.01 | 25.00 | 7.52 | 1.73 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 19 | 7.59 | 0.09 | <0.01 | 26.00 | 7.50 | 2.22 | <0.001 | <0.01 | <0.001 | <0.01 | 5.42 | 0.16 | <0.01 | 23.00 | 5.80 | 1.6 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 20 | 6.93 | 0.21 | <0.01 | 25.00 | 5.40 | 1.24 | <0.001 | <0.01 | <0.001 | <0.01 | 5.94 | 0.19 | <0.001 | 18.00 | 54.0 | 1.33 | <0.001 | <0.01 | <0.001 | <0.01 |

## Table 3a (iv): Salinity and Organic Compounds Concentration (mg/kg) of Soil (Dry season)

| Sampling points | Nitrate | Salinity as $Cl^-$ | THC | AH | Oil & grease | TOC | PAH | Phenol s | BTEX | Nitrate | Salinity as $Cl^-$ | THC | AH | Oil & grease | TOC | PAH | Phenols | BTEX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | | Sub surface soil | | | | | | | | |
| SS 1 | 1.02 | 26.30 | 0.81 | <0.01 | 0.59 | 0.90 | <0.01 | <0.01 | <0.01 | 0.79 | 8.88 | 0.93 | <0.01 | 0.72 | 0.69 | <0.01 | <0.01 | <0.01 |
| SS 2 | 0.56 | 17.80 | 0.80 | <0.01 | 0.78 | 1.20 | <0.01 | <0.01 | <0.01 | 0.66 | 26.30 | 0.78 | <0.01 | 0.69 | 0.82 | <0.01 | <0.01 | <0.01 |
| SS 3 | 0.85 | 35.50 | 1.05 | <0.01 | 0.27 | 0.27 | <0.01 | <0.01 | <0.01 | 1.21 | 8.88 | 0.58 | <0.01 | 0.82 | 0.68 | <0.01 | <0.01 | <0.01 |
| SS 4 | 0.64 | 4.44 | 0.65 | <0.01 | 1.2 | 1.20 | <0.01 | <0.01 | <0.01 | 0.52 | 35.50 | 0.60 | <0.01 | 0.68 | 0.92 | <0.01 | <0.01 | <0.01 |
| SS 5 | 0.90 | 53.30 | 0.55 | <0.01 | 0.82 | 0.82 | <0.01 | <0.01 | <0.01 | 0.17 | 26.30 | 0.67 | <0.01 | 0.92 | 0.83 | <0.01 | <0.01 | <0.01 |
| SS 6 | 1.26 | 53.30 | 0.45 | <0.01 | 0.96 | 0.96 | <0.01 | <0.01 | <0.01 | 0.89 | 26.30 | 0.52 | <0.01 | 0.83 | 0.70 | <0.01 | <0.01 | <0.01 |
| SS 7 | 0.43 | 44.40 | 0.81 | <0.01 | 0.56 | 0.86 | <0.01 | <0.01 | <0.01 | 0.82 | 26.30 | 0.92 | <0.01 | 0.69 | 1.07 | <0.01 | <0.01 | <0.01 |
| SS 8 | 0.23 | 62.10 | 0.49 | <0.01 | 0.49 | 0.75 | <0.01 | <0.01 | <0.01 | 0.35 | 35.50 | 0.35 | <0.01 | 0.82 | 0.72 | <0.01 | <0.01 | <0.01 |
| SS 9 | 0.60 | 44.40 | 1.01 | <0.01 | 0.32 | 1.12 | <0.01 | <0.01 | <0.01 | 0.58 | 26.30 | 0.79 | <0.01 | 0.22 | 0.70 | <0.01 | <0.01 | <0.01 |
| SS 10 | 0.51 | 44.40 | 0.85 | <0.01 | 0.72 | 0.52 | <0.01 | <0.01 | <0.01 | 0.78 | 8.88 | 0.70 | <0.01 | 0.69 | 1.32 | <0.01 | <0.01 | <0.01 |
| SS 11 | 0.88 | 44.40 | 0.94 | <0.01 | 0.42 | 0.78 | <0.01 | <0.01 | <0.01 | 0.43 | 53.30 | 0.89 | <0.01 | 1.01 | 1.07 | <0.01 | <0.01 | <0.01 |
| SS 12 | 0.29 | 26.30 | 0.93 | <0.01 | 0.79 | 0.72 | <0.01 | <0.01 | <0.01 | 0.29 | 17.80 | 0.52 | <0.01 | 0.59 | 0.99 | <0.01 | <0.01 | <0.01 |
| SS 13 | 0.68 | 62.10 | 1.35 | <0.01 | 0.72 | 1.23 | <0.01 | <0.01 | <0.01 | 0.59 | 26.30 | 0.99 | <0.01 | 0.78 | 0.73 | <0.01 | <0.01 | <0.01 |
| SS 14 | 0.82 | 53.30 | 0.66 | <0.01 | 0.69 | 0.86 | <0.01 | <0.01 | <0.01 | 0.77 | 35.50 | 0.53 | <0.01 | 1.23 | 1.20 | <0.01 | <0.01 | <0.01 |
| SS 15 | 0.33 | 26.30 | 1.20 | <0.01 | 0.72 | 0.45 | <0.01 | <0.01 | <0.01 | 0.48 | 44.40 | 1.10 | <0.01 | 0.82 | 1.27 | <0.01 | <0.01 | <0.01 |
| SS 16 | 0.52 | 35.50 | 0.74 | <0.01 | 0.51 | 1.18 | <0.01 | <0.01 | <0.01 | 0.41 | 44.40 | 0.62 | <0.01 | 0.44 | 0.45 | <0.01 | <0.01 | <0.01 |
| SS 17 | 0.82 | 38.00 | 1.09 | <0.01 | 0.52 | 0.80 | <0.01 | <0.01 | <0.01 | 0.72 | 29.00 | 0.82 | <0.01 | 0.62 | 0.29 | <0.01 | <0.01 | <0.01 |
| SS 18 | 0.36 | 45.00 | 1.20 | <0.01 | 0.72 | 0.65 | <0.01 | <0.01 | <0.01 | 0.78 | 39.00 | 1.02 | <0.01 | 0.48 | 0.35 | <0.01 | <0.01 | <0.01 |
| SS 19 | 0.52 | 34.00 | 1.12 | <0.01 | 0.39 | 0.77 | <0.01 | <0.01 | <0.01 | 0.65 | 32.00 | 0.86 | <0.01 | 0.72 | 0.56 | <0.01 | <0.01 | <0.01 |
| SS 20 | 0.82 | 49.00 | 1.06 | <0.01 | 0.82 | 0.62 | <0.01 | <0.01 | <0.01 | 0.78 | 46.00 | 0.98 | <0.01 | 0.58 | 0.28 | <0.01 | <0.01 | <0.01 |

**Table 3a (v): Microbiological characteristics of soil (Dry season)**

| Sampling points | THBC x$10^4$cfu/g | THFC x$10^4$cfu/g | HUB x$10^2$cfu/g | HUF x$10^2$cfu/g | THBC x$10^4$cfu/g | THFC x$10^4$cfu/g | HUF x$10^2$cfu/g | HUB x$10^2$cfu/g |
|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | Subsurface soil | | | |
| SS 1 | 5.00 | 1.00 | 2.00 | 1.00 | 4.00 | 1.00 | 1.00 | 1.00 |
| SS 2 | 2.00 | 1.00 | 0.00 | 1.00 | 3.00 | 0.00 | 1.00 | 0.00 |
| SS 3 | 2.00 | 0.00 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 |
| SS 4 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| SS 5 | 2.00 | 0.00 | 1.00 | 1.00 | 3.00 | 0.00 | 0.00 | 2.00 |
| SS 6 | 2.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 2.00 | 2.00 |
| SS 7 | 2.00 | 1.00 | 3.00 | 0.00 | 3.00 | 2.00 | 1.00 | 2.00 |
| SS 8 | 1.00 | 2.00 | 2.00 | 3.00 | 3.00 | 3.00 | 1.00 | 2.00 |
| SS 9 | 2.00 | 2.00 | 0.00 | 3.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| SS 10 | 4.00 | 0.00 | 1.00 | 1.00 | 3.00 | 1.00 | 0.00 | 0.00 |
| SS 11 | 4.00 | 1.00 | 1.00 | 1.00 | 6.00 | 2.00 | 0.00 | 0.00 |
| SS 12 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 |
| SS 13 | 1.00 | 1.00 | 0.00 | 1.00 | 3.00 | 0.00 | 0.00 | 0.00 |
| SS 14 | 2.00 | 2.00 | 0.00 | 0.00 | 8.00 | 0.00 | 1.00 | 1.00 |
| SS 15 | 3.00 | 0.00 | 1.00 | 1.00 | 2.00 | 0.00 | 1.00 | 1.00 |
| SS 16 | 6.00 | 2.00 | 1.00 | 0.00 | 2.00 | 2.00 | 1.00 | 0.00 |
| SS 17 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| SS 18 | 3.00 | 0.00 | 0.00 | 1.00 | 2.000 | 1.00 | 0.00 | 1.00 |
| SS 19 | 4.00 | 0.00 | 1.00 | 1.00 | 8.00 | 1.00 | 1.00 | 0.00 |
| SS 20 | 1.00 | 3.00 | 1.00 | 0.00 | 1.00 | 2.00 | 1.00 | 1.00 |

## Table 3b (i): Physical characteristics of soil (Wet season)

| Sampling points | BD g/cm$^3$ | Porosity cm$^3$cm$^{-3}$ | AMC % | Sand | Silt | Clay | Texture | BD g/cm$^3$ | Porosity cm$^3$cm$^{-3}$ | AMC % | Sand | Silt | Clay | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % | | | | | | | % | | | |
| | ` Surface soil | | | | | | | `Sub surface soil | | | | | | |
| SS 1 | 1.38 | 0.48 | 0.44 | 90.9 | 3.46 | 5.64 | SAND | 1.55 | 0.42 | 0.39 | 89.38 | 5.28 | 5.34 | LS |
| SS 2 | 1.46 | 0.45 | 0.47 | 92.9 | 1.46 | 5.64 | SAND | 1.55 | 0.42 | 0.45 | 92.72 | 1.28 | 6.00 | LS |
| SS 3 | 1.36 | 0.49 | 0.46 | 90.9 | 3.46 | 5.64 | SAND | 1.62 | 0.39 | 0.42 | 88.72 | 5.28 | 6.00 | LS |
| SS 4 | 1.38 | 0.48 | 0.44 | 86.9 | 7.46 | 5.64 | SAND | 1.39 | 0.48 | 0.44 | 90.72 | 3.28 | 6.00 | LS |
| SS 5 | 1.46 | 0.45 | 0.47 | 86.9 | 5.46 | 7.64 | SAND | 1.36 | 0.49 | 0.45 | 90.72 | 3.28 | 6.00 | LS |
| SS 6 | 1.36 | 0.49 | 0.46 | 86.9 | 7.46 | 5.64 | LS | 1.41 | 0.47 | 0.45 | 94.00 | 0.00 | 6.00 | SAND |
| SS 7 | 1.38 | 0.48 | 0.44 | 88.9 | 5.46 | 5.64 | LS | 1.55 | 0.42 | 0.39 | 90.00 | 4.00 | 6.00 | SAND |
| SS 8 | 1.46 | 0.45 | 0.47 | 84.9 | 7.46 | 7.64 | LS | 1.55 | 0.42 | 0.45 | 88.00 | 6.00 | 6.00 | SAND |
| SS 9 | 1.36 | 0.49 | 0.46 | 90.9 | 3.46 | 5.64 | SAND | 1.62 | 0.39 | 0.42 | 90.00 | 4.00 | 6.00 | SAND |
| SS 10 | 1.45 | 0.45 | 0.42 | 90.9 | 3.46 | 5.64 | SAND | 1.59 | 0.4 | 0.49 | 90.00 | 4.00 | 6.00 | SAND |
| SS 11 | 1.39 | 0.48 | 0.43 | 91.38 | 3.28 | 5.34 | SAND | 1.46 | 0.47 | 0.45 | 92.00 | 2.00 | 6.00 | SAND |
| SS 12 | 1.46 | 0.45 | 0.47 | 91.38 | 3.28 | 5.34 | SAND | 1.62 | 0.39 | 0.46 | 90.00 | 4.00 | 6.00 | SAND |
| SS 13 | 1.45 | 0.45 | 0.42 | 93.38 | 1.28 | 5.34 | SAND | 1.46 | 0.47 | 0.45 | 90.00 | 4.00 | 6.00 | SAND |
| SS 14 | 1.39 | 0.48 | 0.43 | 89.38 | 5.28 | 5.34 | SAND | 1.62 | 0.39 | 0.46 | 94.00 | 0.00 | 6.00 | SAND |
| SS 15 | 1.54 | 0.42 | 0.45 | 85.38 | 9.28 | 5.34 | SAND | 1.49 | 0.44 | 0.51 | 92.00 | 2.00 | 6.00 | SAND |
| SS 16 | 1.44 | 0.46 | 0.45 | 87.38 | 7.28 | 5.34 | LS | 1.6 | 0.39 | 0.46 | 92.00 | 2.00 | 6.00 | SAND |
| SS 17 | 1.36 | 0.49 | 0.52 | 89.38 | 5.28 | 5.34 | LS | 1.65 | 0.38 | 0.39 | 92.00 | 2.00 | 6.00 | SAND |
| SS 18 | 1.39 | 0.48 | 0.44 | 86.7 | 7.96 | 5.34 | LS | 1.54 | 0.42 | 0.44 | 90.66 | 3.34 | 6.00 | SAND |
| SS 19 | 1.36 | 0.49 | 0.45 | 91.38 | 3.28 | 5.34 | LS | 1.37 | 0.48 | 0.46 | 90.90 | 3.10 | 6.00 | SAND |
| SS 20 | 1.41 | 0.47 | 0.45 | 89.38 | 5.28 | 5.34 | LS | 1.42 | 0.46 | 0.42 | 91.00 | 3.00 | 6.00 | SAND |

P = porosity, BD = bulk density, AMC= available moisture content, SL = sandy loam, LS= loamy sand.

## Table 3b (ii): Chemical characteristics of soils (Wet season)

| Sampling points | pH | EC (µS/cm) | Redox potential | SAR | Mg (mg/kg) | Na (meq/100g) | CEC (meq/100g) | Ammonium (mg/kg) | pH | EC (µS/cm) | Redox potential | SAR | Mg (mg/kg) | Na (meq/100g) | CEC (meq/100g) | Ammonium (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | Sub surface soil | | | | | | | |
| SS 1 | 5.55 | 65 | 5.25 | 5.78 | 5.78 | 8.20 | 7.15 | 0.55 | 5.21 | 86 | 3.35 | 4.12 | 4.49 | 9.52 | 8.90 | 0.43 |
| SS 2 | 6.10 | 82 | 6.15 | 2.40 | 3.92 | 2.18 | 10.5 | 0.18 | 5.16 | 95 | 5.60 | 8.3 | 1.34 | 1.15 | 9.95 | 0.15 |
| SS 3 | 4.98 | 60 | 7.20 | 4.70 | 6.62 | 8.00 | 20.5 | 0.58 | 4.23 | 58 | 6.10 | 8.34 | 5.18 | 12.0 | 17.0 | 0.33 |
| SS 4 | 5.22 | 47 | 8.33 | 6.43 | 3.93 | 9.9 | 12.9 | 0.40 | 4.20 | 59 | 5.10 | 4.22 | 3.0 | 5.25 | 7.85 | 0.32 |
| SS 5 | 6.80 | 64 | 8.20 | 3.32 | 4.88 | 1.3 | 19.3 | 0.25 | 5.15 | 72 | 6.25 | 6.04 | 2.78 | 16.3 | 9.30 | 0.18 |
| SS 6 | 6.00 | 69 | 5.17 | 9.30 | 4.04 | 15.21 | 15.0 | 0.40 | 4.30 | 75 | 3.21 | 7.00 | 3.53 | 9.25 | 7.25 | 0.28 |
| SS 7 | 5.92 | 55 | 8.10 | 5.00 | 3.63 | 9.22 | 8.30 | 0.59 | 4.63 | 58 | 5.18 | 4.0 | 2.12 | 11.35 | 2.15 | 0.42 |
| SS 8 | 5.66 | 40 | 6.6 | 3.0 | 6.08 | 16.3 | 13.8 | 0.18 | 4.28 | 45 | 9.9 | 2.0 | 3.73 | 13.0 | 9.10 | 0.15 |
| SS 9 | 6.55 | 85 | 4.25 | 5.78 | 2.78 | 5.63 | 7.15 | 0.55 | 5.21 | 76 | 3.3 | 4.12 | 1.79 | 4.52 | 8.90 | 0.43 |
| SS 10 | 4.89 | 76 | 5.15 | 8.40 | 1.52 | 1.18 | 10.5 | 0.18 | 4.16 | 95 | 4.60 | 7.30 | 1.44 | 0.50 | 9.95 | 0.15 |
| SS 11 | 5.98 | 105 | 6.10 | 6.70 | 2.82 | 7.00 | 20.5 | 0.58 | 4.20 | 94 | 5.0 | 8.34 | 1.18 | 6.30 | 17.0 | 0.33 |
| SS 12 | 5.22 | 67 | 8.33 | 6.43 | 3.93 | 11.9 | 12.9 | 0.40 | 4.20 | 63 | 5.1 | 5.22 | 1.20 | 8.25 | 7.85 | 0.32 |
| SS 13 | 5.80 | 78 | 9.2 | 6.32 | 1.18 | 3.30 | 19.3 | 0.25 | 4.15 | 62 | 6.21 | 6.04 | 1.28 | 16.3 | 9.30 | 0.18 |
| SS 14 | 7.10 | 89 | 6.07 | 9.30 | 3.04 | 13.2 | 15.0 | 0.40 | 5.30 | 73 | 4.11 | 6.05 | 2.43 | 8.25 | 7.25 | 0.28 |
| SS 15 | 5.92 | 59 | 6.10 | 4.14 | 1.11 | 10.2 | 8.30 | 0.59 | 4.13 | 55 | 4.18 | 7.80 | 1.02 | 9.35 | 2.15 | 0.42 |
| SS 16 | 5.06 | 70 | 7.60 | 8.30 | 2.08 | 15.3 | 13.8 | 0.18 | 4.28 | 65 | 8.9 | 8.73 | 1.73 | 11.0 | 9.10 | 0.15 |
| SS 17 | 5.35 | 86 | 6.25 | 5.78 | 2.58 | 7.20 | 6.15 | 0.45 | 5.31 | 76 | 3.45 | 4.12 | 1.19 | 6.52 | 5.90 | 0.33 |
| SS 18 | 5.10 | 92 | 6.35 | 8.40 | 1.92 | 4.18 | 11.3 | 0.12 | 4.16 | 85 | 5.67 | 7.30 | 1.34 | 2.15 | 8.95 | 0.05 |
| SS 19 | 5.98 | 85 | 8.20 | 7.70 | 2.22 | 7.50 | 23.5 | 0.28 | 6.23 | 77 | 7.10 | 5.34 | 1.18 | 4.53 | 15.0 | 0.13 |
| SS 20 | 5.21 | 67 | 8.50 | 6.43 | 2.63 | 8.91 | 13.9 | 0.10 | 4.50 | 53 | 5.11 | 3.22 | 1.56 | 46.2 | 9.85 | 0.09 |

EC = Electrical conductivity, SAR = Sodium Adsorption Ratio, CEC = Cation exchange capacity

## Table 3b (iii): Heavy Metals Concentration (mg/kg) in Soil (Wet season)

| Sampling points | Cu | Lead | Mercury | Iron | Zinc | Nickel | Vanadium | Chromium | Barium | Cadmium | Cu | Lead | Mercury | Iron | Zinc | Nickel | Vanadium | Chromium | Barium | cadmium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | | | Sub surface soil | | | | | | | | | |
| SS 1 | 6.0 | 0.10 | <0.01 | 15.3 | 6.21 | 1.11 | <0.001 | <0.01 | <0.001 | <0.01 | 5.25 | 0.02 | <0.01 | 10.6 | 4.12 | 1.01 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 2 | 8.10 | <0.01 | <0.01 | 15.5 | 6.12 | 1.15 | <0.001 | <0.01 | <0.001 | <0.01 | 5.43 | <0.01 | <0.01 | 11.8 | 5.33 | 0.89 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 3 | 5.89 | <0.01 | <0.01 | 12.5 | 7.61 | 2.52 | <0.001 | <0.01 | <0.001 | <0.01 | 4.12 | <0.01 | <0.01 | 9.5 | 4.04 | 1.61 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 4 | 8.97 | <0.01 | <0.01 | 15.0 | 2.16 | 1.18 | <0.001 | <0.01 | <0.001 | <0.01 | 5.82 | <0.01 | <0.01 | 14.3 | 1.82 | 0.29 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 5 | 8.43 | 0.05 | <0.01 | 15.3 | 6.46 | 1.52 | <0.001 | <0.01 | <0.001 | <0.01 | 6.25 | 0.02 | <0.01 | 12.2 | 5.25 | 1.20 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 6 | 3.04 | 0.10 | <0.01 | 11.9 | 6.04 | 0.52 | <0.001 | <0.01 | <0.001 | <0.01 | 0.82 | 0.08 | <0.01 | 8.9 | 3.82 | 1.28 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 7 | 7.42 | 0.12 | <0.01 | 3.05 | 1.01 | 1.14 | <0.001 | <0.01 | <0.001 | <0.01 | 5.35 | 0.11 | <0.01 | 2.69 | 0.89 | 1.58 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 8 | 7.25 | 0.05 | <0.01 | 2.34 | 6.25 | 1.27 | <0.001 | <0.01 | <0.001 | <0.01 | 5.21 | 0.02 | <0.01 | 2.10 | 4.21 | 1.06 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 9 | 6.0 | 0.05 | <0.01 | 2.54 | 4.12 | 1.11 | <0.001 | <0.01 | <0.001 | <0.01 | 4.25 | 0.02 | <0.01 | 2.37 | 5.12 | 1,01 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 10 | 9.10 | 0.11 | <0.01 | 2.25 | 3.10 | 1.15 | <0.001 | <0.01 | <0.001 | <0.01 | 7.43 | 0.06 | <0.01 | 2.12 | 2.12 | 1.08 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 11 | 5.89 | 0.30 | <0.01 | 2.79 | 6.01 | 1.32 | <0.001 | <0.01 | <0.001 | <0.01 | 8.23 | 0.13 | <0.01 | 2.41 | 5.04 | 1.21 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 12 | 6.97 | 0.13 | <0.01 | 3.24 | 8.0 | 1.18 | <0.001 | <0.01 | <0.001 | <0.01 | 5.82 | 0.10 | <0.01 | 2.89 | 4.82 | 1.09 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 13 | 8.43 | 0.04 | <0.01 | 3.18 | 6.43 | 1.72 | <0.001 | <0.01 | <0.001 | <0.01 | 6.25 | 0.01 | <0.01 | 2.38 | 5.25 | 1.50 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 14 | 3.04 | 0.30 | <0.01 | 4.56 | 8.04 | 1.42 | <0.001 | <0.01 | <0.001 | <0.01 | 1.82 | 0.09 | <0.01 | 3.21 | 3.82 | 1.18 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 15 | 5.42 | 0.42 | <0.01 | 3.68 | 6.42 | 1.54 | <0.001 | <0.01 | <0.001 | <0.01 | 4.44 | 0.15 | <0.01 | 2.88 | 3.35 | 1.48 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 16 | 6.55 | 0.13 | <0.01 | 2.75 | 5.25 | 1.47 | <0.001 | <0.01 | <0.001 | <0.01 | 3.21 | 0.09 | <0.01 | 2.63 | 3.21 | 1.36 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 17 | 8.0 | 0.10 | <0.01 | 2.50 | 5.55 | 2.21 | <0.001 | <0.01 | <0.001 | <0.01 | 7.25 | 0.08 | <0.01 | 2.31 | 3.64 | 1.25 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 18 | 7.10 | 0.15 | <0.01 | 3.06 | 4.22 | 1.55 | <0.001 | <0.01 | <0.001 | <0.01 | 6.43 | 0.60 | <0.01 | 2.89 | 3.53 | 1.18 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 19 | 5.89 | 0.30 | <0.01 | 2.80 | 2.36 | 1.32 | <0.001 | <0.01 | <0.001 | <0.01 | 8.12 | 0.03 | <0.01 | 2.54 | 1.55 | 1.21 | <0.001 | <0.01 | <0.001 | <0.01 |
| SS 20 | 5.97 | 0.11 | <0.01 | 3.01 | 4.23 | 1.18 | <0.001 | <0.01 | <0.001 | <0.01 | 4.82 | 0.14 | <0.01 | 2.55 | 3.13 | 1.09 | <0.001 | <0.01 | <0.001 | <0.01 |

## Table 3b (iv): Salinity and Organic Compounds Concentration (mg/kg) of Soil (Wet season)

| Sampling points | Nitrate | Salinity as $Cl^-$ | THC | AH | Oil & grease | TOC | PAH | Phenol s | BTEX | Nitrate | Salinity as $Cl^-$ | THC | AH | Oil & grease | TOC | PAH | Phenol s | BTEX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface soil | | | | | | | | | Sub surface soil | | | | | | | | |
| SS 1 | 0.82 | 19.3 | 0.12 | <0.01 | 0.59 | 13.0 | <0.01 | <0.001 | <0.01 | 0.57 | 15.8 | 0.50 | <0.01 | 0.72 | 9.8 | <0.01 | <0.001 | <0.01 |
| SS 2 | 0.66 | 20.8 | 0.30 | <0.01 | 0.78 | 4.5 | <0.01 | <0.001 | <0.01 | 0.46 | 23.4 | 0.15 | <0.01 | 0.69 | 3.3 | <0.01 | <0.001 | <0.01 |
| SS 3 | 0.45 | 15.5 | 0.10 | <0.01 | 1.23 | 0.87 | <0.01 | <0.001 | <0.01 | 0.21 | 10.0 | 0.13 | <0.01 | 0.72 | 0.52 | <0.01 | <0.001 | <0.01 |
| SS 4 | 0.84 | 8.44 | 0.02 | <0.01 | 0.82 | 3.2 | <0.01 | <0.001 | <0.01 | 0.53 | 25.5 | 0.40 | <0.01 | 0.51 | 2.68 | <0.01 | <0.001 | <0.01 |
| SS 5 | 0.70 | 24.6 | 0.23 | <0.01 | 0.32 | 2.82 | <0.01 | <0.001 | <0.01 | 0.27 | 20.0 | 0.17 | <0.01 | 0.22 | 1.92 | <0.01 | <0.001 | <0.01 |
| SS 6 | 1.15 | 18.3 | 0.40 | <0.01 | 0.72 | 2.33 | <0.01 | <0.001 | <0.01 | 0.79 | 28.3 | 0.06 | <0.01 | 0.69 | 3.83 | <0.01 | <0.001 | <0.01 |
| SS 7 | 0.56 | 24.3 | 0.19 | <0.01 | 0.42 | 2.3 | <0.01 | <0.001 | <0.01 | 0.72 | 19.3 | 0.25 | <0.01 | 1.01 | 1.0 | <0.01 | <0.001 | <0.01 |
| SS 8 | 0.33 | 18.1 | 0.04 | <0.01 | 0.79 | 0.99 | <0.01 | <0.001 | <0.01 | 0.25 | 16.0 | 0.15 | <0.01 | 1.12 | 0.56 | <0.01 | <0.001 | <0.01 |
| SS 9 | 1.82 | 29.3 | 0.05 | <0.01 | 0.59 | 21.0 | <0.01 | <0.001 | <0.01 | 0.59 | 19.8 | 0.03 | <0.01 | 0.72 | 15.8 | <0.01 | <0.001 | <0.01 |
| SS 10 | 0.76 | 20.8 | 0.32 | <0.01 | 0.78 | 8.5 | <0.01 | <0.001 | <0.01 | 0.53 | 33.4 | 0.10 | <0.01 | 0.69 | 6.3 | <0.01 | <0.001 | <0.01 |
| SS 11 | 0.45 | 45.5 | 0.11 | <0.01 | 1.23 | 5.87 | <0.01 | <0.001 | <0.01 | 0.24 | 18.0 | 0.08 | <0.01 | 0.72 | 3.52 | <0.01 | <0.001 | <0.01 |
| SS 12 | 0.74 | 19.0 | 0.04 | <0.01 | 0.82 | 7.20 | <0.01 | <0.001 | <0.01 | 0.53 | 18.0 | 0.20 | <0.01 | 0.51 | 5.68 | <0.01 | <0.001 | <0.01 |
| SS 13 | 0.70 | 24.1 | 0.13 | <0.01 | 0.32 | 3.82 | <0.01 | <0.001 | <0.01 | 0.37 | 20.5 | 0.07 | <0.01 | 0.22 | 1.9 | <0.01 | <0.001 | <0.01 |
| SS 14 | 1.10 | 19.3 | 0.60 | <0.01 | 0.72 | 3.32 | <0.01 | <0.001 | <0.01 | 0.99 | 28.6 | 0.16 | <0.01 | 0.69 | 2.86 | <0.01 | <0.001 | <0.01 |
| SS 15 | 0.76 | 25.3 | 0.04 | <0.01 | 0.42 | 4.30 | <0.01 | <0.001 | <0.01 | 0.82 | 18.3 | 0.15 | <0.01 | 1.01 | 2.0 | <0.01 | <0.001 | <0.01 |
| SS 16 | 0.43 | 38.1 | 0.06 | <0.01 | 0.79 | 0.89 | <0.01 | <0.001 | <0.01 | 0.25 | 19.0 | 0.14 | <0.01 | 1.12 | 0.54 | <0.01 | <0.001 | <0.01 |
| SS 17 | 0.55 | 22.3 | 0.10 | <0.01 | 0.41 | 13.0 | <0.01 | <0.001 | <0.01 | 0.45 | 19.8 | 0.08 | <0.01 | 0.32 | 9.8 | <0.01 | <0.001 | <0.01 |
| SS 18 | 0.76 | 23.8 | 0.10 | <0.01 | 0.58 | 4.5 | <0.01 | <0.001 | <0.01 | 0.46 | 21.4 | 0.09 | <0.01 | 0.29 | 3.3 | <0.01 | <0.001 | <0.01 |
| SS 19 | 0.55 | 25.5 | 0.15 | <0.01 | 2.13 | 0.87 | <0.01 | <0.001 | <0.01 | 0.31 | 18.0 | 0.07 | <0.01 | 0.45 | 0.52 | <0.01 | <0.001 | <0.01 |
| SS 20 | 0.94 | 9.44 | 0.05 | <0.01 | 0.52 | 3.20 | <0.01 | <0.001 | <0.01 | 0.63 | 15.5 | 0.03 | <0.01 | 0.31 | 2.68 | <0.01 | <0.001 | <0.01 |

**Table 3b (v): Microbiological characteristics of soil (Wet season)**

| Sampling points | THBC $x10^4$cfu/g | THFC $x10^4$cfu/g | HUB $x10^2$cfu/g | HUF $x10^2$cfu/g | THBC $x10^4$cfu/g | THFC $x10^4$cfu/g | HUB $x10^2$cfu/g | HUF $x10^2$cfu/g |
|---|---|---|---|---|---|---|---|---|
| | **Surface soil** | | | | **Subsurface soil** | | | |
| SS 1 | 8.00 | 1.00 | 1.00 | 1.00 | 5.00 | 1.00 | 0.00 | 1.00 |
| SS 2 | 3.00 | 1.00 | 0.00 | 1.00 | 2.00 | 0.00 | 1.00 | 0.00 |
| SS 3 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| SS 4 | 2.00 | 0.00 | 0.00 | 1.00 | 3.00 | 1.00 | 0.00 | 0.00 |
| SS 5 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 | 2.00 | 0.00 | 1.00 |
| SS 6 | 4.00 | 2.00 | 1.00 | 2.00 | 3.00 | 3.00 | 0.00 | 0.00 |
| SS 7 | 1.00 | 2.00 | 2.00 | 2.00 | 3.00 | 1.00 | 3.00 | 3.00 |
| SS 8 | 2.00 | 0.00 | 1.00 | 2.00 | 3.00 | 1.00 | 0.00 | 0.00 |
| SS 9 | 4.00 | 1.00 | 2.00 | 1.00 | 3.00 | 1.00 | 1.00 | 1.00 |
| SS 10 | 2.00 | 1.00 | 2.00 | 1.00 | 1.00 | 2.00 | 1.00 | 0.00 |
| SS 11 | 2.00 | 3.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 1.00 |
| SS 12 | 2.00 | 3.00 | 1.00 | 1.00 | 4.00 | 1.00 | 2.00 | 0.00 |
| SS 13 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 | 2.00 | 1.00 |
| SS 14 | 2.00 | 2.00 | 1.00 | 2.00 | 2.00 | 3.00 | 2.00 | 1.00 |
| SS 15 | 4.00 | 4.00 | 2.00 | 2.00 | 2.00 | 1.00 | 3.00 | 3.00 |
| SS 16 | 2.00 | 1.00 | 1.00 | 2.00 | 5.00 | 2.00 | 2.00 | 1.00 |
| SS 17 | 8.00 | 2.00 | 2.00 | 1.00 | 5.00 | 3.00 | 1.00 | 1.00 |
| SS 18 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 | 2.00 | 1.00 | 0.00 |
| SS 19 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| SS 20 | 3.00 | 2.00 | 0.00 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 |

**Table 4: Vegetation of the Study area**

| Shrub/Tree | Common Names | Family | Count | Shrubs (0.5 To 4m Height) | Trees (> 4m Height) | Height (M) | Stem Diameter (Cm) |
|---|---|---|---|---|---|---|---|
| **VEG 1** | | | | | | | |
| *Anthonotha macrophylla* | | Fabaceae | 4 | 1 | 3 | 5 | 7 |
| *Lonchocarpus cyanescens* | African indigo | Fabaceae | 2 | 0 | 2 | 5 | 6 |
| *Alchornea cordifolia* | Christmas bush | Euphorbiaceae | 3 | 0 | 3 | 4.5 | 6 |
| *Elaeis guineensis* | African Oil palm | Arecaceae | 2 | 0 | 2 | 20 | 32 |
| *Cnestis ferruginea* | Velvet sun fruit | Connaraceae | 3 | 3 | 0 | – | – |
| | | | | | | | |
| **HERBS** | | | | | | | |
| *Aphanostylis leptantha* | | Apocynaceae | Common | | | | |
| *Sphenocentrum jollyanum* | | Menispermaceae | Common | | | | |
| *Byrsocarpus collineus* | | Connaraceae | Common | | | | |
| *Ipomoea involucrata* | Morning glory | Convolvulaceae | Common | | | | |
| *Desmodium ascendens* | | Fabaceae | Common | | | | |
| *Icacina trichantha* | Earth ball | Icacinaceae | Common | | | | |
| *Urena lobata* | Cadillo | Malvaceae | Common | | | | |
| *Chromolaena odorata* | Siam weed | Asteraceae | Common | | | | |
| *Schwenckia americana* | | Solanaceae | Common | | | | |
| | | | | | | | |
| **VEG 2** | | | | | | | |
| *Harungana madagascariensis* | Blood tree | Hypericaceae | 2 | 0 | 2 | 5 | 7 |
| *Alchornea cordifolia* | Christmas bush | Euphorbiaceae | 3 | 1 | 2 | 5 | 7 |
| *Margaritaria discoidea* | | Euphorbiaceae | 2 | 0 | 2 | 4.5 | 5 |
| *Microdemis puberula* | | Euphorbiaceae | 3 | 3 | 0 | – | – |
| *Rauwolfia vomitoria* | India Snake tree | Apocynaceae | 2 | 0 | 2 | 4.5 | 5 |
| *Anthonotha macrophylla* | | Fabaceae | 3 | 0 | 3 | 5 | 8 |

| Shrub/Tree | Common Names | Family | Count | Shrubs (0.5 To 4m Height) | Trees (> 4m Height) | Height (M) | Stem Diameter (Cm) |
|---|---|---|---|---|---|---|---|
| *Lonchorcapus cyanescens* | African indigo | Fabaceae | 2 | 2 | 0 | 4 | 6 |
| *Elaeis guineensis* | African oil palm | Arecaceae | 2 | 0 | 2 | 10 | 30 |
| | | | | | | | |
| **HERBS** | | | | | | | |
| *Chromoleana odorata* | Siam weed | Asteraceae | Common | | | | |
| *Heterotis rotundifolia* | Chickweed | Melastomataceae | Common | | | | |
| *Panicum maximum* | Guinea grass | Poaceae | Common | | | | |
| *Desmodium ramosissimum* | | Fabaceae | Common | | | | |
| *Schwenckia americana* | | Solanaceae | Common | | | | |
| | | | | | | | |
| **VEG 3** | | | | | | | |
| *Elaeis guineensis* | African oil palm | Arecaceae | 2 | 0 | 2 | 25 | 32 |
| *Baphia nitida* | Camwood | Fabaceae | 3 | 2 | 1 | 4.5 | 6 |
| *Manniophyton fulvum* | Gasso nut | Euphorbiaceae | 2 | 0 | 2 | 5 | 6 |
| *Alchorea cordifolia* | Christmas bush | Euphorbiaceae | 4 | 2 | 2 | 5 | 7.5 |
| *Maesobotrya bateri* | Squirrel Cherry | Euphorbiaceae | 2 | 2 | 0 | – | – |
| *Mallotus oppositifolius* | | Euphorbiaceae | 2 | 2 | 0 | _ | _ |
| *Pcynanthus angolensis* | | Myristicaceae | 1 | 0 | 1 | 7 | 25 |
| *Allophyllus africana* | | Sapindaceae | 2 | 2 | 0 | – | – |
| | | | | | | | |
| **HERBS** | | | | | | | |
| *Diodia scandens* | Turtle shell | Rubiaceae | Common | | | | |
| *Heterotis rotundifolia* | Chickweed | Melastomataceae | Common | | | | |
| *Chromolaena odorata* | Siam Weed | Asteraceae | Common | | | | |
| *Ipomoea involucrata* | Morning glory | Convolvulaceae | Common | | | | |
| *Panicum maximum* | Guinea grass | Poaceae | Common | | | | |
| | | | | | | | |

| Shrub/Tree | Common Names | Family | Count | Shrubs (0.5 To 4m Height) | Trees (> 4m Height) | Height (M) | Stem Diameter (Cm) |
|---|---|---|---|---|---|---|---|
| **VEG 4** | | | | | | | |
| *Elaeis guineensis* | African oil palm | Arecaceae | 2 | 0 | 2 | 25 | 32 |
| *Oncoba spinosa* | | Flacourtiaceae | 3 | 3 | 0 | – | – |
| *Anthonotha macrophylla* | | Fabaceae | 2 | 0 | 2 | 5 | 7.5 |
| *Baphia nitida* | Camwood | Fabaceae | 3 | 2 | 1 | 5 | 5 |
| *Napoleona vogellii* | | Lecythidaceae | 2 | 0 | 2 | 4.5 | 6 |
| *Alchornea cordifolia* | Christmas bush | Euphorbiaceae | 4 | 2 | 2 | 4.5 | 6 |
| *Antidesma vogelianum* | | Euphorbiaceae | 2 | 0 | 2 | 5 | 6 |
| *Manniophyton fluvum* | Gassonut | Euphorbiaceae | 2 | 0 | 2 | – | – |
| | | | | | | | |
| **HERB** | | | | | | | |
| *Urena lobata* | Cadillo | Malvaceae | Common | | | | |
| *Sida acuta* | Broom weed | Malvaceae | Common | | | | |
| *Clerodendrum splendens* | African ink | Verbenaceae | Common | | | | |
| *Cyathula prostrata* | | Amaranthaceae | Common | | | | |
| *Panicum maximum* | Guinea grass | Poaceae | Common | | | | |
| *Chromolaena odorata* | Siam weed | Asteraceae | Common | | | | |
| *Similax kraussiana* | W. Afr. Sarsaparilla | Smilacaceae | Common | | | | |
| | | | | | | | |
| | | | | | | | |
| **VEG 5** | | | | | | | |
| *Draceana arborea* | Dragon tree | Agavaceae | Common | 3 | 0 | 3 | 5 |
| *Alchornea cordifolia* | Christmas bush | Euphorbiaceae | Common | 2 | 0 | 2 | 4.5 |
| *Microdemis puberula* | | Euphorbiaceae | Common | 3 | 3 | 0 | – |
| *Antidesma vogelianum* | | Euphorbiaceae | Common | 2 | 0 | 2 | 6 |
| *Rauwolfia vomitoria* | India Snake tree | Apocynaceae | Common | 2 | 0 | 2 | 5 |
| *Elaeis guineensis* | African oil palm | Arecaceaee | Common | 2 | 0 | 2 | 20 |

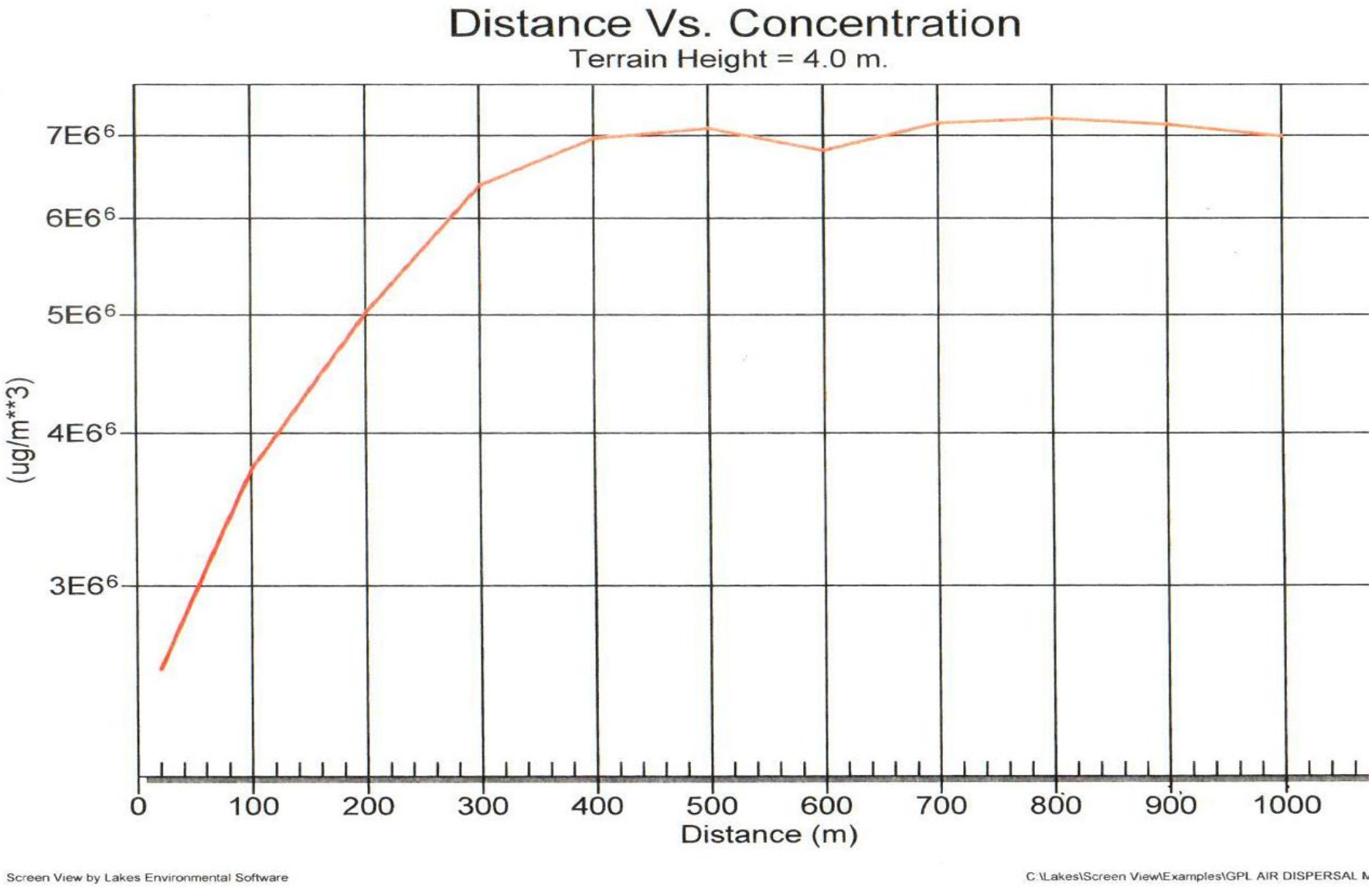
| Shrub/Tree | Common Names | Family | Count | Shrubs (0.5 To 4m Height) | Trees (> 4m Height) | Height (M) | Stem Diameter (Cm) |
|---|---|---|---|---|---|---|---|
| *Bateria nigritiana* | Ants tree | Passifloraceae | Common | 2 | 0 | 2 | 5 |
| *Dalbergia saxatalis* | | Fabaceae | Common | 3 | 1 | 2 | 5 |
| *Albizia zygia* | Albizia | Fabaceae | Common | 2 | 0 | 2 | 7 |
| | | | | | | | |
| **HERBS** | | | | | | | |
| *Clerodendrum splendens* | African ink | Verbenaceae | Common | | | | |
| *Axonopus compressus* | Carpet grass | Poaceae | Common | | | | |
| *Oplismenus burmanii* | | Poaceae | Common | | | | |
| *Panicum maximum* | Guinea grass | Poaceae | Common | | | | |
| *Nephrolepis bisserata* | Sword fern | Davalliaceae | Common | | | | |
| *Chromolaena odorata* | Siamweed | Asteraceae | Common | | | | |
| *Schwenckia americana* | | Solanaceae | Common | | | | |
| *Scleria vogellii* | Razor blade | Cyperaceae | Common | | | | |
| *Heterotis rotundifolia* | Chickweed | Melastomataceae | Common | | | | |
| | | | | | | | |
| **Economic crops** | | | | | | | |
| *Manihot esculenta* | Cassava | Euphorbiaceae | | | | | |
| *Telfairia occidentalis* | Pumpkin | Cucurbitaceae | | | | | |
| *Talinum triangulare* | Waterleaf | Portulacaceae | | | | | |
| *Musa paradisiaca* | Plantain | Musaceae | | | | | |
| *Zea mays* | Maize | Maydeae | | | | | |
| *Abelmoschus esculentus* | Okra | Malvaceae | | | | | |

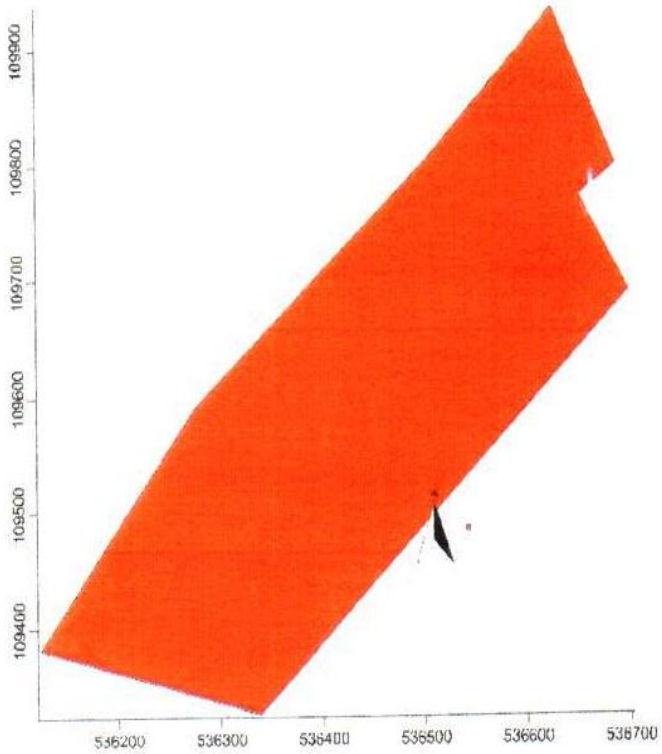
# SECTION II

# Air Dispersion modeling result

```
14:08:35
     ***  MODEL RUN  ***
     *** VERSION DATED 96043 ***

    GPL AIR DISPERSAL MODELLING.

    SIMPLE TERRAIN INPUTS:
       SOURCE TYPE                    =          AREA
       EMISSION RATE (G/(S-M**2))     =       1.00000
       SOURCE HEIGHT (M)              =       25.0000
       LENGTH OF LARGER SIDE (M)      =     5000.0000
       LENGTH OF SMALLER SIDE (M)     =     2000.0000
       RECEPTOR HEIGHT (M)            =        0.0000
       URBAN/RURAL OPTION             =         RURAL
    THE NON-REGULATORY BUT CONSERVATIVE BRODE 2 MIXING HEIGHT OPTION WAS
SELECTED.
    THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

       ANGLE RELATIVE TO LONG AXIS =     175.0000


    BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

    *** STABILITY CLASS  3 ONLY ***

    ***********************************
    *** AUTOMATED DISTANCES ***
    ***********************************

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

      DIST     CONC              U10M   USTK  MIX HT   PLUME  MAX DIR
       (M)   (UG/M**3)   STAB   (M/S)  (M/S)    (M)    HT (M)   (DEG)
    -------  ----------  ----  -----  -----  ------  ------  -------
       10.   0.45123.23    3     1.0    1.1    30.0   25.00    175.
      100.   3.4563.20     3     1.0    1.1    30.0   25.00    175
      200.   5.12563.22    3     1.0    1.1    30.0   25.00    175.
      300.   5.87952.61    3     1.0    1.1    30.0   25.00    175.
      400.   6.5462.30     3     1.1    1.1    30.0   25.00    175.
      500.   6.62598.10    3     1.1    1.1    30.0   25.00    175.
      600.   6.32541.22    3     1.0    1.1    30.0   25.00    175.
      700.   7.23698.00    3     1.0    1.1    30.0   25.00    175.
      800.   7.45256.28    3     1.0    1.1    30.0   25.00    175.
      900.   7.25692.36    3     1.0    1.1    30.0   25.00    175.
     1000.   6.51251.23    3     1.0    1.1    30.0   25.00    175.

    MAXIMUM 1-HR CONCENTRATION AT OR BEYOND    10. M:
     2930.   6.25689.12    3     1.0    1.1    30.0   25.00    175.
```

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

CALCULATION          MAX CONC     DIST TO    TERRAIN
  PROCEDURE          (UG/M**3)     MAX (M)     HT (M)
--------------     -----------    -------    -------
SIMPLE TERRAIN      6.25689.12    2930.         0.

*****************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
*****************************************************
```


Distance Vs. Concentration
Terrain Height = 4.0 m.
7E6⁶
6E6⁶
5E6⁶
4E6⁶
3E6⁶
(ug/m**3)
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)
Screen View by Lakes Environmental Software
C:\Lakes\Screen View\Examples\GPL AIR DISPERSAL M




COMMENTS PROJECT LOCATION 3D

3D OF PROJECT LOCATION

COMPANY NAME GEOMETRIC POWER LTD

**GEOMETRIC POWER LTD POWER PLANT**

BGI RESOURCES LTD

**BGI RESOURCES LTD**

12/08/2013

**8/12/2013**

PROJECT 002

**002**

3D View - Lakes Environmental Software

C:\Lakes\ISC-AERMODView\Tutorial\Met\TRIAL.dat\GPL.isc

# SECTION III

# Atterberg Limit, Triaxal and Bearing capacity Test results

# ATTERBERG LIMITS DETERMINATION

Description of soil: Light Brown clay

Borehole code/ sample depth: BH1, 1.5m

**Table 1: Liquid Limit Determination**

| Can No | D4 | B2 | 90 | U77 |
|---|---|---|---|---|
| Mass of wet soil+ can | 33.4 | 32.0 | 28.2 | 34.9 |
| Mass of dry soil+ soil | 32.3 | 29.9 | 26.1 | 32.3 |
| Mass of can | 29.8 | 25.7 | 22.4 | 28.2 |
| Mass of dry soil | 2.5 | 4.2 | 3.7 | 4.1 |
| Mass of moisture | 1.1 | 2.1 | 2.1 | 2.6 |
| Water content, W% | 44.0 | 50.0 | 56.8 | 63.4 |
| No of blows, N | 44 | 29 | 16 | 10 |

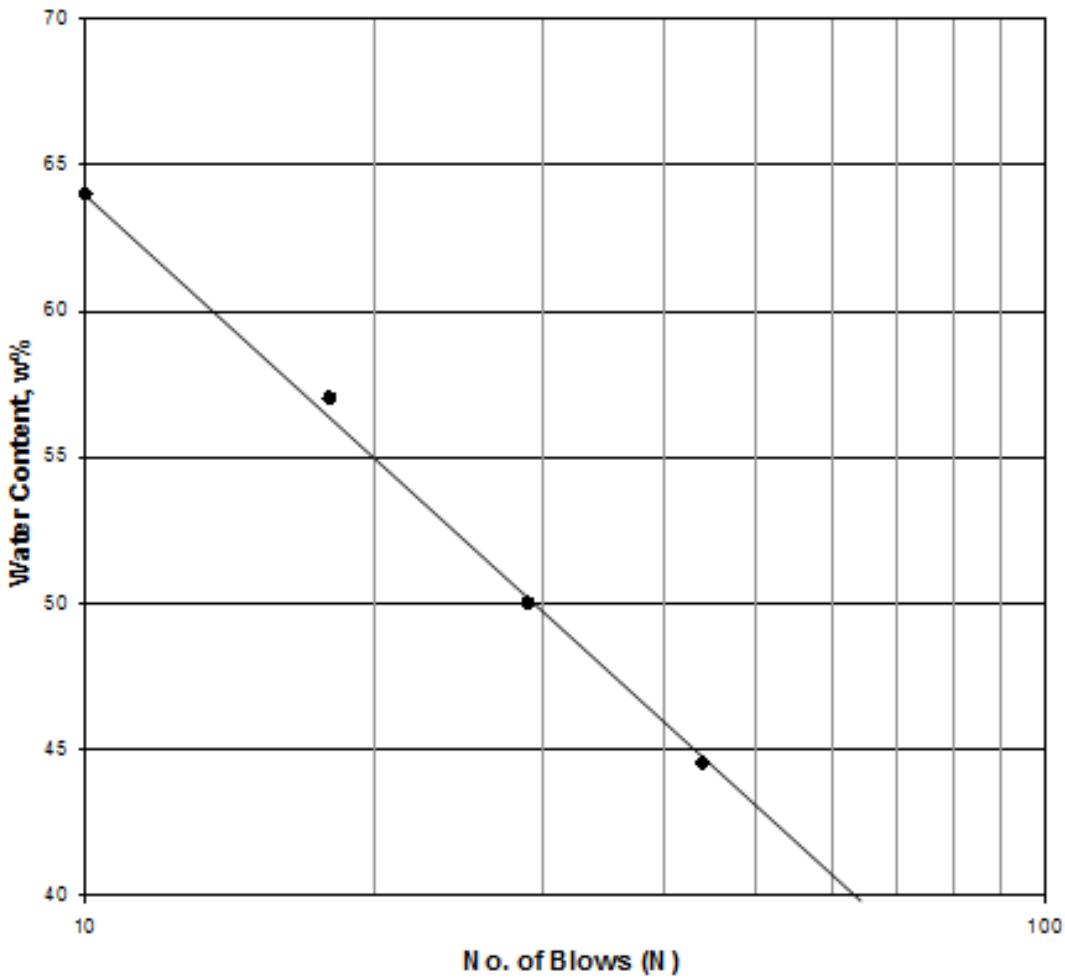



**Figure 1: Liquid Limit Plot of Sample.**

**Table 2: Plastic Limit Determination**

| Can No | Q5 | P5 |
|---|---|---|
| Mass of wet soil+ can | 30.4 | 28.2 |
| Mass of dry soil+ soil | 29.9 | 27.7 |
| Mass of can | 27.8 | 25.5 |
| Mass of dry soil | 2.1 | 2.2 |
| Mass of moisture | 0.5 | 0.5 |
| Water content, W% | 23.8 | 22.7 |

Average Moisture content: 23.3%

**Results**:

Liquid Limit, LL: 52.5%

Plastic Limit, PL: 23.3%

Plasticity Index, $I_p$: 29.2%

# TRIAXIAL TEST SHEET

**Table 3: Triaxial Test Data for the Sampleb**

| | | | | | | |
|---|---|---|---|---|---|---|
| Date of Sample collection: 06/05/13<br>Pre- Test Treatment: Remoulded | | | | Date of Test: 07/05/13<br>Bulk Density: 1.808 $Mg/m^3$<br>Unit Weight: 17.698 $kN/m^3$ | | |
| Diameter of Sample: 38.0mm<br>Height of Sample: 76.0mm | | | | Vol.of Sample (V): 86193$mm^3$<br>Machine Load Factor(F): $4.8x10^{-3}$kN | | |
| Cell Pressure ($\sigma_3$)$kN/m^2$= A | Load Gauge Reading (G) | Corrected Load=GxF=P (kN) | Failure Height H(mm) | Area of Failed Sample= V/Hx$10^{-6}$=A (m2) | Additional Vertical Pressure ($\sigma_1$-$\sigma_3$)kN/m2 =P(KN)/A(m2 ) | Total Vertical Pressure(σ1) ($kN/m^2$) =A+B |
| 100 | 143 | 0.686 | 67.6 | $1.275x10^{-3}$ | 538.35 | 638.35 |
| 200 | 231 | 1.108 | 65.5 | $1.315x10^{-3}$ | 843.19 | 1043.19 |
| 300 | 315 | 1.512 | 63.8 | $1.350x10^{-3}$ | 1120.00 | 1420.00 |

Method: BS1377, ASTM D2850-70 U4-2-2-2

Borehole Code/ Sample Depth: BH1, 1.5M

**Results:**

Cohesion Intercept (Cu): 50.00$kN/m^2$

Angle of Shearing Resistance (Tan θ): $41^0$

Shear Strength (S): 571.57$kN/m^2$

The Mohr Circle arising from these data is shown in Figure 2.

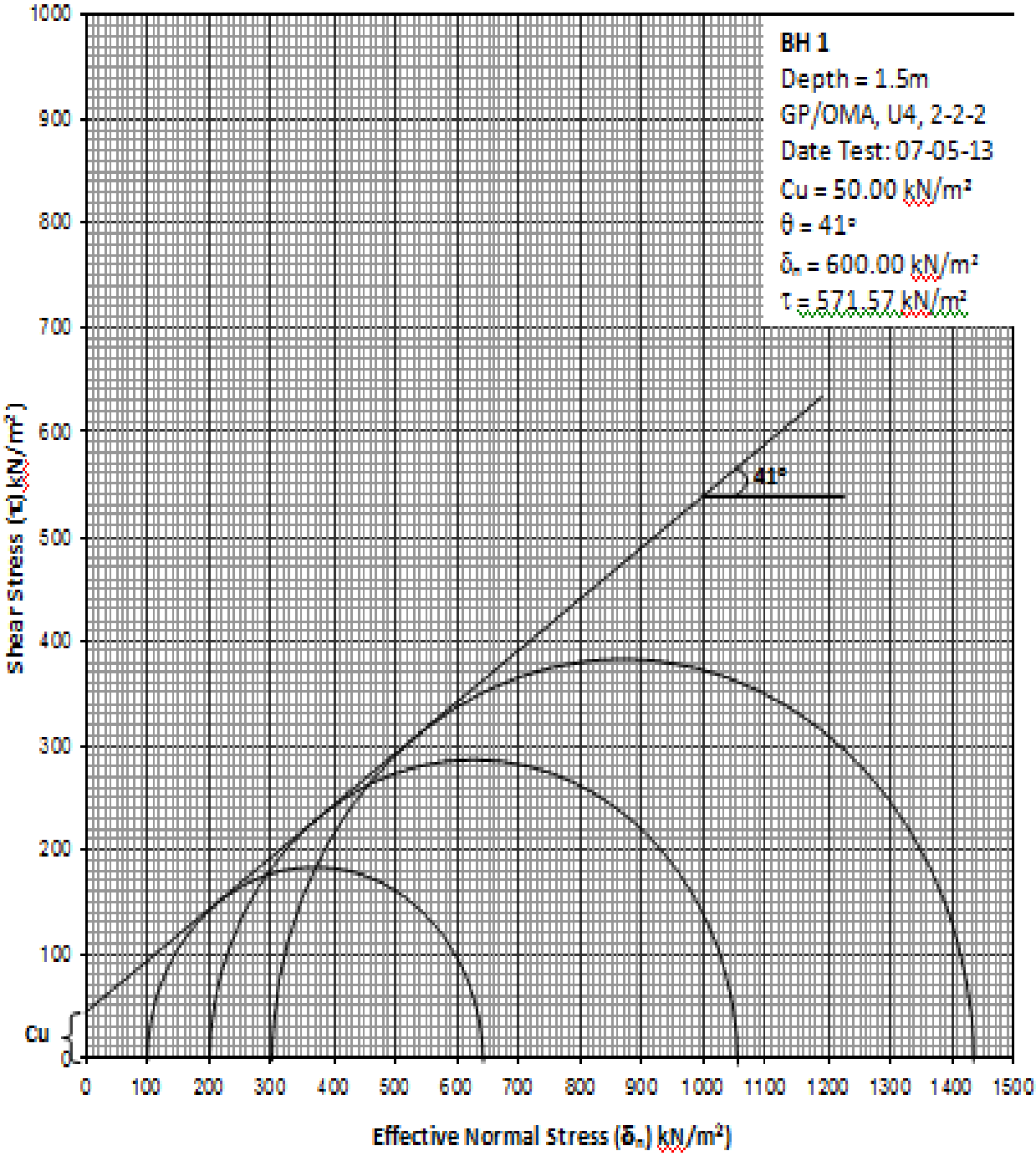



**Figure 2: Mohr Diagram of Sample**

## BEARING CAPACITY

**Table 4: Bearing CapacityValues in the Study Area**

| Sample Code/Depth | Ultimate Bearing Capacity, qf(kN/m$^2$) | Net Foundation Pressure, qnf (kN/m$^2$) | Alowable Bearing Capacity (kN/m$^2$) |
|---|---|---|---|
| BH1/1.5m | 8,720.00 | 8,702.452 | 2,900.82 |

Note: Net Foundation Pressure, qnf= qf-ɤ

Allowable bearing capacity= qnf/3 (where ‘3 ‘is the factor of safety)

## Appendix IV – Scope for socio-economic studies

# Scope for socio-economic studies

The specific objective of the Socio-economic Baseline Study is to describe the prevailing socio-economic baseline conditions of the study area, including the issues and concerns raised by the adjacent communities. To accomplish this, the following tasks should be undertaken:

***Task 1 -Comprehensive Household Surveys***
Conduct 165 household surveys covering each of the adjacent communities including Asa, Oke Ikpe, along the roadway area to the east of the site and in Obehie , and Ogwe (20-40 per community). Please see attached map that highlights the settlement areas to be surveyed and areas of emphasis, which we can discuss in more detail. Use random sampling to select each household. Administer surveys in person. The suggested survey is provided as an attachment.

***Task 2 -Focus Groups***
Conduct 1-3 focus groups in each community including Asa, Oke Ikpe, along the roadway area to the east of the site, in Ogwe and in Obehie for a total of approximately 15 focus groups including key community groups such as youth, elderly and women. See the suggested breakdown of focus group areas on the attached map. Focus groups should consist of groups of 10-15 people that are willing to participate in a brief discussion of the project.

Focus groups should be conducted as follows:

Give an introduction and background on the project and rationale of the socio economic study – Take names, ages and occupations of all participants

1- Qualitative assessment of the baseline situation briefly ask for:
   - Main socio economic characteristics of the area
   - Main general problems in the area
   - Main health, social, environmental problems in the area
   - Main local development challenges in the area

2- Discussion on impacts
   - How do they think the project could affect them/ others?
   - Do they think the management/mitigation measures will be effective?
   - Are there any management/mitigation measures they would like to see included?

***Task 3 -Targeted Interviews***
Because the comprehensive survey work will likely extend beyond the targeted timeline for the ESIA, undertake a targeted interview with local community leaders in each of the surrounding settlements as indicated on the map. Contact the community leaders and organize a one to one interview or a meeting of up to 4 to discuss the general characteristics of each settlement area. Bring the map of the targeted area to the meeting and confirm where houses are and how many there are.

Questions should include the following

1. Verify the number of households in the area/settlement using the map provided by Jacobs.
2. Characterize the settlement area as urban /rural.
3. Which ethnic groups generally live there? Are these different from the surrounding communities?
4. Does community identify with a certain population center (e.g. Asa, Ogwe, Oke Ikpe, or Obehie), or do they identify as a stand-alone community?

5. Where do people from the community generally work? Where do they generally shop?
6. How long has the community been located there?

***Task 4 – Reporting***

Findings of the survey will be presented using statistical analyses, tables, graphs, recommendations and conclusions. The findings will be included into a socioeconomic report for the project that will feed into the main ESIA document upon which environmental and socio-economic decisions regarding the Project will be based. Using the baseline data collected, the potential socioeconomic effects of the project will be assessed in accordance with national requirement and the requirement of the IFC Performance Standards on Environmental and Social Sustainability.

Preliminary results of the targeted interviews will be provided to Jacobs within 2 weeks of commencement of the surveys.

## Appendix V – GE Design Standards

# 10. Codes and Standards

## 10.1 Technical Regulations & Standards

The Gas Turbine & Auxiliaries are designed and manufactured according to European Directives.

Contrary to Technical Regulations, Codes and Standards are applicable on a voluntary basis. For Gas Turbine and its Auxiliaries, Seller's equipment is currently defined as per main Codes and Standards listed hereafter. Other Codes and Standards not listed inside Seller offer may not be taken into account for this proposal.

### 10.1.1 Technical Regulations

GE will comply with mandatory local and national technical regulations that apply to GE as a Manufacturer.

For the avoidance of doubt, GE reminds that local or national technical regulations that apply to the Importer, Final User or Employer of the Plant will not be considered.

Although the hazardous area classification falls under the scope of the Final User, Seller draw up and provide a hazardous area map used to ensure a safe design of the Gas Turbine and Auxiliaries.

- EC DIRECTIVES CONFORMITY OF EQUIPMENTS
  - 1- Pressure Equipment Directive (PED) 97/23/EC applies to pressure equipment of the Gas Turbine and Auxiliaries having a maximal allowable pressure (PS) greater than 0.5 bar.
  - 2- Explosive Atmosphere Directive (ATEX) 94/9/EC applies to equipment and protective systems of the Gas Turbine and Auxiliaries intended for use in potentially explosive atmosphere as defined by Seller in their hazardous area map.
  - 3- Machinery Directive 2006/42/EC applies to machines, partly completed machines, safety components and lifting devices of the Gas Turbine and Auxiliaries.
  - 4- Low Voltage Directive 2006/95/EC applies to Gas Turbine and Auxiliaries electrical equipment and connections between them for use in non-explosive atmosphere with a voltage rating between 50 and 1000 VAC or 75 and 1500 VDC.
  - 5- Electro Magnetic Compatibility Directive (EMC) 2004/108/EC applies to electrical and electronic appliances, systems and installations belonging to Gas Turbine and Auxiliaries.

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### 10.1.2 Gas Turbine, DLN module, Air inlet system, Structure and Motors Codes and Standards

Contrary to Technical Regulations, Codes and Standards are applicable on a voluntary basis. For Gas Turbine and its Auxiliaries, Seller's equipment is currently defined as per main Codes and Standards listed hereafter. Other Codes and Standards not listed inside this document offer are not taken into account for this proposal.

In the event conflicts arise between the codes and standards of practice described herein and laws, decrees of the country where the equipment is to be installed, laws and decrees will govern. If the OWNER desires other codes and standards of practice to be utilized by GE or its Suppliers, they will be subject to negotiation and mutual agreement between the OWNER and GE.

GE considers the applicable sections of the following US and ISO codes and standards to be the most relevant for the gas turbine equipment. Our designs and procedures are compliant or partly compliant (see text in brackets) on the following:

| **Mechanical & Lube oil system** | |
|---|---|
| ASME VIII, Division 1 | Boiler and Pressure Vessels Code—Pressure Vessels |
| TEMA C | Mechanical Standards for Class C Heat Exchangers |
| ANSI/ASME B31.3 | Chemical Plant and Petroleum Refinery Piping Gas turbine piping systems comply, with the exceptions to the following section:(Section 345: Fuel gas and steam injection piping systems are hydrostatically tested as individual fabrications, not as entire assemblies, at 1.5 times their design operating pressures. Leak testing of all other gas turbine unit, peripheral, and skid piping hardware/systems is done as part of the field start-up and commissioning procedures). |
| ANSI/ASME B16.5 | Pipe Flanges and Flanged Fittings |
| ANSI/ASME B1.20.1 | General Purpose (Inch) Pipe Threads |
| ASME - section II | Chemical Plant and Petroleum Refinery Piping Gas turbine piping systems comply - (metals input) |
| ASME - section V | Chemical Plant and Petroleum Refinery Piping Gas turbine piping systems comply - (Non-destructive testing) |
| ASME - section IX | Chemical Plant and Petroleum Refinery Piping Gas turbine piping systems comply - (welders and welding operation qualification). |

| **Vibrations** | |
|---|---|
| ISO 1940-1 | MECHANICAL VIBRATION - BALANCE QUALITY REQUIREMENTS FOR ROTORS IN A CONSTANT (RIGID) STATE - PART 1: SPECIFICATION AND VERIFICATION OF BALANCE TOLERANCES (GE employs this standard for theoretical and balance response calculation) |
| ISO 7919- | MECHANICAL VIBRATION OF NON-RECIPROCATING MACHINES - MEASUREMENTS ON |

| | |
|---|---|
| 4 | ROTATING SHAFTS AND EVALUATION CRITERIA - PART 4: GAS TURBINE SETS (GE employs this standard strictly for vibration measurements) |
| ISO 10816-4 | Mechanical Vibrations - Evaluation of Machine Vibration by Measurements of Non-rotating Parts - PART 4: GAS TURBINE DRIVEN SETS EXCLUDING AIRCRAFT DERIVATIVES (GE employs this standard strictly for vibration measurements) |

| **Noise** | |
|---|---|
| IEC 61672-1 & 2 | ELECTROACOUSTICS - SOUND LEVEL METERS: PART 1: SPECIFICATIONS; PART 2: PATTERN EVALUATION TESTS |
| ANSI/ASME PTC-36 | Measurement of Industrial Sound (Used for Near-field Measurements Only) |
| ISO 1680 | ACOUSTICS - TEST CODE FOR THE MEASUREMENT OF AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINERY - ENGINEERING METHOD FOR FREE FIELD CONDITIONS OVER A REFLECTING PLANE |
| ISO 9614-1 Grade 2 | ACOUSTICS - DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND INTENSITY - MEASUREMENT AT DISCRETE POINTS |
| ISO 3746 | ACOUSTICS - DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND PRESSURE - SURVEY METHOD USING AN ENVELOPING MEASUREMENT SURFACE OVER A REFLECTING PLANE |
| ISO 10494 - Grade 2 | Gas Turbines and Gas Turbine Sets – Measurement of Emitted Airborne Noise (Used for Near-field Measurements Only) |
| ISO 6190 | ACOUSTICS - MEASUREMENT OF SOUND PRESSURE LEVELS OF GAS TURBINE INSTALLATIONS FOR EVALUATING ENVIRONMENTAL NOISE - SURVEY METHOD (far field) |
| ANSI B133.8 | GAS TURBINE INSTALLATION SOUND EMISSIONS (far field) |

| **Fire Safety** | |
|---|---|
| ANSI/NFPA 12 | Dioxide Extinguishing Systems (for C02 extinguishing systems) |
| NFPA 37 | Installation and use of stationary combustion engines and gas turbines |
| NFPA 72 | National fire Alarm code |

| **Explosive atmospheres** | |
|---|---|
| NFPA 497A | Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas |
| API RP 500 | Recommended practice for Classification of Locations for Electrical Installations at Petroleum facilities Classified as Class I, Division I and Division 2 |
| API RP 505 | Recommended practice for Classification of Locations for Electrical Installations at Petroleum facilities Classified as Class I, Zone 0, Zone 1 and Zone 2 |

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| | |
|---|---|
| IEC 60079 | Electrical apparatus for explosive gas atmospheres |
| EN 1127-1 | Explosive atmospheres, Explosion prevention and protection, Part 1: Basic concepts and methodology |
| EN 13463 | Non-electrical equipment for potentially explosive atmospheres |

| **Control & Instrumentation** | |
|---|---|
| EN 61010-1 | SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL AND LABORATORY USE - PART 1: GENERAL REQUIREMENTS |
| IEEE 141 | ELECTRIC POWER DISTRIBUTION FOR INDUSTRIAL PLANTS |
| IEEE 519 | RECOMMENDED PRACTICES AND REQUIREMENTS FOR HARMONIC CONTROL IN ELECTRICAL POWER SYSTEMS |
| ISA-MC96.1 | TEMPERATURE MEASUREMENT THERMOCOUPLES |
| ANSI C84.1 | ELECTRIC POWER SYSTEMS AND EQUIPMENT - VOLTAGE RATINGS |
| IEC 60529 | DEGREES OF PROTECTION PROVIDED BY ENCLOSURES(IP CODE) |
| ANSI C37.2 | Electrical power system device numbers |
| IEEE 100 | Standard dictionary of electrical and electronic terms |
| ANSI/IEEE C37.91 | Guide for protective relay applications to power transformers |
| ANSI/IEEE C37.101 | Guide for generator ground protection |
| ANSI/IEEE C37.102 | Guide for AC generator protection |
| ANSI/IEEE C37.106 | Guide for abnormal Frequency protection for power generatingplants |
| EN50178 | Electronic equipment for use in power installations |

| **Fuel gas** | |
|---|---|
| GPA 2166 | OBTAINING NATURAL GAS SAMPLES FOR ANALYSIS BY GAS CHROMATOGRAPHY (Gas sampling procedure) |
| GPA 2286 | TENTATIVE METHOD OF EXTENDED ANALYSIS FOR NATURAL GAS AND SIMILAR GASEOUS MIXTURES BY TEMPERATURE PROGRAMMED GAS CHROMATOGRAPHY |
| ASTM D1945 | TEST METHOD FOR ANALYSIS OF NATURAL GAS BY GAS CHROMATOGRAPHY |
| ASTM D 3588 | PRACTICE FOR CALCULATING HEAT VALUE, COMPRESSIBILITY FACTOR, AND RELATIVE DENSITY OF GASEOUS FUELS (Heating value, specific gravity, compressibility factor) |
| ASTM D 11 42 | TEST METHOD FOR WATER VAPOR CONTENT OF GASEOUS FUELS BY MEASUREMENT OF DEW-POINT TEMPERATURE (dew point - test method note 1) |

| **Inlet Air Filter** | |
|---|---|
| International IEC | International Electrotechnical Commission |
| International ASME | International American Society of Mechanical Engineers |

| | |
|---|---|
| International ASME Sect. V | International Non destructive examination |
| International ASME Sect. VIII | International Rules for construction of pressure vessels |
| International ASME Sect. IX | International Welding and brazing qualification |
| International ASME B 31.3 | International Process piping |
| International ASTM | International American Society for testing and Materials |
| International ASTM A 53/A53M | International Specification for pipe, black and hot dipped, zinc coated welded and seamless. |
| International ANSI | International American national Standards Institute |
| International ASHRAE 52.1 | International Gravimetric and dust spot procedures for testing air cleaning devices used in general ventilation for removing particulate matter. |
| International EN 779-2002 | International Particulate air filters for general ventilation – Determination of the filtration performance |
| International EN 1822-1 | International High efficiency air filters (EPA, HEPA and ULPA) – Part 1: Classification, performance testing, marking |
| International EN 287-1 | International Approval testing of welders – Fusion welding – Part 1: steel |
| International EN ISO 15614-1 | International Specification and qualification of welding procedures for metallic materials |
| | International Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys |
| International EN 473 | International Non-destructive testing-qualification and certification of NDT personnel – general principles |
| International EN 10025-1 | International Hot rolled products of structural steels – Part 1: General technical delivery conditions |
| International EN 10025-2 | International Hot rolled products of structural steels – Part 2: Technical delivery conditions for non- alloy structural steels |
| International NF X 35-109 | International Ergonomics – Manual load handling for lifting, moving and pushing/pulling – Analysis methodology and threshold values |
| International NF A 91-122 | International Metallic Coatings – Finished products of hop dip galvanized steel – Specifications for the zinc coating and recommended method of fabrication for the products to be galvanized |
| International EN ISO 13920 | International Welding – general tolerances for welded construction – dimensions for lengths and angles – shape and position |
| International EN ISO 1461 | International Hot dip galvanized coatings on fabricated iron and steel articles – specifications and test methods |
| International EN ISO 15609-1 | International Specification and qualification of welding procedures for metallic materials Welding procedure specification - Part 1: Arc welding |
| International EN | International Safety of machinery - Risk assessment - Part 1: principles |

| | |
|---|---|
| ISO 14121 – 1 | |
| International EN ISO 14122 | International Safety of machinery - Permanent means of access to machinery |
| International EN 547-2 | International Safety of machinery – Human body measurements – Part 2: Principles for determining the dimensions required for access openings |
| International ISO 7235 | International Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units Insertion loss, flow noise and total pressure loss |
| International NF EN 10240 | International Internal and/or external protective coatings for steel tubes. Specification for hot dip galvanized coatings applied in automatic plants |
| International NF E 83-100-4 | International Construction of fabricated assemblies. Welding processes. Part 4: manufacture Inspection |
| International NF EN ISO 6520-1 | International Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: fusion welding |
| International EN ISO 14713-1 | International Zinc coating – Guidelines and recommendations for the protection against corrosion of iron and steel in structures – Part 1: General principles of design and corrosion resistance |
| International EN ISO 5817 | International Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections |
| ASNT-TC-1A | Personnel qualification and certification in non-destructive testing |
| NF EN 1090-2 | Execution of steel structures and aluminum structures – Part 2: technical requirements for steel structures |
| EN 571 – 1 | Non destructive testing. Penetrant testing. Part 1: general principles |
| ISO 262 ISO | General purpose metric screw threads. Selected sizes for screws, bolts and nuts |
| International ISO 4017 | International Hexagon head screws. Product grades A and B |
| International ISO 4014 | International Hexagon head bolts - Product grades A and B |
| International NF EN ISO 4032 | International Hexagon nuts, style 1 - Product grades A and B |
| International SAE J 1237 | International Metric thread rolling screws |
| International ANSI B1.13M | International Metric screw threads - M Profile |

| **Structure** | |
|---|---|
| AWS D1.1 | STRUCTURAL WELDING CODE – STEEL (with manufacture in US) |
| EN 287 | APPROVAL TESTING OF WELDERS - FUSION WELDING - STEELS - (with manufacture in Europe) |

| | |
|---|---|
| EN 288 | SPECIFICATION AND APPROVAL OF WELDING PROCEDURES FOR METALLIC MATERIALS – WELDING PROCEDURE TESTS FOR THE ARC WELDING OF STEELS – (with manufacture in Europe) |

| **Motors (Mounted on Gas Turbines Modules)** | |
|---|---|
| IEC 60034 | Rotating electrical machines |
| IEC 60038 | IEC standard voltages |
| IEC 60072 | Dimensions and output series for rotating electrical machines |
| IEC 60079 | Electrical apparatus for explosive gas atmospheres |
| IEC 60085 | Electrical insulation - Thermal evaluation and designation |
| IEC 60721-2-1 | Classification of natural environment conditions. Temperature and humidity |
| IEC 61000 | Electromagnetic compatibility (EMC) |
| IEC 60751 | Industrial platinum resistance thermometers and platinum temperature sensors |
| ISO 281 | Rolling bearings - dynamic load ratings and rating life |
| ISO 1680 | Acoustics -- Test code for the measurement of airborne noise emitted byrotating electrical machines |
| ISO 8821 | Mechanical vibration - balancing - shaft and fitment key convention |

### 10.1.3 Mark VIe Codes and Standards

GE Energy, Controls and Power Electronics (C&PE), maintains a Quality Management System that is based on the ISO 9001 standard. C&PE is currently registered to the 2000 standard by Lloyd's Register Quality Assurance.

This section discusses the codes, standards and environmental guidelines used for the design of all printed circuits, modules, cores, panels and cabinet line-ups in the Mark VIe control system. Requirements for harsh environmental applications, such as marine applications, are not covered in this section.

| **Safety Standards** | |
|---|---|
| EN 61010-1 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, Part 1 |
| CAN/CSA 22.2 No. 1010.1-92 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, Part 1 |
| IEC 60529 | Intrusion Protection Codes/NEMA 1/IP 20 |
| ANSI/ISA S82.02.01 1999 | Safety Standard for Electrical and Electronic Test, Measuring, Controlling and Related Equipment |
| Printed Wire Board | |

| | |
|---|---|
| Assemblies | |
| ANSI | IPC guidelines |
| IPC-SM-840C Class 3 | Solder Mask Performance Standard (Military/High Rel) |
| Electromagnetic Compatibility (EMC) | |
| EN 50081-2 | General Emissions Industrial Environment |
| EN 61000-6-2 | Generic Immunity Industrial Environment |
| IEC 61000-4-2 | Electrostatic Discharge Susceptibility |
| IEC 61000-4-3 | Radiated RF Immunity |
| IEC 61000-4-4 | Electrical Fast Transient Susceptibility |
| IEC 61000-4-5 | Surge Immunity |
| IEC 61000-4-6 | Conducted RF Immunity |
| IEC 61000-4-11 | Voltage Variation, Dips, and Interruptions |
| ANSI/IEEE C37.90.1 | Surge |
| Low Voltage Directive | |
| EN 61010-1 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, Part 1 |
| ATEX Directive 94/9/EC | |
| EN 50021 | Electrical Apparatus for Potentially Explosive Atmospheres |

| **Supply Voltage** |
|---|
| Line Variations |
| AC Supplies – Operating line variations of –10%, +10%. (IEEE Std. 141-1993 defines the Equipment Terminal Voltage – Utilization Voltage). This limit meets IEC 60204-1 1999, and exceeds IEEE Std. 141-1993, and ANSI C84.1 – 1989. |
| DC Supplies – Operating line variations of –30%, +20% or 145 Vdc. (Meets IEC 60204-1 1999). |
| Voltage Unbalance |
| Less than 2% of the positive sequence component for the negative sequence component. Less than 2% of the positive sequence component for the zero sequence component. (This meets IEC 60204-1 1999, and IEEE Std. 141-1993). |
| Harmonic Distortion |
| Voltage – Less than 10% of the total rms voltage between live conductors for the 2nd through 5th harmonic. Additional 2% of the total rms voltage between live conductors for the sum of the 6th through the 30th harmonic. (This meets IEC 60204-1 1999). |
| Current - The system specification is not per individual equipment. Less than 15% of the maximum demand load current for harmonics less than 11th. Less than 7% of the maximum demand load current for harmonics between the 11th and 17th. Less than 6% of the maximum demand load current for harmonics between the 17th and the 23rd. Less than 2.5% of the maximum demand load current for harmonics between the 23rd and the 35th. (This meets IEEE Std. 519-1992). |

| |
|---|
| Frequency Variations |
| Frequency variation of –5%, +5% when operating from AC supplies (20Hz/sec slew rate). (This exceeds IEC 60204-1 1999). |
| Surge |
| Withstand 2 kV common mode, 1 kV differential mode ((This meets IEC 61000-4-5 (ENV50142), and ANSI C62.41 (Combination wave)). |
| Clearances |
| NEMA Tables 7-1 and 7-2 from NEMA ICS1-2000. (This meets IEC 61010-1:1993/A2: 1995, CSA 22.2 #14, and UL 508C). |

### 10.1.4 Mark VIe Environmental Guidelines

This section discusses the environmental guidelines used for the design of all printed circuits, modules, cores, panels and cabinet line-ups in the Mark VIe control system. Requirements for harsh environmental applications, such as marine applications, are not covered in this section.

| |
|---|
| Operating I/O modules = -30°C to 65°C (-22°F to 149°F) |
| Operating controller with forced air cooling = 0°C to 60°C (32°F to 140°F) |
| Operating control room equipment (HMI, etc.) = 0°C to 40°C (32°F to 104°F) with preferred range of 20°F to 30°C (68°F to 86°F) |
| Shipping and storage = -40°C to 85°C (-40°F to 185°F) for I/O modules and controller; 0°C to 30°C (32°F to 86°F) for control room equipment (HMI, etc.) |
| Allowable temperature drop without condensation is 15°C (27°F) over a 4 hour period for 50% RH and smaller temperature variations at higher humidity. |
| Humidity |
| The ambient humidity range is 5% to 95% non-condensing |
| Elevation |
| Normal operation – 0 to 1000 m (0 to 3,300 feet) (101.3 KPa – 89.8 KPa) |
| Extended operation – 1000 to 3050 m (3,300 to 10,000 feet) (89.9 KPa – 69.7 KPa) (exceeds EN50178). |
| Shipping – 4600 m (15,000 feet maximum) (57.2 KPa) (exceeds EN50178). |
| Note: A guideline for system behavior as a function of altitude is that for altitudes above 1000 m (3,300 feet), the maximum ambient rating of the equipment decreases linearly to a rating of 5°C (41°F) at 3050 m (10,000 feet). |
| Contaminants |
| Gas – The control equipment withstands the following concentrations of corrosive gases at 50% relative humidity and 40oC (104oF): |
| Sulfur dioxide (SO2) – 30 ppb |
| Hydrogen sulfide (H2 S) – 10 ppb |
| Nitrous fumes (NOx) – 30 ppb |

| |
|---|
| Chlorine (Cl2) – 10 ppb |
| Hydrogen fluoride (HF) – 10 ppb |
| Ammonia (NH3) – 500 ppb |
| Ozone (O3) – 5 ppb |
| Note: The above gas contamination limits meets EN50178, Section A.6.1.4, Table A.2(m). |
| Enclosure Rating |
| Enclosure –Standard (IP-54 cabinet) |

### 10.1.5 Generator Codes and Standards

GE considers the applicable sections of the following codes and standards to be the most relevant for the generator equipment. Our designs and procedures are generally compliant with the applicable section for the following. Unless specified, the latest version applies:

| **50 Hz** | |
|---|---|
| Flange to flange generator | |
| ANSI/ASME B1.1-2003 | Unified Inch Screw Threads (GE complies at the customer's connection) |
| IEEE 115-1996 | Test procedures for Synchronous machines |
| ANSI/ASME B1.20.1-1983 (R2006) | General Purpose (Inch) Pipe Threads |
| ANSI/ASME B16.5-2003 | Pipe Flanges and Flanged Fittings |
| ANSI/ASME B16.9-2003 | Factory–Made Wrought Steel Butt Welding Fittings |
| ANSI/ASME B16.21-2005 | Nonmetallic Flat Gaskets for Pipe Flanges |
| ANSI/ASME B31.3-2006 | Chemical Plant and Petroleum Refinery Piping |
| ANSI/ASME B31.1-2007 | Power Piping |
| ANSI/NFPA 12-2008 | Carbon Dioxide Extinguishing Systems |
| ANSI/NFPA 70-2008 | National Electrical Code (Electrical components are designed to meet Class 1, Group D, Div. 2, Hazardous area classification, where appropriate.) |
| IEEE C50.13-2005 | Standard for cylindrical Rotor 50Hz and 60Hz Synchronous Generators rated 10 MVA and above |
| ANSI/IEEE 100-2000 | Dictionary of Electrical and Electronics Terms |
| NEMA MG1-2006 | Motors and Generators |
| NFPA 497A-2008 | Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas |

| | |
|---|---|
| EN 60079-10-2003 | Electrical apparatus for explosive gas atmospheres |
| UBC-1997 | Uniform Building Code (Used for wind loads and seismic design) |
| ANSI/IEEE 421.1-2007 | Definitions for Excitation Systems for Synchronous Machines |
| ASME BPVC Section VIII, Division 1 - 2007 | Boiler and Pressure Vessel Code - Pressure Vessels (for Stator Frame Welds and for design of Coolers with exception of U stamp application) |
| ISO 7919-2 - 2001 | Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts Part 2: land based steam turbines and generators in excess of 50 MW. |
| ISO 10816-4 - 1998 | Mechanical Vibration- Evaluation of machine vibration by measurements on non-rotating parts. Gas turbine sets excluding aircraft derivatives |
| TEMA C, 9th Edition | Mechanical Standards for Class C Heat Exchangers (for Commercial Coolers) |
| ANSI/ASME B46.1-2002 | Surface Texture |
| ANSI/ASME Y14.5M-1994 (R2004) | Dimensioning and Tolerancing |
| ANSI Y14.36-1996 (R2004) | Surface Texture Symbols |
| ANSI/IEEE 315-1975 (R1993) | Graphic Symbols for Electrical and Electronics Diagrams |
| ANSI/AWS A2.4-2007 | Symbols for Welding, Brazing and Nondestructive Examination |
| ANSI/IEEE C37.2-1996 (R2001) | Electrical Power System Device Function Numbers (GE complies with respect to device designations except that, in a few cases, device numbers were modified or added to fit GE's needs.) |
| 98/37/EC | Safety of machinery Directive |
| EN 60204-1 - 1997 | Safety of machinery, Electrical Equipment of machines |
| 2004/108/EC | EMC directive |
| IEC 61000-6-4 – 2006 | Generic Standards - Emission standards for industrial environments |
| IEC 61000-4-3 – 2002 | Radiated Immunity test |
| IEC 60034-1 - 2004 | Rotating electric machines- rating and performance |
| 73/23/EC | Low voltage directive |
| EN 60034-1 - 2004 | Rotating Electrical machines, rating and performance |
| EN 60034-3 - 2005 | Rotating electrical machines specific requirements for turbine type synchronous machines |
| EN 60204-1 - 1997 | Safety of machinery, Electrical Equipment of machines |

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# Appendix VI – Project Greenhouse Gas Emissions Calculations

# Oma Power Project GHG Calculation

## 1. Power Station Fuel Consumption

| | | | Ref |
|---|---|---|---|
| Phase 1 | 500 | MW (4 x 125 MW) SCGT | Project Description |
| | 34% | Efficiency | Project Description |
| Phase 2 | 250 | MW (2x 125MW) SCGT | Project Description |
| | 34% | Efficiency | Project Description |
| Phase 3 | 375 | MW - CCGT | Project Description |
| | 51% | Efficiency | Project Description |

**Factros and Conversions**

| | | |
|---|---|---|
| 4 | No GTGs are operational at full load | **Change number for Phase 1 or Phase 2** |
| 7500 | hours /yr | Project Description |
| 35.37 | MJ/Sm3 | Project Description -have changed from kj to MJ based on efficiency and size of units |
| 0.27778 | kWh/MJ | |
| 277,777.78 | kWh/Tj | |
| 1000000 | Various Conversions | |
| 1000000000 | Various Conversions | |

**Using Phase 1 Information**

**Estimated Fuel Gas Consumption Rate by the Proposed Power Plant**
**For GTG 1, 2, 3 & 4**

| | **15oC** | **26.8oC** | **35oC** | |
|---|---|---|---|---|
| Per hour (Sm3/h) | *40,130* | *37,158* | *35,303* | |
| Per day (Sm3/d) | *922,990* | *862,914* | *811,969* | 23 |
| Per year (Sm3/y) | *300,975,000* | *281,385,000* | *264,772,500* | |
| Per hour (kWh) | 1,577,122 | 1,460,321 | 1,387,419 | |
| Per day (kWh) day | 36,273,797 | 33,912,792 | 31,910,637 | |
| Per year (kWh/year | 11,828,412,127 | 11,058,518,967 | 10,405,642,494 | |

## 2. Conversion Factors

**IEA (2012) CO2 emissions from Fuel Combustion**

| | g/kWh | kg/kWh |
|---|---|---|
| Natural Gas | 400 | 0.4 |
| Bitumous Coal | 860 | 0.86 |
| Crude Oil | 630 | 0.63 |
| Gas/Diesel Oil | 690 | 0.69 |
| | | |
| | | |

**IPCC Guidelines for National Greenhouse Gas Inventories (2006)**

1Tj kWh

IPPC 2006

| | CO2 Default | CH4 Default | N2O Default | Total |
|---|---|---|---|---|
| | kg CO2/tJ | kg CH4/tJ | kg N2O/tJ | kgCO2/Tj |
| Natual Gas | 56100 | 1 | 0.1 | 56,101 |
| Other Bituminous Coal | 94600 | 10 | 1.5 | 94,612 |
| Crude Oil | 73300 | 3 | 0.6 | 73,304 |
| Gas Diesel Oil | 74100 | 3 | 0.6 | 74,104 |
| Wood/Wood waste | | | | |

**Summary of Connversion Factors (IEA 2012) numbers used**

| IPCC 2006 | IFC | Defra Net kg CO2/kWh | **IEA 2012 kgCO2/kWh** |
|---|---|---|---|
| kgCo2/kWh | | | |
| 0.20 | 0.39 | 0.205525559 | **0.4** |
| 0.34 | 0.901 | 0.327412916 | **0.86** |
| 0.26 | 0.666 | | **0.63** |
| 0.27 | | | **0.69** |

## 3. Carbon Emissions (tCO2/yr)

Middle scenario - 26.8°C

| | **tCO2/yr** | | | |
|---|---|---|---|---|
| | IPCC 2006 | IFC | Defra Net kg CO2/kWh | **IEA (2012)** |
| Natual Gas | 2,233,422 | 4,312,822 | 2,272,808 | **4,423,408** |
| Other Bituminous Coal | 3,766,547 | 9,963,726 | 3,620,702 | **9,510,326** |
| Crude Oil | 2,918,265 | 7,364,974 | - | **6,966,867** |
| Gas Diesel Oil | 2,950,114 | - | - | **7,630,378** |

| Carbon Saving Against other Fuels | | | |
|---|---|---|---|
| IPCC 2006 | IFC | Defra Net kg CO2/kWh | IEA |
| | | | |
| 41% | 57% | 37% | **53%** |
| 23% | 41% | | **37%** |
| 24% | | | **42%** |

## 4.Comparison with Nigerian Carbon Emissions (Production and Consumption)

| 2010 Nigeria Carbon Emissions | | | | Reference |
|---|---|---|---|---|
| Total CO2 emissions emissions from fuel combustion | 45.9 | 45,900,000 | tonnes CO2 2010 | |
| Additional Carbon from com fuel combustion | | 10% | Additional CO2 per year from fuel combustion | |
| Total CO2 emissions from consumption of energy | 73.69 | 73,690,000 | tonnes CO2 2010 | http://knoema.com/atlas/Nigeria/topics/Energy/Total-Energy/Carbon-Dioxide-Emissions |
| Additional Carbon from consumption of energy | | 6% | Additional CO2 per year from consumption of energy | |
| Average CO2 emissions per kWh from electricity generation (2010) | 405 | | | http://www.iea.org/publications/freepublications/publication/CO2emissionfromfuelcombustionhighlightsMarch2013.pdf |
| Improvement of Proposed Plant carbon emissions from | 1% | | Improvement of Proposed Plant from average carbon dioxide emissions from electricity generation | |
| | | | | |
| **Other Nigeria Facts** | | | | |
| Population (2013) | 173.6 million | | | http://data.worldbank.org/country/nigeria |
| GDP (2013) | $522.6 billion | | | http://data.worldbank.org/country/nigeria |
| Electricity and heat production | 10.6 | 10,600,000 | tonnes CO2 | |
| Primary Energy | 4733 | | Petajoules | http://www.factfish.com/statistic-country/nigeria/co2+emissions |
| Electricity Output | | 26.1 | terrwatt hours | |
| Electricity Consumption | 19 | 19,210,000,000 | kWh/yr in 2010 | http://www.indexmundi.com/g/g.aspx?v=81&c=ni&l=en |
| Electricity Production | 21.92 | 21,920,000,000 | KWh/yr 2010 | http://www.indexmundi.com/g/g.aspx?v=81&c=ni&l=en |

| Electricity Generation | |
|---|---|
| Oil | 35% |
| Natural Gas | 16% |
| Hydroelectric? | |

# Appendix VII – Air Quality Technical Appendix

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# OMA Nigeria

# Air Quality Technical Appendix

March 2015

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# Document Control Sheet

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# Contents


| | | |
|---|---|---|
| **1** | **Introduction** | **1** |
| **2** | **Methodology and Study Inputs** | **2** |
| 2.1 | Description of Dispersion Model | 2 |
| 2.2 | Outline of Method | 3 |
| 2.3 | Air Quality Standards and Guidelines | 4 |
| 2.4 | Model Inputs | 4 |
| 2.5 | Conservative Assumptions | 13 |
| 2.6 | Baseline Air Quality | 13 |
| **3** | **Dispersion Modelling Results** | **15** |
| 3.1 | Summary of Results at Human Receptor Locations | 15 |
| 3.2 | Predicted Concentrations at Individual Human Receptor Locations | 17 |


**Figures**


| | |
|---|---|
| Figure 1: | Phase 1 + 2 site layout plan showing modelled emission points and buildings |
| Figure 2: | Phase 3 site layout plan showing modelled emission points and buildings (horizontally aligned HRSG) |
| Figure 3: | Phase 3 site layout plan showing modelled emission points and buildings (vertically aligned HRSG) |
| Figure 4: | Site location plan showing modelled receptor locations |
| Figure 5: | Annual mean nitrogen dioxide process contributions, Phase 1, 2011 meteorological data |
| Figure 6: | Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 1, 2012 meteorological data |
| Figure 7: | Annual mean nitrogen dioxide process contributions, Phase 2, 2012 meteorological data |
| Figure 8: | Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 2, 2013 meteorological data |
| Figure 9: | Annual mean nitrogen dioxide process contributions, Phase 3a, 2012 meteorological data |
| Figure 10: | Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 3a, 2011 meteorological data |
| Figure 11: | Annual mean nitrogen dioxide process contributions, Phase 3b, 2012 meteorological data |
| Figure 12: | Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 3b, 2011 meteorological data |

# 1 Introduction

This report provides the technical appendix for Chapter 5 (Air Quality) of the Environmental and Social Impact Assessment (ESIA) to accompany the application for the proposed OMA Independent Power Project (IPP) by Oma Power Generation Company Ltd. This report should be read in conjunction with Chapter 6 of the ESIA and provides the data on the assessment methodology and study inputs and also sets out the results of the air quality assessment.

In summary, Jacobs has undertaken an atmospheric dispersion modelling assessment to predict concentrations of pollutants at sensitive locations within the vicinity of the IPP development site. The predicted concentrations have been compared to relevant ambient air quality guidelines specified for the protection of human health.

For the purposes of the air quality assessment, the project has been assessed in three separate phases. Although, the current ESIA covers the implementation of Phase 1 and Phase 2, Phase 3 has been included using an indicative design to ensure the full range of potential air quality impacts have been considered and to identify any relevant additional mitigation. The three phases are described below:

| | |
|---|---|
| Phase 1: | 4 x gas turbines operating in simple (open) cycle mode; |
| Phase 2: | 6 x gas turbines operating in simple (open) cycle mode; and |
| Phase 3: | 6 x gas turbines operating in combined cycle mode (through the addition of waste heat boilers to each gas turbine which will provide steam to two steam turbine generators). At this stage, the exhaust stack location will change from downstream of the gas turbine to downstream of the waste heat boiler (also known as a heat recovery steam generator, or HRSG). Two different configurations of HRSG have been assessed for Phase 3, representing both a horizontally aligned HRSG (Phase 3a) and vertically aligned HRSG (Phase 3b). |

Atmospheric emissions from the natural gas-fired turbines will predominately consist of oxides of nitrogen (NOx) and carbon monoxide (CO). Emissions of other substances associated with the combustion of fossil fuels (e.g. sulphur dioxide and particulate matter) are negligible for the combustion of natural gas and are therefore not included in the air quality assessment.

The assessment was carried out using an air dispersion modelling technique and in outline consisted of the following components:

1) Determination of likely background concentrations of the relevant pollutants (CO and $NO_x$), established from available measurement information;
2) Computer dispersion modelling of the relevant releases (i.e. CO and $NO_x$) from the gas turbines, to identify likely ground level concentrations of pollutants at properties in the vicinity of the plant; and
3) Evaluation of significance by comparing modelled levels of emissions against standards and guidelines for air quality.

The dispersion modelling methodology and study inputs are provided in Chapter 2 of this technical appendix report and the dispersion modelling results are set out in Chapter 3. The interpretation and determination of significance of the modelled results is provided in the ESIA Chapter 6, along with the identification of mitigation measures.

# 2 Methodology and Study Inputs

## 2.1 Description of Dispersion Model

A current industry standard atmospheric dispersion model, ADMS version 5, was used to model releases of substances from the proposed power station. In summary, the modelling procedure was as follows, with further detail on inputs provided in subsequent sections:

Air dispersion modelling using appropriate dispersion modelling software is an internationally accepted tool that can be used to determine if the design and location of emission sources result in acceptable air quality in the vicinity of a development site. This determination is made by comparing the maximum predicted dispersion modelling results at appropriate locations to the ambient air quality guideline stated in the applicable government regulations or other international standards. As such, if the predicted dispersion modelling results are within the air quality limits, the plant design is assumed to be acceptable for regulatory approval.

For this assessment, it was decided to apply the UK Atmospheric Dispersion Modelling System (ADMS) version 5 code. In general, the results produced by AERMOD (an equivalent dispersion model developed in the US) and ADMS under identical input data and meteorological conditions are essentially very similar. Both ADMS and AERMOD are listed as appropriate for assessing “more complex and refined models” in the International Finance Corporation (IFC) “Environmental, Health and Safety Guidelines: Environmental, Air Emissions and Ambient Air Quality” guideline document[1].

The model takes, as a starting point, information on emissions from each source, including:

- Release rate of the substances under consideration;
- Release temperature;
- Release velocity or volumetric flow;
- Release point location;
- Release point height;
- Release point diameter; and
- The location and dimensions of nearby buildings.

Information characterising a set of meteorological conditions is also required. This includes the wind speed, wind direction, and information relating to the atmospheric stability. This information is normally provided in the form of sequential hourly measurements, obtained from the nearest or most representative meteorological station. Given this information, the model provides an estimated concentration of the substance of interest at a specified location. This process can is repeated for each hour in the year, and at each location under consideration, to build up an estimate of long-term mean and short-term peak concentrations over an area of interest or at a number of points of interest.

In any modelling study, there will be a degree of uncertainty in the model results. In the case of atmospheric dispersion modelling, models are generally more reliable for long period means than short period means. Models are usually more reliable over intermediate distances (100m to 1000m) than very close to the source or more distant from the source. This reflects the range of data that have been used to compile the models. To allow for these uncertainties, a conservative approach has been adopted in this study.

[1] International Finance Corporation, World Bank Group, Environmental, Health and Safety Guidelines, General EHS Guidelines: Environmental, Air Emissions and Ambient Air Quality” guideline document, April 30, 2007

The model incorporates a number of complex modules, allowing for the effects of plume rise, complex terrain, buildings and coastlines to be incorporated within the modelling study. The ADMS model has a number of distinct features that can be summarised as follows:

- Concentration distributions are Gaussian in stable and neutral conditions, but the vertical distribution is non-Gaussian in convective conditions to take account of the skewed structure of the vertical component of turbulence;
- Actual plume spread depends on the local wind speed and turbulence which therefore depends on plume height. This is accounted for within ADMS and contrasts with Pasquill-Gifford methods that are used within some alternative modelling systems where plume spread is independent of height;
- Where required, a meteorological pre-processor calculates the required boundary layer parameters from a variety of input data (e.g. wind speed, day, time, cloud cover or surface heat flux). Meteorological data may be of statistically analysed or raw, hourly averaged (or hourly sequential) format;
- A number of complex modules allow for the effects of plume rise, complex terrain, structures, coastlines and the calculation of concentration fluctuations and radioactive decay to be incorporated within the dispersion modelling study; and
- The presence of buildings close to the release point can significantly affect the dispersion of material from a source. This influence can be taken into account by the use of an appropriate module in ADMS. The site buildings may influence the dispersion of emissions from the main stack. It is therefore important that building effects on dispersion are evaluated in detail. This was done using the ADMS buildings module.

## 2.2 Outline of Method

The dispersion modelling procedure is summarised as follows:

- Information on the design of the proposed IPP facility including site layout, stack location, design of the proposed gas turbines and relevant emissions data was obtained from Geometric Power Ltd. Details of the buildings and structures on site were also obtained and the buildings module in ADMS was used to account for the effect of site buildings on the dispersion of pollutants.
- Three years of hourly sequential meteorological data from the nearest weather station which records all the necessary parameters for dispersion modelling was used for the assessment (see chapter 2.6.3).
- A number of human receptors in the vicinity of the facility were identified at which the ambient concentrations of released substances were modelled. These represented individual properties located within the nearest residential areas or towns such as Asa, Ogwe and Obehie. There are no sensitive habitats such as national parks within the vicinity of the proposed IPP and no further consideration of habitats was required – the receptors represent human exposure only. As well as at discrete receptors, concentrations were modelled on a receptor grid with 20 m spacing, covering a 5 km x 5 km square centred on the proposed IPP development site – this enabled generation of contour plots of the predicted ground level concentrations of the modelled pollutants.
- The above information was entered into the dispersion model.
- The dispersion model was run to provide predicted ground-level concentrations of the released substances (NOx and CO). To ensure a conservative assessment, the results interpretation was based on the highest modelled concentration at any of the sensitive receptor locations for any of the three years of meteorological data. Concentrations of NOx were converted to nitrogen dioxide ($NO_2$) as this is the pollutant associated with health effects .

- The modelled concentrations of pollutants due to gas turbine emissions were combined with estimated baseline concentrations of $NO_2$ and CO in the vicinity of the site.
- Modelled concentrations were assessed against the relevant ambient air quality guidelines, for $NO_2$ and CO, taking the background concentrations into account.

## 2.3 Air Quality Standards and Guidelines

The IFC "Environmental, Health and Safety Guidelines: Environmental, Air Emissions and Ambient Air Quality"[1] specifies the following with regard to the general approach to the air quality assessment:

*"Projects with significant sources 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 (see Table 1.1.1), or other internationally recognized sources;*
- *Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests 25 percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed"*

The relevant national ambient air quality standard or guidelines for the protection of human health are those specified by the Federal Ministry of Environment (FMEnv) and guidelines are also provided by the IFC, the latter being based upon World Health Organization (WHO) air quality guidelines. The relevant ambient air quality guidelines are set out in Table 2.1.

**Table 2.1: Comparison of Ambient Air Quality Standards and Guidelines**

| Pollutant | Averaging Period | Air Quality Guideline (µg/m$^3$) | |
|---|---|---|---|
| | | FMEnv | IFC / WHO |
| Nitrogen dioxide ($NO_2$) | 1 hour | - | 200 |
| | 24-hour | 75 - 113 | - |
| | 1 year (annual mean) | - | 40 |
| Carbon monoxide (CO) | 1-hour | - | 30,000 |
| | 8-hour | 22,800 | 10,000 |
| | 24-hour | 11,400 | - |

The predicted concentrations of $NO_2$ and CO were compared to the relevant IFC / WHO ambient air quality guidelines. Although these are generally more stringent than the FMEnv ambient air quality standards, the predicted concentrations were also compared to the FMEnv standards for completeness.

The results of the dispersion modelling study were assessed against the IFC requirements set out above.

## 2.4 Model Inputs

### 2.4.1 Emissions Data

Emission data were provided by Geometric Power Ltd and its engineering contractors / plant suppliers. Table 2.2 presents the input parameters specified within the ADMS dispersion model for the detailed dispersion modelling of the combustion plant associated with the proposed IPP. The site layout plan showing the location of the exhaust stacks for Phase 1 and Phase 2 are shown in Figure 1 and the site layout plans showing the Phase 3 emission points are shown in Figure 2 and Figure 3 for the horizontally aligned HRSG and vertically aligned HRSG, respectively.

**Table 2.2: Emissions Parameters for Each Phase**

| Source Description | Centre Point Grid Ref (m) (UTM grid coordinate system) | | Stack Height | Stack Internal Diameter | Exhaust Gas Efflux Velocity | Exhaust Gas Volumetric Flow | | Exhaust Gas Temperature | Emission Concentration | | Emission Rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | NOx | CO | NOx | CO |
| | E | N | M | | m/s | $m^3/s$ (actual) | $Nm^3/s$ (reference) | °C | $mg/Nm^3$ | | g/s | |
| **Phase 1: 4 x Gas Turbines Operating in Open Cycle Mode** | | | | | | | | | | | | |
| Gas Turbine 1 | 309679 | 551680 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 2 | 309643 | 551632 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 3 | 309607 | 551584 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 4 | 309571 | 551536 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| **Phase 2: 6 x Gas Turbines Operating in Open Cycle Mode** | | | | | | | | | | | | |
| Gas Turbine 1 | 309679 | 551680 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 2 | 309643 | 551632 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 3 | 309607 | 551584 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 4 | 309571 | 551536 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 5 | 309535 | 551488 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 6 | 309499 | 551440 | 40 | 5.5 | 35.7 | 848.2 | 315.7 | 555 | 51.3 | 100 | 16.2 | 31.6 |
| **Phase 3a: 6 x Gas Turbines Operating in Combined Cycle Mode (with Horizontally Aligned HRSGs)** | | | | | | | | | | | | |
| Gas Turbine 1 | 309647 | 551703 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 2 | 309611 | 551656 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 3 | 309575 | 551607 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 4 | 309539 | 551559 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 5 | 309504 | 551511 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 6 | 309468 | 551463 | 42.7 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| **Phase 3b: 6 x Gas Turbines Operating in Combined Cycle Mode (with Vertically Aligned HRSGs)** | | | | | | | | | | | | |
| Gas Turbine 1 | 309660 | 551694 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 2 | 309624 | 551646 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 3 | 309588 | 551598 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 4 | 309552 | 551550 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 5 | 309516 | 551502 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |
| Gas Turbine 6 | 309480 | 551453 | 65 | 4.2 | 29.8 | 413.2 | 315.7 | 130.4 | 51.3 | 100 | 16.2 | 31.6 |

### 2.4.2 Hours of Operation

For the purposes of the modelling study, it has been assumed that the gas turbines would operate simultaneously and continuously at maximum load (100% of maximum continuous rating) for the entire year. In practice, there will be some downtime for routine maintenance and inspection, and so the modelling assessment represents an overestimate of actual operating hours and operating load may not always be 100%.

### 2.4.3 Meteorological Data

Meteorological data from the nearest weather station which records all the necessary parameters for dispersion modelling was used for the assessment. The nearest weather station is Port Harcourt, however, there is very low data capture for the weather parameters required for dispersion modelling from this weather station (approximately 10-50 data points per month when data are reported). The closest station with useable data recorded on an hourly basis, and which records all the parameters for dispersion modelling, is Douala, Cameroon which is approximately 285km to the east southeast of the proposed development site. Hourly sequential data from 2011 to 2013 were used in this study; wind roses for each year of meteorological data are shown in Diagrams 1 to 3. The highest forecast concentrations for any of the years of meteorological data were used. The surface roughness value at Douala weather station is 0.6m. Not using locally recorded meteorological data (say within 50 – 100 km of the site location) is a limitation of the modelling assessment. The actual weather conditions, particularly wind speed and direction, could vary between the Doula data utilised for the assessment and actual conditions experienced at the site, which could lead to higher uncertainty in the model predictions at the modelled receptor locations. Data in Chapter 5 of the ESIA indicates that there will be some wind from the north east during the dry season. However, these observations were recorded over a very short timescale and long-term wind data recorded in other countries in the same region (e.g. Sierra Leone, Liberia, Ghana and the Cameroon data used in the assessment) indicate a low proportion of winds from the north east, with predominant wind from the south west and west south west sectors.

**Diagram 1: Wind Rose for the Douala 2011 Data.**

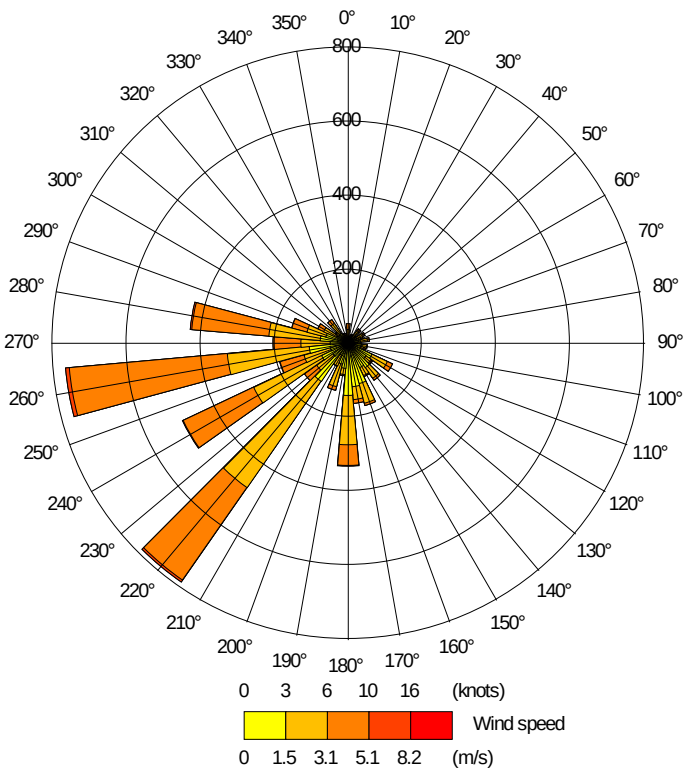


**Diagram 2: Wind Rose for the Douala 2012 Data.**

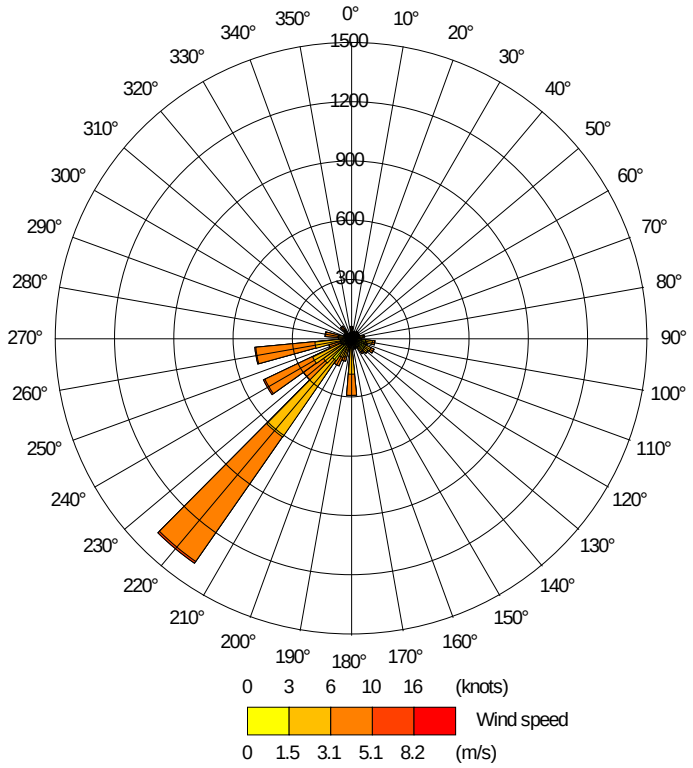
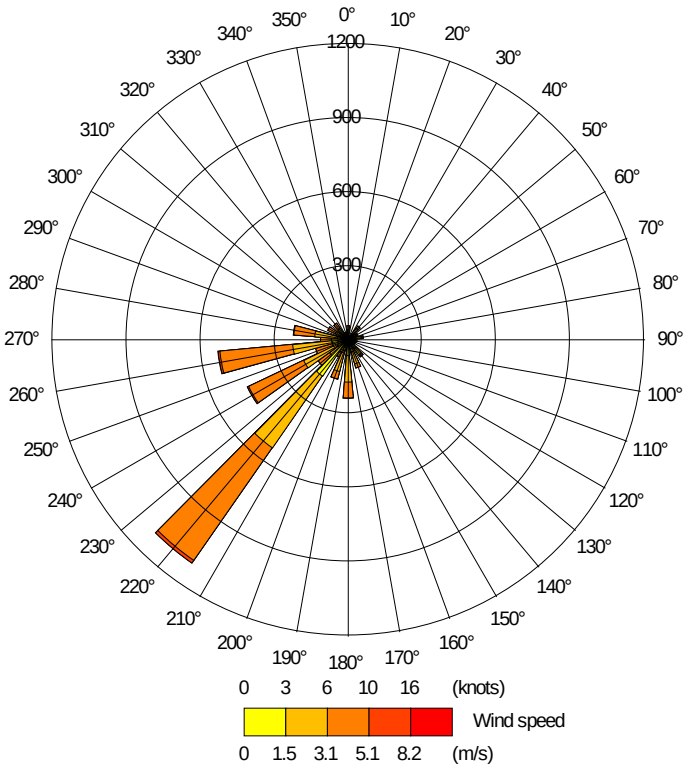



**Diagram 3: Wind Rose for the Douala 2013 Data.**




The Douala weather data contains many periods where the wind speed is recorded as 0 m/s indicating calm conditions, which is typical of weather conditions in this region. To ensure these were included within the modelling, all scenarios were run with calm conditions modelled as ADMS 5 usually excludes wind speeds of less than 0.75 m/s.

Calm conditions were assessed using average emissions for the year that lead to the maximum concentrations at receptors in the without calm models.

The calm conditions parameters displayed in Table 2.3 were used in this assessment. The meteorological data set contained wind speed data from the maximum down to 0.5m/s and below this the next wind speed is recorded as 0 m/s. On this basis, the minimum wind speed was set to 0.25m/s as this is the median of the lowest and next lowest value. The model was set to use the Gaussian solution for the wind speeds of 1.0m/s and higher and the radial solution was used for all the wind speeds below 0.5m/s (i.e. those wind speeds previously recorded as 0m/s and set to 0.25m/s by the minimum wind speed setting).

**Table 2.3 Details of Calm Input Parameters**

| Parameter | Value (m/s) |
|---|---|
| Minimum wind speed at height 10m | 0.25 |
| Wind speed at height 10m for radial solution | 0.5 |
| Parameter for critical wind speed | 1.0 |

### 2.4.4 Buildings

Buildings or other structures can have a significant influence on local air flows that, under certain circumstances, may draw an emission plume down towards ground level. This is referred to as “building downwash”. The buildings included within the model are set out in Table 2.4. The buildings and structures modelled for Phase 1 and Phase 2 are shown in Figure 1 and those modelled for Phase 3 are shown in Figure 2 and Figure 3 for the horizontally aligned HRSG and vertically aligned HRSG, respectively.

**Table 2.4: Modelled Buildings and Structures**

| Description | Centre Point Grid Ref (m) (UTM grid coordinate system) | | Height | Length | Width | Angle with North (˚) |
|---|---|---|---|---|---|---|
| | E | N | m | | | |
| **Phase 1: 4 x Gas Turbines Operating in Open Cycle Mode** | | | | | | |
| Gas Turbine Canopy | 309643 | 551601 | 21.0 | 260 | 20.3 | 37 |
| **Phase 2: 6 x Gas Turbines Operating in Open Cycle Mode** | | | | | | |
| Gas Turbine Canopy | 309607 | 551552 | 21.0 | 380 | 20.3 | 37 |
| **Phase 3a: 6 x Gas Turbines Operating in Combined Cycle Mode (with Horizontally Aligned HRSGs)** | | | | | | |
| Gas Turbine Canopy | 309607 | 551552 | 21.0 | 380.0 | 20.3 | 37 |
| HRSG (Gas Turbine 1) | 309660 | 551694 | 37.7 | 22.5 | 15.0 | 37 |
| HRSG (Gas Turbine 2) | 309624 | 551646 | 37.7 | 22.5 | 15.0 | 37 |
| HRSG (Gas Turbine 3) | 309588 | 551598 | 37.7 | 22.5 | 15.0 | 37 |
| HRSG (Gas Turbine 4) | 309552 | 551550 | 37.7 | 22.5 | 15.0 | 37 |
| HRSG (Gas Turbine 5) | 309516 | 551502 | 37.7 | 22.5 | 15.0 | 37 |
| HRSG (Gas Turbine 6) | 309480 | 551453 | 37.7 | 22.5 | 15.0 | 37 |
| Steam Turbine Building | 309419 | 551536 | 20.0 | 115.0 | 30.0 | 37 |
| Air Cooled Condenser | 309350 | 551606 | 38.0 | 166.0 | 148.0 | 37 |
| **Phase 3b: 6 x Gas Turbines Operating in Combined Cycle Mode (with Vertically Aligned HRSGs)** | | | | | | |
| Gas Turbine Canopy | 309607 | 551552 | 21.0 | 380.0 | 0.0 | 37 |

| Description | Centre Point Grid Ref (m) (UTM grid coordinate system) | | Height | Length | Width | Angle with North (˚) |
|---|---|---|---|---|---|---|
| | E | N | m | | | |
| HRSG Gas Turbine 1 | 309660 | 551694 | 60 | 22.5 | 15.0 | 127 |
| HRSG Gas Turbine 2 | 309624 | 551646 | 60 | 22.5 | 15.0 | 127 |
| HRSG Gas Turbine 3 | 309588 | 551598 | 60 | 22.5 | 15.0 | 127 |
| HRSG Gas Turbine 4 | 309552 | 551550 | 60 | 22.5 | 15.0 | 127 |
| HRSG Gas Turbine 5 | 309516 | 551502 | 60 | 22.5 | 15.0 | 127 |
| HRSG Gas Turbine 6 | 309480 | 551453 | 60 | 22.5 | 15.0 | 37 |
| Steam Turbine Building | 309419 | 551536 | 20.0 | 115.0 | 30.0 | 37 |
| Air Cooled Condenser | 309350 | 551606 | 38.0 | 166.0 | 148.0 | 37 |

### 2.4.5 Terrain

The topography in the vicinity of the plant could also potentially have an effect upon the dispersion of pollutants. This is only likely to be significant if slopes exceed a gradient of 1:10 over significant distances compared with the distance over which dispersion is being modelled. The topography of the local area was judged to have a gradient less than 1:10 in most places, so terrain effects were not modelled in this study.

### 2.4.6 Surface Roughness

The surface roughness is a length scale used to represent the turbulent effect of obstructions in the surrounding area. The surface roughness used in this study was 0.6m which is appropriate for an area where the local land use is categorised as a mix of forest, open scrub land/agriculture and habitation. The same value was used to represent the surface roughness at the Doula meteorological station.

### 2.4.7 Minimum Monin-Obukhov Length, Surface Albedo and Priestley-Taylor Parameter

The ADMS model default values were used for the Minimum Monin-Obukhov Length (1m), Surface Albedo (0.23) and Priestley-Taylor Parameter (1).

### 2.4.8 Calculation of $NO_x$ and $NO_2$

Only a very small proportion of the NOx in emitted flue gases is present as $NO_2$ – typically 5-10%, the balance being nitric oxide (NO). $NO_2$ is formed from NO by oxidation in the atmosphere in the presence of sunlight and ozone. In order to account for this $NO_2$ production in the atmosphere as the plumes disperse, the following worst-case assumptions have been made:

- For annual average $NO_2$, a conversion rate of 70% of total NOx emitted has been applied; and
- For shorter-term averaging periods, a conversion rate of total NOx emitted of 35% has been applied.

### 2.4.9 Model Domain / Study Area

The ADMS model calculates the predicted ground level concentrations based on a user defined grid system of up to 101 x 101 points. Generally, the larger the study area, the greater the distance between the grid calculation points and the lower the resolution of the dispersion model predictions. This is to be offset against the need to encompass an

appropriately wide area within the dispersion modelling study to capture the dispersion of the stack emissions.

The modelled grid was specified as a 5 km x 5 km grid with calculation points every 50m (i.e. 101 points along each grid axis). This size of grid was selected to provide a good grid resolution and also encompass a sufficient area so that the maximum predicted concentrations would be determined for presenting on contour plots. The modelled grid parameters are provided in Table 2.4.

**Table 2.4: Modelled *Grid Parameters***

| Grid | Start | Finish | Number of points |
|---|---|---|---|
| X | 307176 | 312176 | 101 |
| Y | 549090 | 554090 | 101 |
| Z (height) | 0 | 0 | 1 |

The modelling study was also carried out to identify the highest levels of air pollutants that would arise at potentially sensitive off-site locations such as residential properties. Modelled concentrations at other similar sensitive locations further away from the facility will be lower than those presented in this report. 102 potentially sensitive locations were identified in the vicinity of the IPP development site, as detailed in Table 2.5. The modelled receptor locations are shown in Figure 4. Pollutant concentrations were predicted at these specific locations.

**Table 2.5: Modelled Sensitive Receptor Locations**

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 1 | Near town of Ogwe | NNW | 1.7 | 308954 | 553098 |
| 2 | Near town of Ogwe | NNW | 1.7 | 308858 | 553124 |
| 3 | Near town of Ogwe | NNW | 1.8 | 308795 | 553112 |
| 4 | Near town of Ogwe | NNW | 2.0 | 308354 | 553112 |
| 5 | Near town of Ogwe | NW | 1.5 | 308145 | 552107 |
| 6 | Near town of Ogwe | NW | 1.8 | 308085 | 552567 |
| 7 | Near town of Ogwe | NW | 1.9 | 308035 | 552650 |
| 8 | Near town of Ogwe | NW | 2.0 | 308033 | 552774 |
| 9 | Near town of Ogwe | NW | 1.9 | 308314 | 552892 |
| 10 | Near town of Ogwe | NNW | 2.1 | 308229 | 553102 |
| 11 | Near town of Ogwe | NNW | 2.0 | 308438 | 553220 |
| 12 | Near town of Ogwe | NNW | 2.0 | 308634 | 553302 |
| 13 | Near town of Ogwe | NNW | 2.0 | 308871 | 553372 |
| 14 | Near town of Ogwe | NNW | 2.1 | 308957 | 553531 |
| 15 | Near town of Ogwe | NNW | 2.1 | 309170 | 553633 |
| 16 | Near town of Ogwe | NW | 2.2 | 308065 | 553151 |
| 17 | Near town of Ogwe | NW | 2.1 | 308245 | 553192 |
| 18 | Near town of Ogwe | NNW | 2.2 | 308511 | 553410 |
| 19 | Near town of Ogwe | NNW | 2.2 | 308789 | 553580 |
| 20 | Near town of Ogwe | NNW | 2.2 | 308924 | 553633 |
| 21 | Near town of Ogwe | NNW | 2.2 | 309039 | 553690 |

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 22 | Near town of Ogwe | N | 2.3 | 309243 | 553805 |
| 23 | Near town of Ogwe | NW | 2.4 | 308033 | 553310 |
| 24 | Near town of Asa | SSW | 0.8 | 309182 | 550881 |
| 25 | Near town of Asa | SSW | 0.7 | 309241 | 550866 |
| 26 | Near town of Asa | SSW | 0.7 | 309250 | 550866 |
| 27 | Near town of Asa | SSW | 0.7 | 309298 | 550858 |
| 28 | Near town of Asa | SSW | 0.7 | 309311 | 550853 |
| 29 | Near town of Asa | S | 0.8 | 309379 | 550766 |
| 30 | Near town of Asa | S | 0.7 | 309371 | 550867 |
| 31 | Near town of Asa | S | 0.6 | 309644 | 550950 |
| 32 | Near town of Asa | S | 0.6 | 309666 | 550963 |
| 33 | Near town of Asa | S | 0.6 | 309632 | 550982 |
| 34 | Near town of Asa | S | 0.5 | 309453 | 551012 |
| 35 | Near town of Ogwe | NW | 1.7 | 308160 | 552505 |
| 36 | Near town of Ogwe | NW | 1.7 | 308218 | 552533 |
| 37 | Near town of Ogwe | NW | 1.8 | 308056 | 552480 |
| 38 | Near town of Ogwe | NW | 1.4 | 308367 | 552221 |
| 39 | Near town of Asa | SW | 1.0 | 308695 | 550973 |
| 40 | Near town of Asa | SW | 1.0 | 308803 | 550936 |
| 41 | Near town of Asa | SW | 1.0 | 308831 | 550891 |
| 42 | Near town of Asa | SSW | 1.0 | 308885 | 550852 |
| 43 | Near town of Asa | SSW | 1.0 | 308911 | 550822 |
| 44 | Near town of Asa | SSW | 0.9 | 308977 | 550837 |
| 45 | Near town of Asa | SSW | 0.8 | 309092 | 550863 |
| 46 | Near town of Asa | SSW | 0.6 | 309767 | 550956 |
| 47 | Near town of Asa | S | 0.9 | 309288 | 550680 |
| 48 | Near town of Asa | S | 0.9 | 309388 | 550626 |
| 49 | Near town of Asa | S | 0.9 | 309464 | 550655 |
| 50 | Near town of Asa | S | 0.8 | 309513 | 550698 |
| 51 | Near town of Asa | S | 0.8 | 309496 | 550710 |
| 52 | Near town of Ogwe | NW | 1.7 | 308223 | 552611 |
| 53 | Near town of Ogwe | NW | 1.8 | 308136 | 552646 |
| 54 | Near town of Ogwe | NW | 1.7 | 308278 | 552563 |
| 55 | Near town of Ogwe | NNW | 1.7 | 308406 | 552833 |
| 56 | Near town of Ogwe | NNW | 1.6 | 308408 | 552663 |
| 57 | Near town of Ogwe | NNW | 1.8 | 308293 | 552810 |
| 58 | Near town of Ogwe | NNW | 1.8 | 308245 | 552807 |
| 59 | Near town of Asa | S | 0.7 | 309647 | 550880 |
| 60 | Near town of Asa | S | 0.6 | 309733 | 550926 |
| 61 | Port Harcourt Aba Road | SSE | 0.7 | 310044 | 550982 |
| 62 | Port Harcourt Aba Road | SSE | 0.7 | 310019 | 551000 |

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 63 | Port Harcourt Aba Road | SSE | 0.7 | 310077 | 551086 |
| 64 | Port Harcourt Aba Road | SSE | 0.7 | 310050 | 551061 |
| 65 | Port Harcourt Aba Road | SSE | 0.6 | 310027 | 551079 |
| 66 | Port Harcourt Aba Road | SSE | 0.6 | 310029 | 551090 |
| 67 | Port Harcourt Aba Road | SSE | 0.7 | 310004 | 551027 |
| 68 | Port Harcourt Aba Road | SSE | 0.5 | 309880 | 551099 |
| 69 | Port Harcourt Aba Road | SSE | 0.7 | 310114 | 551113 |
| 70 | Port Harcourt Aba Road | SSE | 0.7 | 310100 | 551101 |
| 71 | Port Harcourt Aba Road | SSE | 0.7 | 310087 | 551114 |
| 72 | Port Harcourt Aba Road | SE | 0.8 | 310202 | 551124 |
| 73 | Port Harcourt Aba Road | SE | 0.7 | 310203 | 551151 |
| 74 | Near town of Ogwe | NNW | 2.0 | 308590 | 553239 |
| 75 | Near town of Ogwe | NNW | 1.9 | 308624 | 553228 |
| 76 | Near town of Ogwe | NNW | 1.9 | 308677 | 553265 |
| 77 | Near town of Ogwe | NNW | 1.9 | 308743 | 553242 |
| 78 | Near town of Ogwe | NNW | 1.9 | 308706 | 553228 |
| 79 | Near town of Ogwe | NNW | 1.8 | 308805 | 553166 |
| 80 | Near town of Ogwe | NNW | 1.9 | 308622 | 553199 |
| 81 | Near town of Ogwe | NNW | 1.9 | 308667 | 553206 |
| 82 | Near town of Ogwe | NNW | 1.8 | 308715 | 553161 |
| 83 | Near town of Ogwe | NNW | 1.7 | 308825 | 553096 |
| 84 | Near town of Obehie | NE | 2.2 | 311295 | 552818 |
| 85 | Near town of Obehie | NE | 2.2 | 311204 | 552934 |
| 86 | Near town of Obehie | NE | 2.1 | 311072 | 553011 |
| 87 | Near town of Obehie | NE | 2.1 | 310989 | 553051 |
| 88 | Near town of Obehie | NE | 2.1 | 311084 | 552916 |
| 89 | Near town of Obehie | NE | 2.1 | 311161 | 552882 |
| 90 | Near town of Obehie | NNE | 2.9 | 311323 | 553827 |
| 91 | Near town of Obehie | NNE | 2.9 | 311170 | 553893 |
| 92 | East of site beyond Aba Road | E | 1.1 | 310695 | 551442 |
| 93 | Near town of Obehie | NE | 2.6 | 311773 | 552881 |
| 94 | Near town of Obehie | NE | 2.7 | 311914 | 552770 |
| 95 | East of site beyond Aba Road | E | 1.6 | 311142 | 551558 |
| 96 | East of site beyond Aba Road | E | 1.2 | 310782 | 551355 |
| 97 | NW of Obehie | NNE | 4.1 | 309840 | 555584 |
| 98 | NW of Obehie | NNE | 4.1 | 310289 | 555605 |
| 99 | NW of Obehie | NE | 4.2 | 310745 | 555530 |
| 100 | NW of Obehie | NE | 4.2 | 310878 | 555475 |
| 101 | NW of Obehie | NE | 4.1 | 311008 | 555365 |
| 102 | NW of Obehie | NE | 4.1 | 311124 | 555285 |

## 2.5 Conservative Assumptions

### 2.5.1 Uncertainty

There are always uncertainties in dispersion models in common with any environmental modelling study, because a dispersion model is no more than an approximation to the complex processes which take place in the atmosphere. Some of the key factors which lead to uncertainty in atmospheric dispersion modelling are as follows:

- The quality of the model output depends on the accuracy of the input data that goes into the model. Where model input data are a less reliable representation of the true situation, the results are likely to be less accurate;
- The meteorological datasets used in the model are not likely to be completely representative of the meteorological conditions at the Site. However, the most suitable available meteorological data were chosen for the assessment;
- Models are generally designed on the basis of data obtained for large scale point sources, and may be less well validated for modelling emissions from smaller scale sources;
- The dispersion of pollutants around buildings is a complex scenario to replicate. Dispersion models can take account of the effects of buildings on dispersion. However, there will be greater uncertainty in the model results when buildings are included in the model; and
- Modelling does not specifically take into account individual small-scale features such as vegetation, local terrain variations and off-site buildings. The roughness length (zo) selected is suitable to take account of the typical size of these local features.

To take account of these uncertainties and to ensure the predictions are more likely to be over-estimates than under-estimates, the conservative assumptions described below have been used for this assessment.

### 2.5.2 Conservative Assumptions

The conservative assumptions adopted in this study are summarised below:

- It has been assumed that the gas turbines would operate simultaneously and continuously at maximum load (100% of maximum continuous rating) for the entire year. In practice, there will be some downtime for routine maintenance and inspection, and so the modelling assessment represents an overestimate of actual operating hours and operating load may not always be 100%;
- The study is based on emissions from the plant being continuously at the maximum emission concentrations for the proposed plant;
- The highest predicted concentrations obtained using any of the three different years of meteorological data have been used in this assessment. During a typical year the ground level concentrations are likely to be lower;
- The highest predicted concentration at any of the sensitive human locations included in the assessment of environmental effects. Concentrations at other locations are likely to be less than the maximum values presented.

## 2.6 Baseline Air Quality

As described in the ESIA, a baseline monitoring survey was carried out in the vicinity of the proposed IPP project development site. This included measurements of $NO_2$ and CO at 10 locations undertaken over the period of several days during the wet season (February 2013) and dry season (October 2013). The average concentrations used to represent the long

term background concentrations of $NO_2$ and CO were calculated from the raw baseline monitoring data and are shown in Table 2.6.

**Table 2.6: Comparison of Ambient Air Quality Standards and Guidelines**

| Pollutant | Long Term Mean Baseline Concentration (µg/m$^3$) |
|---|---|
| $NO_2$ | 28.1 |
| CO | 2,548 |

The long-term baseline concentrations were doubled to estimate the short-term baseline concentrations, for example, to determine the short-term baseline concentration of $NO_2$ or CO for calculation of the 1-hour mean concentrations.

The concentration of $NO_2$ indicates compliance with the IFC/WHO annual mean guideline of 40 µg/m$^3$. The measured concentrations of CO also indicate compliance with the relevant IFC/WHO guidelines.

# 3 Dispersion Modelling Results

## 3.1 Summary of Results at Human Receptor Locations

The dispersion model results for each Phase of the proposed IPP are set out in Tables 3.1 to 3.4, respectively. The tables give the following information:

- Ambient Air Quality Guideline (AAQG) or guideline for each substance under consideration;
- Estimated annual mean baseline concentrations of the substance;
- Process Contribution (PC), the maximum modelled concentration of the substance due to process emissions alone from the IPP facility;
- Predicted Environmental Concentration (PEC), the maximum modelled concentration (of $NO_2$ or CO) due to process emissions combined with estimated baseline concentrations; and
- PC and PEC as a percentage of the AAQG.

**Phase 1**

The results for Phase 1 (i.e. 4 x gas turbines operating in open cycle mode) are shown in Table 3.1.

**Table 3.1: Predicted maximum modelled concentrations at sensitive receptors for Phase 1**

| Pollutant | Averaging Period | AAQG (µg/m$^3$) | Baseline concentration (µg/m$^3$) | PC (µg/m$^3$) | PEC (µg/m$^3$) | PC / AAQG | PEC / AAQG |
|---|---|---|---|---|---|---|---|
| Nitrogen dioxide | Annual mean | 40 | 28.1 | 0.2 | 28.4 | 0.6% | 71% |
| | 24 hour mean (maximum) | 75 - 113 | 28.1 | 1.6 | 29.7 | 2.1% | 40% |
| | 1 hour mean (maximum) | 200 | 56.2 | 13.3 | 69.6 | 7% | 35% |
| Carbon monoxide | 24 hour mean (maximum) | 11,400 | 2,548 | 4.5 | 2553 | 0.04% | 22% |
| | 8 hour running mean (maximum) | 10,000 | 2,548 | 13 | 2,561 | 0.1% | 26% |
| | 1 hour mean (maximum) | 30,000 | 5,097 | 74 | 5,171 | 0.2% | 17% |

Contour plots displaying annual mean $NO_2$ and 1 hour mean $NO_2$ process contributions for Phase 1 are shown in Figure 5 and Figure 6 respectively. The contour plots display the PCs for the year that resulted in the maximum concentration on the modelled grid.

**Phase 2**

The results for Phase 2 (i.e. 6 x gas turbines operating in open cycle mode) are shown in Table 3.2.

**Table 3.2: Predicted maximum modelled concentrations at sensitive receptors for Phase 2**

| Pollutant | Averaging Period | AAQG (µg/m$^3$) | Baseline concentration (µg/m$^3$) | PC (µg/m$^3$) | PEC (µg/m$^3$) | PC / AAQG | PEC / AAQG |
|---|---|---|---|---|---|---|---|
| Nitrogen dioxide | Annual mean | 40 | 28.1 | 0.3 | 28.4 | 1% | 71% |
| | 24 hour mean (maximum) | 75 - 113 | 28.1 | 2.4 | 30.5 | 3% | 41% |
| | 1 hour mean (maximum) | 200 | 56.2 | 17.7 | 73.9 | 9% | 37% |
| Carbon monoxide | 24 hour mean (maximum) | 11,400 | 2,548 | 6.1 | 2554 | 0.1% | 22% |
| | 8 hour running mean (maximum) | 10,000 | 2,548 | 18 | 2,567 | 0.2% | 26% |
| | 1 hour mean (maximum) | 30,000 | 5,097 | 98 | 5,195 | 0.3% | 17% |

Contour plots displaying annual mean $NO_2$ and 1 hour mean $NO_2$ process contributions for Phase 2 are shown in Figure 7 and Figure 8 respectively. The contour plots display the PCs for the year that resulted in the maximum concentration on the modelled grid.

**Phase 3a**

The results for Phase 3 (i.e. 6 x gas turbines operating in combined cycle mode - horizontal HRSG) are shown in Table 3.3.

**Table 3.3: Predicted maximum modelled concentrations at sensitive receptors for Phase 3a**

| Pollutant | Averaging Period | AAQG (µg/m$^3$) | Baseline concentration (µg/m$^3$) | PC (µg/m$^3$) | PEC (µg/m$^3$) | PC / AAQG | PEC / AAQG |
|---|---|---|---|---|---|---|---|
| Nitrogen dioxide | Annual mean | 40 | 28.1 | 2.3 | 30.4 | 6% | 76% |
| | 24 hour mean (maximum) | 75 - 113 | 28.1 | 11.3 | 39.4 | 15% | 53% |
| | 1 hour mean (maximum) | 200 | 56.2 | 59.5 | 115.7 | 30% | 58% |
| Carbon monoxide | 24 hour mean (maximum) | 11,400 | 2,548 | 31.4 | 2580 | 0.3% | 23% |
| | 8 hour running mean | 10,000 | 2,548 | 94 | 2,642 | 0.9% | 26% |

| Pollutant | Averaging Period | AAQG (µg/m$^3$) | Baseline concentration (µg/m$^3$) | PC (µg/m$^3$) | PEC (µg/m$^3$) | PC / AAQG | PEC / AAQG |
|---|---|---|---|---|---|---|---|
| | (maximum) | | | | | | |
| | 1 hour mean (maximum) | 30,000 | 5,097 | 332 | 5,429 | 1.1% | 18% |

Contour plots displaying annual mean $NO_2$ and 1 hour mean $NO_2$ process contributions for Phase 3a are shown in Figure 9 and Figure 10 respectively. The contour plots display the PCs for the year that resulted in the maximum concentration on the modelled grid.

**Phase 3b**

The results for Phase 1 (i.e. 6 x gas turbines operating in combined cycle mode - vertical HRSG) are shown in Table 3.4.

**Table 3.4: Predicted maximum modelled concentrations at sensitive receptors for Phase 3b**

| Pollutant | Averaging Period | AAQG (µg/m$^3$) | Baseline concentration (µg/m$^3$) | PC (µg/m$^3$) | PEC (µg/m$^3$) | PC / AAQG | PEC / AAQG |
|---|---|---|---|---|---|---|---|
| Nitrogen dioxide | Annual mean | 40 | 28.1 | 1.8 | 29.9 | 4% | 75% |
| | 24 hour mean (maximum) | 75 - 113 | 28.1 | 7.5 | 35.6 | 10% | 47% |
| | 1 hour mean (maximum) | 200 | 56.2 | 54.6 | 110.8 | 27% | 55% |
| Carbon monoxide | 24 hour mean (maximum) | 11,400 | 2,548 | 20.8 | 2569 | 0.2% | 23% |
| | 8 hour running mean (maximum) | 10,000 | 2,548 | 63 | 2,611 | 0.6% | 26% |
| | 1 hour mean (maximum) | 30,000 | 5,097 | 304 | 5,401 | 1% | 18% |

Contour plots displaying annual mean $NO_2$ and 1 hour mean $NO_2$ process contributions for Phase 3b are shown in Figure 11 and Figure 12 respectively. The contour plots display the PCs for the year that resulted in the maximum concentration on the modelled grid.

## 3.2 Predicted Concentrations at Individual Human Receptor Locations

The dispersion model results for each Phase of the proposed IPP are set out in Tables 3.5 to 3.8, respectively. The tables give the following information:

- Receptor location;
- Process Contribution (PC), the maximum modelled concentration of each of the substances due to process emissions alone from the IPP facility. This is the maximum PC determined from the three years of meteorological data.

**Table 3.5: Predicted concentrations at sensitive receptors for Phase 1**

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 1 | 0.01 | 2.6 | 0.5 | 2.1 | 15 | 0.7 |
| 2 | 0.01 | 3.1 | 0.4 | 2.3 | 17 | 0.8 |
| 3 | 0.01 | 3.3 | 0.4 | 2.4 | 18 | 0.8 |
| 4 | 0.01 | 3.9 | 0.4 | 2.9 | 22 | 1.0 |
| 5 | 0.02 | 7.5 | 1.0 | 8.6 | 42 | 2.9 |
| 6 | 0.01 | 5.4 | 0.7 | 5.7 | 30 | 1.9 |
| 7 | 0.01 | 5.3 | 0.7 | 5.5 | 30 | 1.8 |
| 8 | 0.01 | 5.2 | 0.6 | 4.7 | 29 | 1.6 |
| 9 | 0.01 | 5.6 | 0.5 | 4.2 | 31 | 1.4 |
| 10 | 0.01 | 4.6 | 0.4 | 3.4 | 26 | 1.1 |
| 11 | 0.01 | 2.4 | 0.4 | 1.8 | 13 | 0.6 |
| 12 | 0.01 | 3.1 | 0.4 | 2.3 | 18 | 0.8 |
| 13 | 0.01 | 2.1 | 0.5 | 1.7 | 12 | 0.6 |
| 14 | 0.01 | 2.0 | 0.4 | 1.5 | 11 | 0.5 |
| 15 | 0.01 | 2.0 | 0.2 | 1.7 | 11 | 0.6 |
| 16 | 0.01 | 4.6 | 0.4 | 3.5 | 26 | 1.2 |
| 17 | 0.01 | 3.9 | 0.4 | 2.9 | 22 | 1.0 |
| 18 | 0.01 | 2.9 | 0.3 | 2.1 | 16 | 0.7 |
| 19 | 0.01 | 1.9 | 0.4 | 1.6 | 11 | 0.5 |
| 20 | 0.01 | 1.9 | 0.4 | 1.5 | 11 | 0.5 |
| 21 | 0.01 | 2.0 | 0.3 | 1.6 | 11 | 0.5 |
| 22 | 0.02 | 2.5 | 0.3 | 2.2 | 14 | 0.7 |
| 23 | 0.01 | 4.0 | 0.4 | 3.0 | 22 | 1.0 |
| 24 | 0.004 | 7.1 | 0.6 | 4.9 | 40 | 1.7 |
| 25 | 0.01 | 8.3 | 0.7 | 5.8 | 46 | 1.9 |
| 26 | 0.01 | 8.7 | 0.7 | 6.1 | 48 | 2.0 |
| 27 | 0.01 | 10.6 | 0.9 | 7.4 | 59 | 2.5 |
| 28 | 0.01 | 10.9 | 0.9 | 7.6 | 61 | 2.5 |
| 29 | 0.01 | 9.9 | 0.8 | 6.9 | 55 | 2.3 |
| 30 | 0.01 | 11.4 | 1.0 | 7.9 | 63 | 2.6 |
| 31 | 0.01 | 12.6 | 1.1 | 8.8 | 70 | 2.9 |
| 32 | 0.01 | 11.1 | 0.9 | 7.7 | 62 | 2.6 |
| 33 | 0.01 | 13.3 | 1.1 | 9.3 | 74 | 3.1 |
| 34 | 0.01 | 11.1 | 0.9 | 7.8 | 62 | 2.6 |
| 35 | 0.02 | 5.6 | 0.7 | 5.9 | 31 | 2.0 |
| 36 | 0.01 | 5.8 | 0.7 | 6.0 | 32 | 2.0 |
| 37 | 0.02 | 5.4 | 0.6 | 5.4 | 30 | 1.8 |
| 38 | 0.02 | 6.8 | 0.8 | 6.6 | 38 | 2.2 |
| 39 | 0.004 | 3.6 | 0.8 | 2.6 | 20 | 0.9 |
| 40 | 0.003 | 3.0 | 0.7 | 2.2 | 17 | 0.7 |
| 41 | 0.003 | 2.9 | 0.9 | 2.1 | 16 | 0.7 |
| 42 | 0.003 | 5.0 | 1.0 | 3.5 | 28 | 1.2 |
| 43 | 0.003 | 6.3 | 1.0 | 4.4 | 35 | 1.5 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 44 | 0.004 | 7.6 | 1.0 | 5.3 | 42 | 1.8 |
| 45 | 0.004 | 8.5 | 0.9 | 5.9 | 47 | 2.0 |
| 46 | 0.01 | 3.9 | 0.3 | 2.8 | 22 | 0.9 |
| 47 | 0.01 | 10.1 | 0.8 | 7.0 | 56 | 2.4 |
| 48 | 0.01 | 8.2 | 0.7 | 6.0 | 46 | 2.0 |
| 49 | 0.01 | 10.1 | 0.8 | 7.0 | 56 | 2.3 |
| 50 | 0.01 | 12.2 | 1.0 | 8.5 | 68 | 2.8 |
| 51 | 0.01 | 11.6 | 1.0 | 8.1 | 65 | 2.7 |
| 52 | 0.01 | 6.1 | 0.7 | 5.5 | 34 | 1.8 |
| 53 | 0.01 | 5.4 | 0.7 | 5.4 | 30 | 1.8 |
| 54 | 0.01 | 6.3 | 0.7 | 5.7 | 35 | 1.9 |
| 55 | 0.01 | 5.8 | 0.5 | 4.4 | 33 | 1.5 |
| 56 | 0.01 | 7.6 | 0.7 | 5.6 | 42 | 1.9 |
| 57 | 0.01 | 6.4 | 0.6 | 4.7 | 36 | 1.6 |
| 58 | 0.01 | 6.4 | 0.6 | 4.7 | 36 | 1.6 |
| 59 | 0.01 | 12.2 | 1.0 | 8.5 | 68 | 2.8 |
| 60 | 0.01 | 6.2 | 0.5 | 4.3 | 34 | 1.4 |
| 61 | 0.01 | 4.8 | 0.8 | 6.4 | 27 | 2.1 |
| 62 | 0.01 | 4.7 | 0.7 | 6.3 | 26 | 2.1 |
| 63 | 0.01 | 7.6 | 0.8 | 6.9 | 42 | 2.3 |
| 64 | 0.01 | 6.0 | 0.8 | 6.9 | 34 | 2.3 |
| 65 | 0.01 | 6.2 | 0.8 | 6.9 | 35 | 2.3 |
| 66 | 0.01 | 6.7 | 0.8 | 6.9 | 37 | 2.3 |
| 67 | 0.01 | 4.6 | 0.8 | 6.4 | 26 | 2.1 |
| 68 | 0.01 | 3.1 | 0.6 | 5.3 | 17 | 1.8 |
| 69 | 0.02 | 9.3 | 0.8 | 6.7 | 52 | 2.2 |
| 70 | 0.02 | 8.6 | 0.8 | 6.6 | 48 | 2.2 |
| 71 | 0.02 | 8.9 | 0.8 | 6.6 | 50 | 2.2 |
| 72 | 0.02 | 10.4 | 1.0 | 8.0 | 58 | 2.7 |
| 73 | 0.03 | 11.3 | 1.1 | 9.0 | 63 | 3.0 |
| 74 | 0.01 | 3.0 | 0.4 | 2.1 | 17 | 0.7 |
| 75 | 0.01 | 3.1 | 0.4 | 2.2 | 17 | 0.7 |
| 76 | 0.01 | 3.2 | 0.4 | 2.3 | 18 | 0.8 |
| 77 | 0.01 | 3.2 | 0.4 | 2.3 | 18 | 0.8 |
| 78 | 0.01 | 3.2 | 0.4 | 2.3 | 18 | 0.8 |
| 79 | 0.01 | 3.2 | 0.4 | 2.4 | 18 | 0.8 |
| 80 | 0.01 | 3.1 | 0.4 | 2.2 | 17 | 0.7 |
| 81 | 0.01 | 3.2 | 0.4 | 2.3 | 18 | 0.8 |
| 82 | 0.01 | 3.3 | 0.4 | 2.4 | 18 | 0.8 |
| 83 | 0.01 | 3.3 | 0.4 | 2.4 | 18 | 0.8 |
| 84 | 0.15 | 5.4 | 1.3 | 10.6 | 30 | 3.5 |
| 85 | 0.18 | 3.9 | 0.9 | 7.1 | 22 | 2.4 |
| 86 | 0.22 | 5.0 | 1.4 | 11.1 | 28 | 3.8 |
| 87 | 0.24 | 5.4 | 1.6 | 13.1 | 30 | 4.5 |
| 88 | 0.20 | 4.5 | 1.1 | 9.1 | 25 | 3.1 |
| 89 | 0.18 | 4.2 | 0.9 | 7.7 | 23 | 2.6 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 90 | 0.20 | 4.2 | 1.3 | 10.4 | 23 | 3.5 |
| 91 | 0.16 | 4.0 | 1.0 | 8.3 | 22 | 2.8 |
| 92 | 0.16 | 8.2 | 1.6 | 13.0 | 46 | 4.3 |
| 93 | 0.11 | 4.5 | 1.4 | 11.3 | 25 | 3.8 |
| 94 | 0.10 | 4.2 | 1.3 | 10.6 | 24 | 3.5 |
| 95 | 0.16 | 6.1 | 1.3 | 9.1 | 34 | 3.0 |
| 96 | 0.13 | 8.5 | 1.4 | 11.9 | 48 | 4.0 |
| 97 | 0.03 | 2.7 | 0.4 | 3.4 | 15 | 1.1 |
| 98 | 0.02 | 1.9 | 0.3 | 2.3 | 10 | 0.8 |
| 99 | 0.02 | 1.7 | 0.3 | 2.4 | 10 | 0.8 |
| 100 | 0.02 | 1.8 | 0.3 | 2.8 | 10 | 0.9 |
| 101 | 0.03 | 2.0 | 0.4 | 3.1 | 11 | 1.0 |
| 102 | 0.03 | 2.1 | 0.4 | 3.3 | 12 | 1.1 |

**Table 3.6: Predicted concentrations at sensitive receptors for Phase 2**

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 1 | 0.02 | 3.2 | 0.7 | 2.9 | 18 | 1.0 |
| 2 | 0.02 | 4.0 | 0.7 | 3.2 | 22 | 1.1 |
| 3 | 0.01 | 4.5 | 0.6 | 3.4 | 25 | 1.1 |
| 4 | 0.01 | 4.9 | 0.6 | 3.6 | 27 | 1.2 |
| 5 | 0.01 | 3.4 | 1.4 | 2.7 | 19 | 1.0 |
| 6 | 0.02 | 7.2 | 1.0 | 5.5 | 40 | 1.8 |
| 7 | 0.02 | 7.4 | 0.9 | 5.6 | 41 | 1.9 |
| 8 | 0.02 | 8.2 | 0.7 | 6.1 | 45 | 2.0 |
| 9 | 0.02 | 7.7 | 0.7 | 5.8 | 43 | 1.9 |
| 10 | 0.01 | 6.1 | 0.6 | 4.5 | 34 | 1.5 |
| 11 | 0.01 | 3.7 | 0.6 | 2.6 | 21 | 0.9 |
| 12 | 0.01 | 4.5 | 0.5 | 3.3 | 25 | 1.1 |
| 13 | 0.02 | 2.6 | 0.7 | 2.4 | 15 | 0.8 |
| 14 | 0.02 | 3.0 | 0.6 | 2.4 | 17 | 0.8 |
| 15 | 0.02 | 3.3 | 0.3 | 2.6 | 18 | 0.9 |
| 16 | 0.01 | 6.4 | 0.6 | 4.8 | 36 | 1.6 |
| 17 | 0.01 | 5.0 | 0.5 | 3.7 | 28 | 1.2 |
| 18 | 0.01 | 4.3 | 0.5 | 3.1 | 24 | 1.0 |
| 19 | 0.02 | 2.4 | 0.6 | 2.1 | 13 | 0.7 |
| 20 | 0.02 | 2.9 | 0.6 | 2.3 | 16 | 0.8 |
| 21 | 0.02 | 2.8 | 0.4 | 2.4 | 16 | 0.8 |
| 22 | 0.03 | 3.9 | 0.5 | 2.8 | 22 | 0.9 |
| 23 | 0.01 | 5.3 | 0.5 | 4.0 | 30 | 1.3 |
| 24 | 0.01 | 10.5 | 0.9 | 7.3 | 58 | 2.4 |
| 25 | 0.01 | 6.4 | 1.2 | 4.5 | 36 | 1.5 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 26 | 0.01 | 5.9 | 1.3 | 4.1 | 33 | 1.4 |
| 27 | 0.01 | 3.3 | 1.5 | 2.6 | 18 | 0.9 |
| 28 | 0.01 | 3.2 | 1.5 | 2.7 | 18 | 0.9 |
| 29 | 0.005 | 3.5 | 1.2 | 2.8 | 20 | 0.9 |
| 30 | 0.005 | 3.6 | 1.5 | 3.0 | 20 | 1.0 |
| 31 | 0.01 | 5.5 | 1.2 | 3.8 | 30 | 1.3 |
| 32 | 0.01 | 5.3 | 1.0 | 3.7 | 29 | 1.2 |
| 33 | 0.01 | 5.3 | 1.3 | 3.7 | 30 | 1.3 |
| 34 | 0.01 | 3.3 | 1.3 | 2.8 | 18 | 0.9 |
| 35 | 0.02 | 7.6 | 1.0 | 5.7 | 42 | 1.9 |
| 36 | 0.02 | 8.9 | 1.0 | 6.7 | 50 | 2.2 |
| 37 | 0.02 | 5.5 | 1.0 | 4.2 | 31 | 1.4 |
| 38 | 0.01 | 6.0 | 1.1 | 4.6 | 33 | 1.5 |
| 39 | 0.01 | 5.8 | 1.4 | 4.4 | 32 | 1.5 |
| 40 | 0.005 | 3.8 | 1.1 | 2.9 | 21 | 1.0 |
| 41 | 0.004 | 4.0 | 1.4 | 2.8 | 22 | 0.9 |
| 42 | 0.005 | 7.4 | 1.7 | 5.1 | 41 | 1.7 |
| 43 | 0.01 | 9.5 | 1.7 | 6.6 | 53 | 2.2 |
| 44 | 0.01 | 11.6 | 1.7 | 8.1 | 65 | 2.7 |
| 45 | 0.01 | 13.1 | 1.5 | 9.1 | 73 | 3.0 |
| 46 | 0.01 | 3.2 | 0.5 | 2.6 | 18 | 0.9 |
| 47 | 0.005 | 3.5 | 1.4 | 2.9 | 20 | 1.0 |
| 48 | 0.004 | 3.2 | 1.0 | 2.4 | 18 | 0.8 |
| 49 | 0.01 | 2.9 | 1.4 | 2.0 | 16 | 0.7 |
| 50 | 0.01 | 4.1 | 1.6 | 2.9 | 23 | 1.0 |
| 51 | 0.01 | 3.6 | 1.6 | 2.6 | 20 | 0.8 |
| 52 | 0.02 | 9.6 | 0.8 | 7.1 | 53 | 2.4 |
| 53 | 0.02 | 8.7 | 0.9 | 6.5 | 48 | 2.2 |
| 54 | 0.02 | 10.0 | 0.9 | 7.4 | 56 | 2.5 |
| 55 | 0.02 | 7.8 | 0.7 | 5.9 | 44 | 2.0 |
| 56 | 0.02 | 10.2 | 0.9 | 7.5 | 57 | 2.5 |
| 57 | 0.02 | 8.5 | 0.8 | 6.3 | 47 | 2.1 |
| 58 | 0.02 | 8.7 | 0.8 | 6.5 | 49 | 2.2 |
| 59 | 0.01 | 5.7 | 1.2 | 4.0 | 32 | 1.3 |
| 60 | 0.01 | 4.2 | 0.5 | 2.9 | 23 | 1.0 |
| 61 | 0.02 | 8.7 | 1.1 | 6.2 | 49 | 2.1 |
| 62 | 0.02 | 9.0 | 1.1 | 6.4 | 50 | 2.1 |
| 63 | 0.04 | 14.9 | 1.4 | 11.6 | 83 | 3.9 |
| 64 | 0.03 | 13.1 | 1.2 | 9.7 | 73 | 3.2 |
| 65 | 0.03 | 13.7 | 1.2 | 10.2 | 76 | 3.4 |
| 66 | 0.03 | 14.4 | 1.3 | 10.8 | 80 | 3.6 |
| 67 | 0.02 | 10.0 | 1.1 | 7.1 | 56 | 2.4 |
| 68 | 0.02 | 10.3 | 1.1 | 7.3 | 57 | 2.4 |
| 69 | 0.05 | 16.7 | 1.7 | 13.8 | 93 | 4.6 |
| 70 | 0.04 | 16.0 | 1.5 | 12.8 | 89 | 4.3 |
| 71 | 0.05 | 16.6 | 1.6 | 13.4 | 93 | 4.5 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 72 | 0.06 | 16.8 | 1.8 | 15.4 | 94 | 5.1 |
| 73 | 0.07 | 17.7 | 2.0 | 16.9 | 98 | 5.7 |
| 74 | 0.01 | 4.5 | 0.5 | 3.3 | 25 | 1.1 |
| 75 | 0.01 | 4.6 | 0.5 | 3.3 | 26 | 1.1 |
| 76 | 0.01 | 4.4 | 0.5 | 3.3 | 25 | 1.1 |
| 77 | 0.01 | 4.3 | 0.6 | 3.2 | 24 | 1.1 |
| 78 | 0.01 | 4.5 | 0.5 | 3.3 | 25 | 1.1 |
| 79 | 0.01 | 4.2 | 0.6 | 3.2 | 23 | 1.1 |
| 80 | 0.01 | 4.6 | 0.5 | 3.3 | 26 | 1.1 |
| 81 | 0.01 | 4.6 | 0.5 | 3.4 | 26 | 1.1 |
| 82 | 0.01 | 4.6 | 0.5 | 3.4 | 26 | 1.1 |
| 83 | 0.01 | 4.4 | 0.6 | 3.4 | 24 | 1.1 |
| 84 | 0.12 | 7.0 | 1.8 | 10.5 | 39 | 3.5 |
| 85 | 0.12 | 5.3 | 1.3 | 10.3 | 29 | 3.5 |
| 86 | 0.13 | 7.4 | 2.0 | 12.0 | 41 | 4.2 |
| 87 | 0.14 | 7.9 | 2.4 | 14.0 | 44 | 5.0 |
| 88 | 0.13 | 6.7 | 1.7 | 10.6 | 37 | 3.5 |
| 89 | 0.12 | 5.3 | 1.3 | 10.6 | 29 | 3.6 |
| 90 | 0.12 | 6.1 | 1.9 | 11.6 | 34 | 4.1 |
| 91 | 0.10 | 5.8 | 1.5 | 9.4 | 32 | 3.3 |
| 92 | 0.27 | 11.1 | 2.2 | 18.2 | 62 | 6.1 |
| 93 | 0.11 | 6.1 | 2.0 | 11.3 | 34 | 3.8 |
| 94 | 0.12 | 6.1 | 1.9 | 12.4 | 34 | 4.1 |
| 95 | 0.25 | 8.2 | 1.9 | 12.9 | 46 | 4.3 |
| 96 | 0.22 | 11.1 | 2.1 | 17.9 | 62 | 6.0 |
| 97 | 0.04 | 3.3 | 0.6 | 4.3 | 19 | 1.6 |
| 98 | 0.03 | 2.7 | 0.4 | 3.4 | 15 | 1.2 |
| 99 | 0.03 | 2.6 | 0.4 | 3.4 | 15 | 1.1 |
| 100 | 0.03 | 2.7 | 0.5 | 3.5 | 15 | 1.2 |
| 101 | 0.03 | 2.7 | 0.6 | 3.5 | 15 | 1.2 |
| 102 | 0.03 | 2.6 | 0.6 | 3.4 | 15 | 1.1 |

**Table 3.7: Predicted concentrations at sensitive receptors for Phase 3a**

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 1 | 0.15 | 26.5 | 3.3 | 27 | 148 | 9.3 |
| 2 | 0.14 | 25.2 | 3.0 | 25 | 140 | 8.5 |
| 3 | 0.13 | 22.4 | 2.8 | 22 | 125 | 7.7 |
| 4 | 0.11 | 22.5 | 2.3 | 19 | 126 | 6.5 |
| 5 | 0.10 | 24.9 | 4.1 | 34 | 138 | 11.5 |
| 6 | 0.11 | 16.1 | 3.0 | 25 | 89 | 8.3 |
| 7 | 0.11 | 14.4 | 2.6 | 22 | 80 | 7.4 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 8 | 0.11 | 13.5 | 2.2 | 19 | 75 | 6.2 |
| 9 | 0.11 | 21.9 | 2.4 | 20 | 122 | 6.8 |
| 10 | 0.11 | 21.5 | 2.2 | 19 | 119 | 6.2 |
| 11 | 0.12 | 17.3 | 2.2 | 18 | 96 | 6.1 |
| 12 | 0.13 | 17.3 | 2.1 | 17 | 96 | 5.8 |
| 13 | 0.15 | 20.9 | 2.7 | 22 | 116 | 7.6 |
| 14 | 0.17 | 18.6 | 2.4 | 20 | 103 | 6.5 |
| 15 | 0.23 | 16.2 | 2.9 | 24 | 90 | 8.2 |
| 16 | 0.11 | 17.8 | 2.0 | 17 | 99 | 5.7 |
| 17 | 0.11 | 20.9 | 2.3 | 19 | 116 | 6.3 |
| 18 | 0.12 | 16.0 | 2.0 | 17 | 89 | 5.5 |
| 19 | 0.15 | 18.1 | 2.3 | 19 | 101 | 6.5 |
| 20 | 0.18 | 19.2 | 2.3 | 19 | 107 | 6.4 |
| 21 | 0.20 | 18.1 | 2.4 | 19 | 101 | 6.6 |
| 22 | 0.26 | 16.3 | 3.1 | 26 | 91 | 8.6 |
| 23 | 0.11 | 18.2 | 2.1 | 18 | 101 | 5.9 |
| 24 | 0.08 | 43.4 | 4.8 | 40 | 241 | 13.4 |
| 25 | 0.10 | 48.3 | 5.3 | 45 | 269 | 14.9 |
| 26 | 0.10 | 49.7 | 5.5 | 46 | 277 | 15.2 |
| 27 | 0.12 | 51.8 | 5.4 | 46 | 288 | 15.2 |
| 28 | 0.12 | 52.5 | 5.5 | 48 | 292 | 15.3 |
| 29 | 0.12 | 41.3 | 4.6 | 50 | 231 | 12.9 |
| 30 | 0.14 | 51.8 | 5.6 | 57 | 289 | 15.6 |
| 31 | 0.15 | 50.8 | 6.5 | 54 | 283 | 18.0 |
| 32 | 0.15 | 47.6 | 6.9 | 58 | 266 | 19.2 |
| 33 | 0.16 | 54.3 | 6.7 | 56 | 301 | 18.7 |
| 34 | 0.17 | 54.6 | 5.9 | 61 | 304 | 16.4 |
| 35 | 0.11 | 17.4 | 3.2 | 27 | 97 | 8.9 |
| 36 | 0.11 | 16.2 | 3.0 | 25 | 90 | 8.3 |
| 37 | 0.11 | 17.7 | 3.3 | 28 | 98 | 9.3 |
| 38 | 0.11 | 23.6 | 4.8 | 40 | 131 | 13.2 |
| 39 | 0.08 | 31.4 | 4.1 | 34 | 175 | 11.3 |
| 40 | 0.10 | 37.1 | 3.4 | 28 | 206 | 9.3 |
| 41 | 0.10 | 40.3 | 3.4 | 28 | 224 | 9.3 |
| 42 | 0.10 | 36.8 | 3.3 | 27 | 206 | 9.1 |
| 43 | 0.09 | 37.5 | 3.4 | 28 | 209 | 9.5 |
| 44 | 0.09 | 41.7 | 3.5 | 29 | 233 | 9.8 |
| 45 | 0.07 | 43.8 | 4.4 | 36 | 244 | 12.1 |
| 46 | 0.17 | 48.3 | 7.1 | 59 | 270 | 19.6 |
| 47 | 0.10 | 40.3 | 4.4 | 39 | 223 | 12.3 |
| 48 | 0.11 | 36.8 | 3.6 | 40 | 204 | 10.0 |
| 49 | 0.11 | 47.6 | 4.0 | 34 | 265 | 11.2 |
| 50 | 0.11 | 50.8 | 4.3 | 36 | 283 | 11.9 |
| 51 | 0.12 | 52.5 | 4.4 | 37 | 292 | 12.3 |
| 52 | 0.11 | 15.8 | 2.7 | 22 | 88 | 7.4 |
| 53 | 0.11 | 14.9 | 2.6 | 22 | 83 | 7.2 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 54 | 0.11 | 16.7 | 2.8 | 23 | 93 | 7.8 |
| 55 | 0.11 | 26.1 | 2.6 | 21 | 145 | 7.2 |
| 56 | 0.11 | 19.2 | 2.8 | 23 | 107 | 7.9 |
| 57 | 0.11 | 16.9 | 2.4 | 20 | 94 | 6.8 |
| 58 | 0.11 | 16.3 | 2.4 | 20 | 91 | 6.8 |
| 59 | 0.14 | 49.4 | 5.8 | 48 | 274 | 16.0 |
| 60 | 0.15 | 47.6 | 7.2 | 60 | 266 | 20.1 |
| 61 | 0.28 | 51.8 | 8.1 | 68 | 289 | 22.6 |
| 62 | 0.29 | 54.3 | 8.5 | 71 | 302 | 23.6 |
| 63 | 0.40 | 52.2 | 8.5 | 71 | 291 | 23.7 |
| 64 | 0.35 | 53.9 | 8.7 | 73 | 301 | 24.2 |
| 65 | 0.36 | 52.5 | 9.2 | 77 | 293 | 25.6 |
| 66 | 0.37 | 52.9 | 9.2 | 77 | 295 | 25.8 |
| 67 | 0.31 | 51.8 | 8.8 | 74 | 289 | 24.6 |
| 68 | 0.32 | 59.5 | 9.8 | 82 | 332 | 27.3 |
| 69 | 0.48 | 43.1 | 7.9 | 66 | 240 | 22.1 |
| 70 | 0.44 | 46.6 | 8.1 | 67 | 260 | 22.6 |
| 71 | 0.46 | 50.1 | 8.5 | 71 | 279 | 23.6 |
| 72 | 0.57 | 38.2 | 6.5 | 55 | 212 | 18.2 |
| 73 | 0.67 | 42.0 | 6.7 | 56 | 233 | 18.8 |
| 74 | 0.12 | 18.0 | 2.2 | 18 | 100 | 6.1 |
| 75 | 0.12 | 18.3 | 2.2 | 18 | 102 | 6.1 |
| 76 | 0.13 | 17.6 | 2.2 | 18 | 98 | 6.2 |
| 77 | 0.13 | 20.7 | 2.5 | 20 | 115 | 7.0 |
| 78 | 0.13 | 18.8 | 2.4 | 18 | 104 | 6.5 |
| 79 | 0.13 | 23.2 | 2.8 | 23 | 129 | 7.8 |
| 80 | 0.12 | 18.6 | 2.2 | 19 | 104 | 6.2 |
| 81 | 0.12 | 18.7 | 2.2 | 18 | 104 | 6.1 |
| 82 | 0.12 | 19.3 | 2.4 | 19 | 108 | 6.5 |
| 83 | 0.13 | 23.9 | 2.9 | 23 | 133 | 8.1 |
| 84 | 1.54 | 15.0 | 6.7 | 46 | 84 | 18.6 |
| 85 | 1.79 | 14.5 | 5.6 | 39 | 81 | 15.6 |
| 86 | 2.14 | 14.2 | 7.4 | 52 | 79 | 20.4 |
| 87 | 2.32 | 15.7 | 8.8 | 62 | 88 | 24.3 |
| 88 | 2.01 | 14.9 | 6.1 | 43 | 83 | 16.9 |
| 89 | 1.81 | 14.7 | 6.0 | 40 | 82 | 16.6 |
| 90 | 1.89 | 12.0 | 7.1 | 47 | 67 | 19.9 |
| 91 | 1.62 | 10.4 | 6.1 | 41 | 58 | 17.1 |
| 92 | 2.02 | 40.3 | 11.3 | 94 | 225 | 31.4 |
| 93 | 1.15 | 13.9 | 5.6 | 43 | 78 | 15.5 |
| 94 | 1.03 | 14.0 | 4.8 | 40 | 78 | 13.3 |
| 95 | 1.69 | 23.3 | 6.9 | 57 | 130 | 19.2 |
| 96 | 1.60 | 32.4 | 9.9 | 82 | 181 | 27.6 |
| 97 | 0.37 | 14.2 | 3.4 | 27 | 79 | 9.5 |
| 98 | 0.28 | 13.1 | 2.5 | 21 | 73 | 7.0 |
| 99 | 0.25 | 9.9 | 2.1 | 17 | 55 | 5.9 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 100 | 0.27 | 9.7 | 2.3 | 18 | 54 | 6.3 |
| 101 | 0.31 | 9.8 | 2.4 | 20 | 55 | 6.7 |
| 102 | 0.38 | 10.0 | 2.5 | 21 | 56 | 6.9 |

**Table 3.8: Predicted concentrations at sensitive receptors for Phase 3b**

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 1 | 0.07 | 16.9 | 2.5 | 20 | 94 | 6.8 |
| 2 | 0.06 | 16.0 | 2.3 | 19 | 89 | 6.3 |
| 3 | 0.06 | 14.7 | 2.0 | 17 | 82 | 5.6 |
| 4 | 0.06 | 12.9 | 2.0 | 17 | 72 | 5.7 |
| 5 | 0.06 | 16.5 | 3.8 | 32 | 92 | 10.7 |
| 6 | 0.06 | 13.7 | 2.6 | 22 | 76 | 7.3 |
| 7 | 0.06 | 12.7 | 2.4 | 20 | 71 | 6.6 |
| 8 | 0.06 | 11.6 | 2.0 | 17 | 64 | 5.7 |
| 9 | 0.06 | 12.7 | 2.1 | 18 | 71 | 6.0 |
| 10 | 0.06 | 12.2 | 2.0 | 17 | 68 | 5.5 |
| 11 | 0.06 | 12.6 | 2.0 | 16 | 70 | 5.5 |
| 12 | 0.06 | 13.3 | 1.9 | 16 | 74 | 5.2 |
| 13 | 0.07 | 13.8 | 2.1 | 18 | 77 | 5.9 |
| 14 | 0.08 | 13.1 | 1.8 | 15 | 73 | 4.9 |
| 15 | 0.12 | 11.9 | 2.0 | 16 | 66 | 5.5 |
| 16 | 0.06 | 11.6 | 1.8 | 15 | 65 | 5.1 |
| 17 | 0.06 | 11.9 | 1.9 | 16 | 67 | 5.4 |
| 18 | 0.06 | 12.4 | 1.8 | 15 | 69 | 4.9 |
| 19 | 0.07 | 12.1 | 1.9 | 16 | 68 | 5.3 |
| 20 | 0.09 | 12.3 | 1.7 | 14 | 68 | 4.7 |
| 21 | 0.10 | 11.6 | 1.6 | 13 | 65 | 4.5 |
| 22 | 0.15 | 13.0 | 2.3 | 20 | 72 | 6.5 |
| 23 | 0.06 | 12.2 | 1.8 | 15 | 68 | 4.9 |
| 24 | 0.05 | 52.9 | 4.9 | 41 | 294 | 13.5 |
| 25 | 0.06 | 45.5 | 4.2 | 35 | 254 | 11.8 |
| 26 | 0.06 | 47.6 | 4.4 | 37 | 265 | 12.2 |
| 27 | 0.06 | 52.9 | 4.8 | 40 | 294 | 13.4 |
| 28 | 0.06 | 52.2 | 4.7 | 40 | 291 | 13.2 |
| 29 | 0.06 | 38.9 | 3.8 | 29 | 216 | 10.5 |
| 30 | 0.07 | 50.1 | 4.7 | 36 | 278 | 13.1 |
| 31 | 0.06 | 50.1 | 4.2 | 35 | 278 | 11.6 |
| 32 | 0.05 | 45.5 | 4.2 | 35 | 253 | 11.7 |
| 33 | 0.06 | 53.6 | 4.5 | 37 | 298 | 12.4 |
| 34 | 0.09 | 54.6 | 5.0 | 42 | 304 | 14.1 |
| 35 | 0.06 | 14.6 | 2.8 | 23 | 81 | 7.7 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 36 | 0.06 | 14.5 | 2.6 | 22 | 81 | 7.4 |
| 37 | 0.06 | 13.8 | 2.9 | 24 | 77 | 8.0 |
| 38 | 0.06 | 17.8 | 3.8 | 31 | 99 | 10.5 |
| 39 | 0.04 | 30.6 | 4.0 | 33 | 170 | 11.1 |
| 40 | 0.06 | 32.7 | 2.7 | 23 | 182 | 7.6 |
| 41 | 0.07 | 36.4 | 3.0 | 25 | 202 | 8.5 |
| 42 | 0.07 | 36.8 | 3.1 | 26 | 205 | 8.5 |
| 43 | 0.07 | 36.8 | 3.2 | 26 | 204 | 8.8 |
| 44 | 0.06 | 39.9 | 3.4 | 28 | 222 | 9.5 |
| 45 | 0.05 | 45.5 | 4.1 | 34 | 253 | 11.4 |
| 46 | 0.06 | 44.1 | 3.7 | 31 | 246 | 10.4 |
| 47 | 0.05 | 37.8 | 3.5 | 30 | 211 | 9.9 |
| 48 | 0.05 | 27.1 | 2.8 | 21 | 151 | 7.7 |
| 49 | 0.05 | 31.6 | 2.6 | 22 | 176 | 7.4 |
| 50 | 0.05 | 39.2 | 3.3 | 27 | 218 | 9.1 |
| 51 | 0.06 | 38.2 | 3.2 | 27 | 212 | 8.9 |
| 52 | 0.06 | 13.8 | 2.4 | 20 | 77 | 6.6 |
| 53 | 0.06 | 13.0 | 2.3 | 20 | 72 | 6.5 |
| 54 | 0.06 | 14.5 | 2.5 | 21 | 81 | 6.9 |
| 55 | 0.06 | 14.2 | 2.2 | 19 | 79 | 6.3 |
| 56 | 0.06 | 14.4 | 2.3 | 19 | 80 | 6.4 |
| 57 | 0.06 | 12.5 | 2.1 | 18 | 70 | 6.0 |
| 58 | 0.06 | 12.3 | 2.1 | 18 | 68 | 5.8 |
| 59 | 0.05 | 46.6 | 3.9 | 33 | 260 | 10.9 |
| 60 | 0.05 | 43.1 | 3.7 | 31 | 239 | 10.3 |
| 61 | 0.10 | 36.1 | 3.9 | 33 | 200 | 10.9 |
| 62 | 0.10 | 37.5 | 3.9 | 33 | 209 | 10.8 |
| 63 | 0.11 | 33.8 | 4.3 | 36 | 188 | 12.1 |
| 64 | 0.11 | 36.8 | 4.3 | 36 | 204 | 12.0 |
| 65 | 0.10 | 38.2 | 4.3 | 36 | 212 | 12.0 |
| 66 | 0.11 | 37.8 | 4.4 | 36 | 211 | 12.1 |
| 67 | 0.10 | 38.5 | 4.0 | 33 | 215 | 11.1 |
| 68 | 0.08 | 44.1 | 4.2 | 35 | 246 | 11.6 |
| 69 | 0.13 | 29.8 | 4.2 | 35 | 166 | 11.7 |
| 70 | 0.12 | 31.2 | 4.3 | 36 | 174 | 11.9 |
| 71 | 0.12 | 31.9 | 4.3 | 36 | 177 | 11.9 |
| 72 | 0.19 | 26.8 | 3.7 | 31 | 149 | 10.3 |
| 73 | 0.22 | 29.8 | 3.5 | 30 | 166 | 9.8 |
| 74 | 0.06 | 13.8 | 1.9 | 16 | 77 | 5.4 |
| 75 | 0.06 | 14.0 | 1.9 | 16 | 78 | 5.4 |
| 76 | 0.06 | 13.6 | 1.9 | 16 | 76 | 5.2 |
| 77 | 0.06 | 13.7 | 1.9 | 16 | 76 | 5.3 |
| 78 | 0.06 | 13.9 | 1.9 | 16 | 77 | 5.3 |
| 79 | 0.06 | 15.0 | 2.1 | 17 | 83 | 5.8 |
| 80 | 0.06 | 14.2 | 2.0 | 17 | 79 | 5.5 |
| 81 | 0.06 | 14.3 | 2.0 | 16 | 80 | 5.4 |

| Receptor | Modelled PC (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Nitrogen dioxide | | | Carbon monoxide | | |
| | Annual mean | Maximum hourly mean | Maximum 24-hour mean | Maximum 8-hour mean | Maximum hourly mean | Maximum 24-hour mean |
| 82 | 0.06 | 14.7 | 2.0 | 17 | 82 | 5.5 |
| 83 | 0.06 | 15.5 | 2.1 | 18 | 86 | 5.9 |
| 84 | 1.18 | 13.3 | 5.5 | 39 | 74 | 15.3 |
| 85 | 1.38 | 12.6 | 4.4 | 32 | 70 | 12.4 |
| 86 | 1.65 | 13.2 | 6.0 | 47 | 74 | 16.7 |
| 87 | 1.79 | 14.7 | 7.1 | 55 | 82 | 19.8 |
| 88 | 1.54 | 13.1 | 4.9 | 39 | 73 | 13.8 |
| 89 | 1.39 | 13.0 | 4.7 | 32 | 72 | 13.0 |
| 90 | 1.48 | 9.9 | 6.1 | 42 | 55 | 17.0 |
| 91 | 1.25 | 9.3 | 5.2 | 36 | 52 | 14.4 |
| 92 | 1.13 | 27.2 | 7.5 | 63 | 152 | 20.8 |
| 93 | 0.90 | 11.2 | 4.9 | 36 | 62 | 13.7 |
| 94 | 0.81 | 10.4 | 4.2 | 32 | 58 | 11.7 |
| 95 | 1.14 | 17.9 | 5.3 | 45 | 100 | 14.9 |
| 96 | 0.95 | 24.1 | 6.7 | 56 | 134 | 18.6 |
| 97 | 0.28 | 12.7 | 2.8 | 23 | 71 | 7.7 |
| 98 | 0.22 | 12.0 | 2.4 | 20 | 67 | 6.6 |
| 99 | 0.20 | 9.5 | 1.8 | 15 | 53 | 5.0 |
| 100 | 0.21 | 9.1 | 1.8 | 15 | 51 | 5.0 |
| 101 | 0.25 | 9.1 | 2.0 | 17 | 51 | 5.5 |
| 102 | 0.30 | 9.3 | 2.2 | 18 | 52 | 6.1 |

# Figures


**Figure 1:** Phase 1 + 2 site layout plan showing modelled emission points and buildings

**Figure 2:** Phase 3 site layout plan showing modelled emission points and buildings (horizontally aligned HRSG)

**Figure 3:** Phase 3 site layout plan showing modelled emission points and buildings (vertically aligned HRSG)

**Figure 4:** Site location plan showing modelled receptor locations

**Figure 5:** Annual mean nitrogen dioxide process contributions, Phase 1, 2011 meteorological data

**Figure 6:** Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 1, 2012 meteorological data

**Figure 7:** Annual mean nitrogen dioxide process contributions, Phase 2, 2012 meteorological data

**Figure 8:** Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 2, 2013 meteorological data

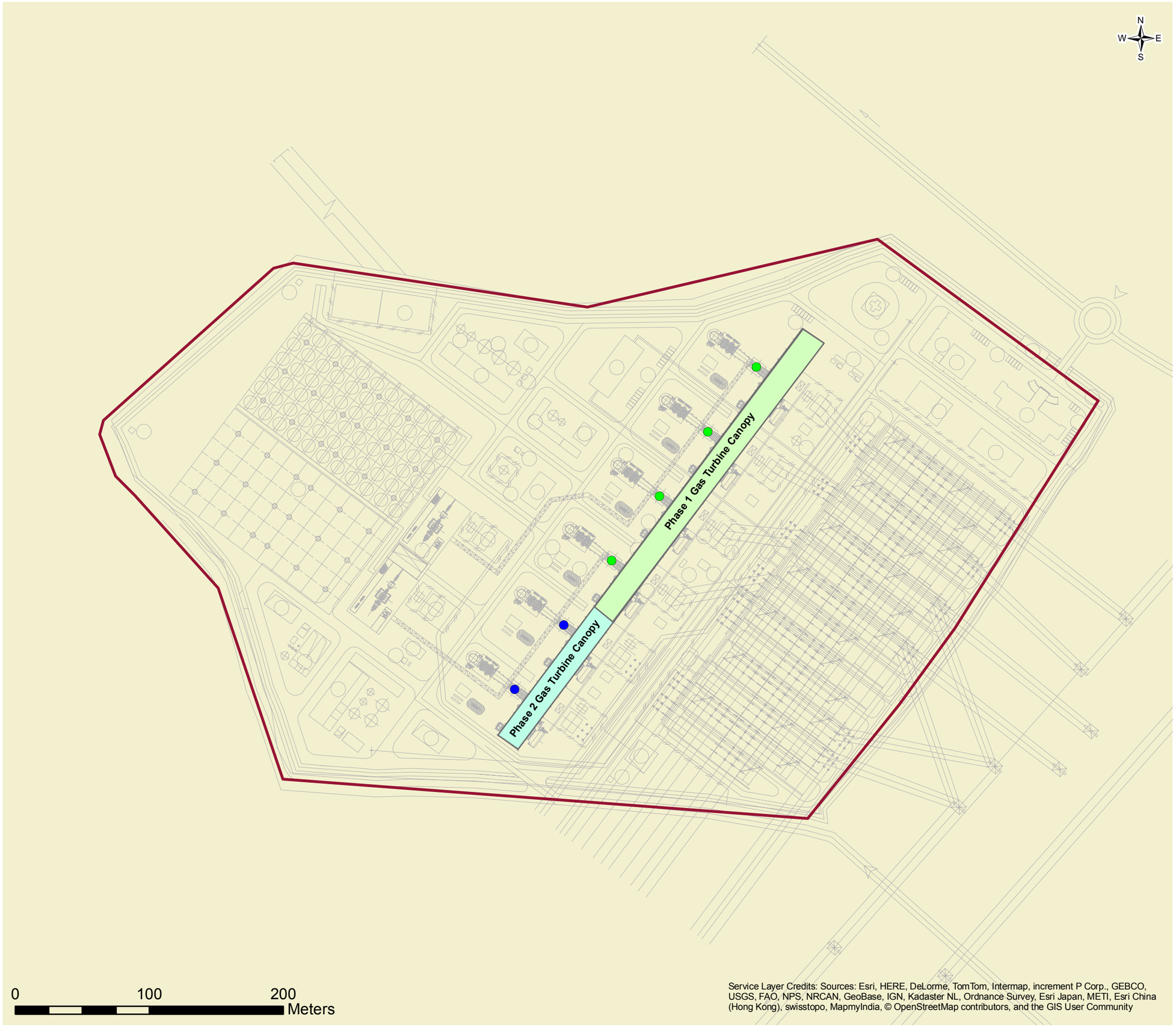
**Figure 9:** Annual mean nitrogen dioxide process contributions, Phase 3a, 2012 meteorological data

**Figure 10:** Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 3a, 2011 meteorological data

**Figure 11:** Annual mean nitrogen dioxide process contributions, Phase 3b, 2012 meteorological data

**Figure 12:** Hourly mean nitrogen dioxide process contributions (100$^{th}$ percentile), Phase 3b, 2011 meteorological data

# FIGURE 1




## Legend

- Site Boundary
- Proposed Site Layout (based on phase 3a)
- Phase 1 gas turbine emission point
- Phase 2 gas turbine emission point

| Rev. | Date | Purpose of revision | Drawn | Check'd | Rev'd | Appr'd |
|---|---|---|---|---|---|---|
| 0 | 02/03/2015 | Initial Issue | TA | OR | SBY | SBY |

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Project

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Drawing Title

Phase 1 + 2 site layout plan showing modelled emission points and buildings

Drawing Status

| | | |
|---|---|---|
| Scale @ A3 | 1:2,750 | DO NOT SCALE |
| Jacobs No. | KU090500 | |
| Client No. | | |

Drawing No.

Figure 1

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# FIGURE 2

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## Legend

- **Site Boundary**
- **Proposed Site Layout (based on phase 3a)**
- Phase 3 Gas Turbine Emission Point
- HRSG - Horizontal Alignment

| Rev. | Date | Purpose of revision | Drawn | Check'd | Rev'd | Appr'd |
|---|---|---|---|---|---|---|
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Project

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Drawing Title

Phase 3 site layout plan showing modelled emission points and buildings (horizontally aligned HRSG)

Drawing Status

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| Drawing No. | Figure 2 | |


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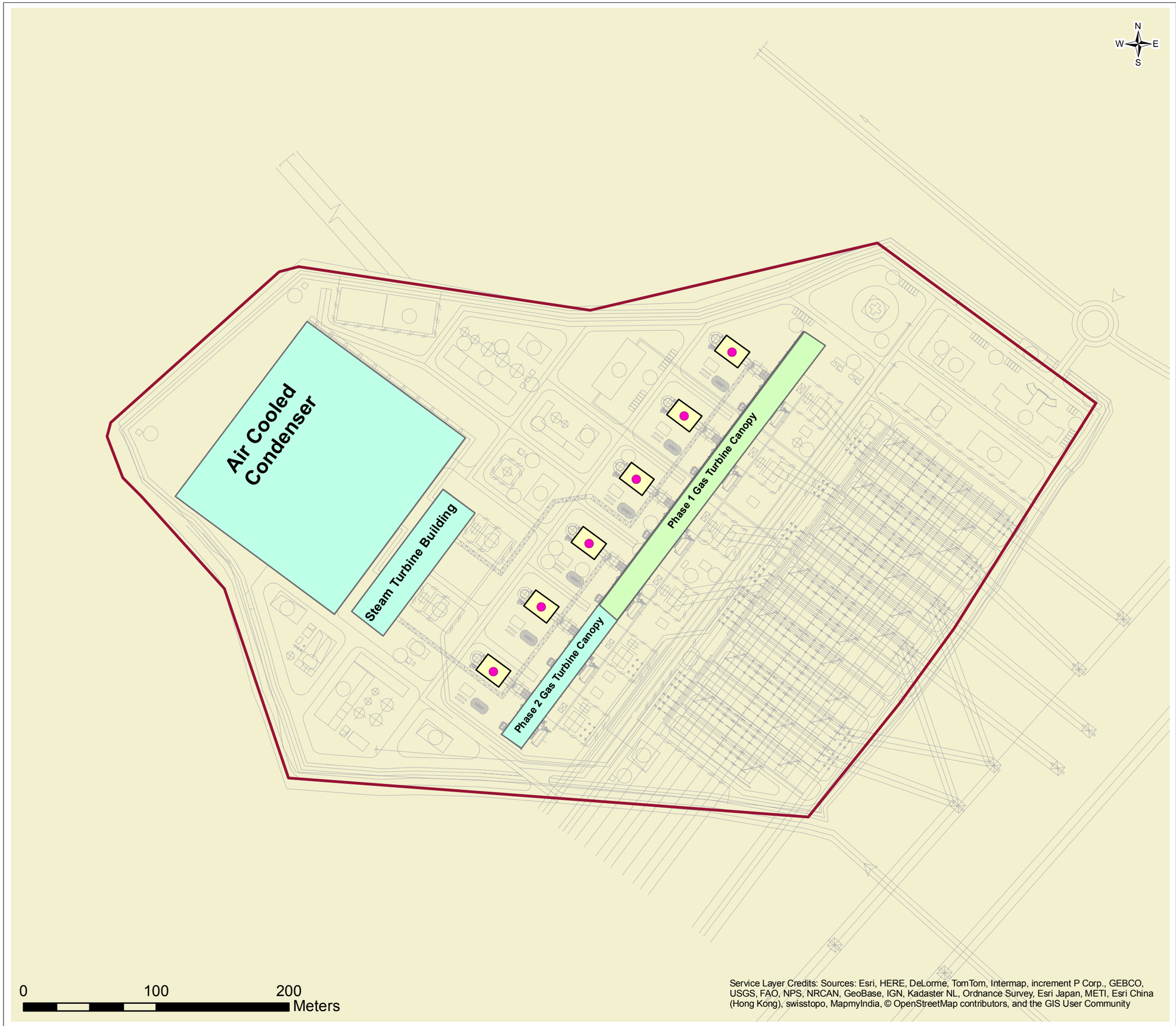
# FIGURE 3

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## Legend

- Site Boundary
- Proposed Site Layout (based on phase 3a)
- Phase 3 Gas Turbine Emission Point
- HRSG - Vertical Alignment

| Rev. | Date | Purpose of revision | Drawn | Check'd | Rev'd | Appr'd |
|---|---|---|---|---|---|---|
| 0 | 02/03/2015 | Initial Issue | TA | OR | SBY | SBY |


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Drawing Title

Phase 3 site layout plan showing modelled emission points and buildings (vertically aligned HRSG)

Drawing Status

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|---|---|---|
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| Jacobs No. | KU090500 | |
| Client No. | | |

Drawing No.

Figure 3


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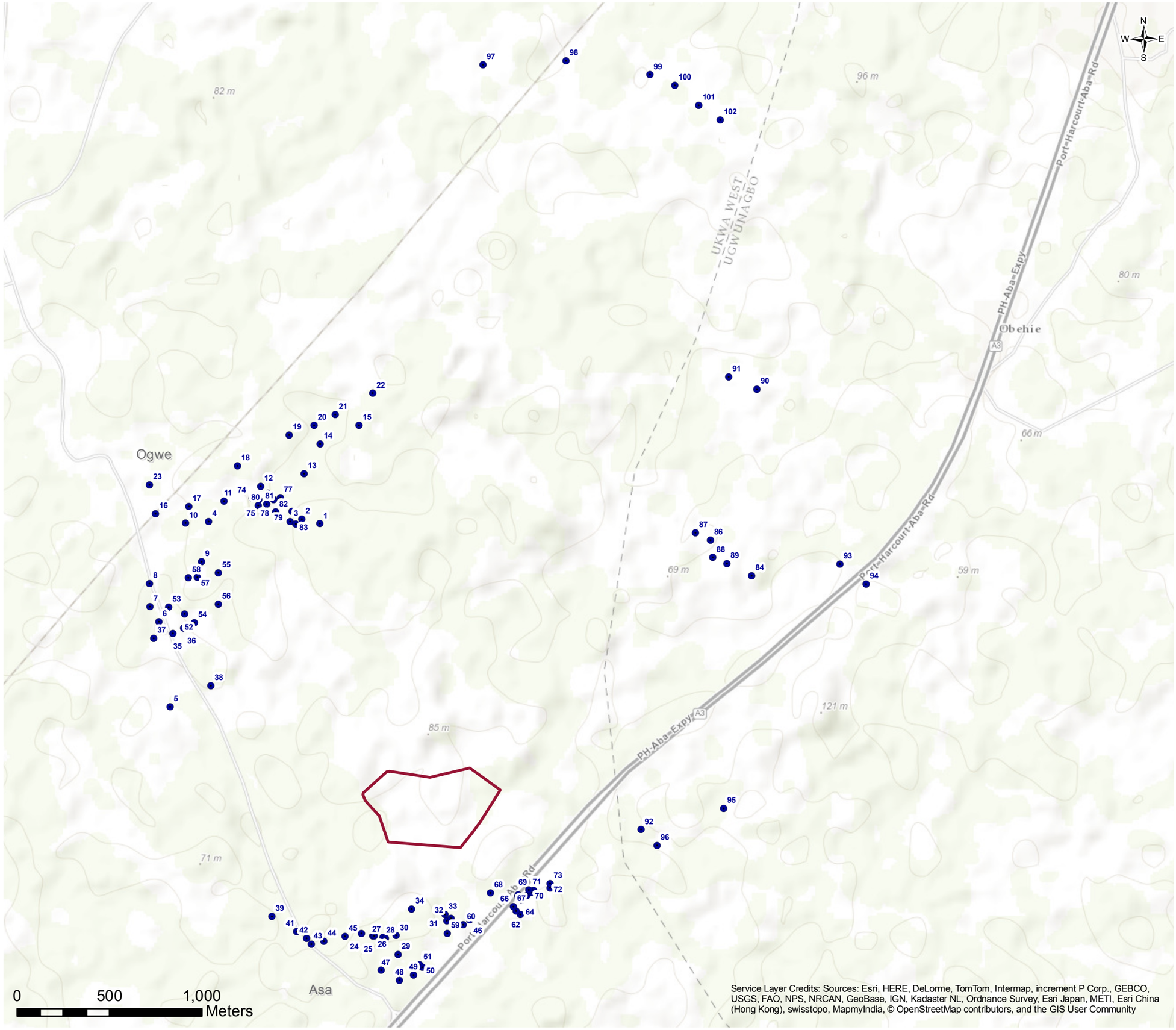
# FIGURE 4

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## Legend

- Modelled sensitive receptor locations
- Site Boundary

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Project

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Drawing Title

Site location plan showing modelled receptor locations

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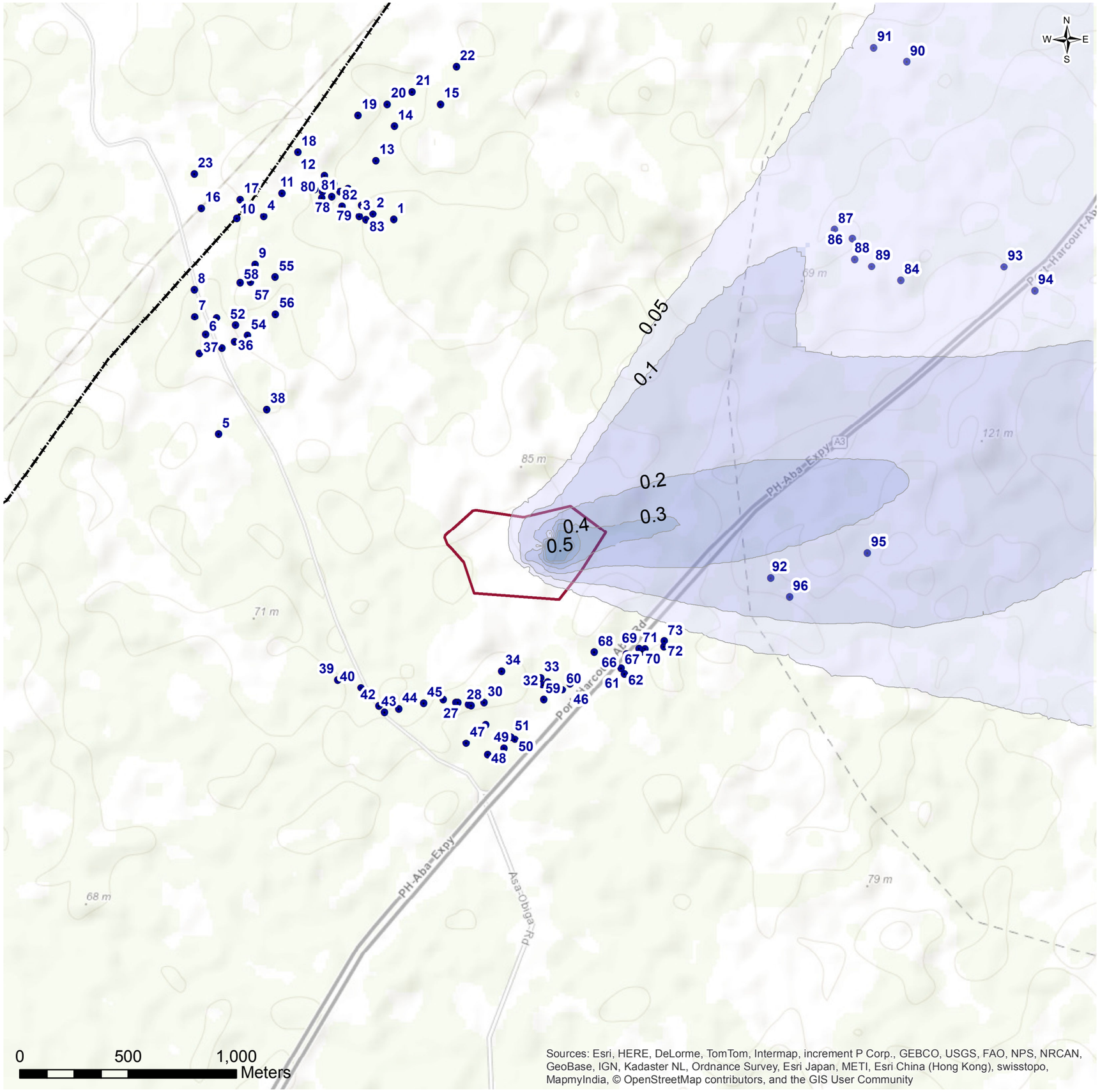


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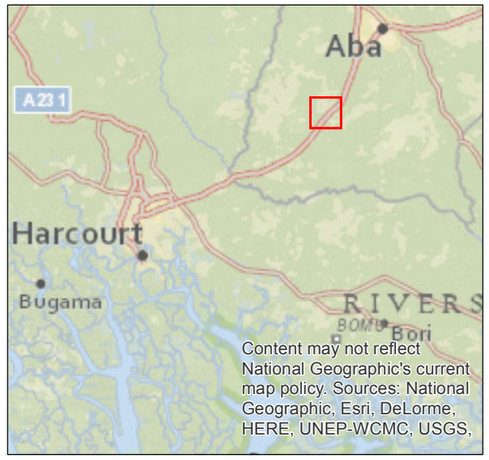
# FIGURE 5

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Annual mean nitrogen dioxide process contributions**

- 0.05 - 0.1 µg/m³
- 0.1 - 0.2 µg/m³
- 0.2 - 0.3 µg/m³
- 0.3 - 0.4 µg/m³
- 0.4 - 0.5 µg/m³
- >0.5 µg/m³

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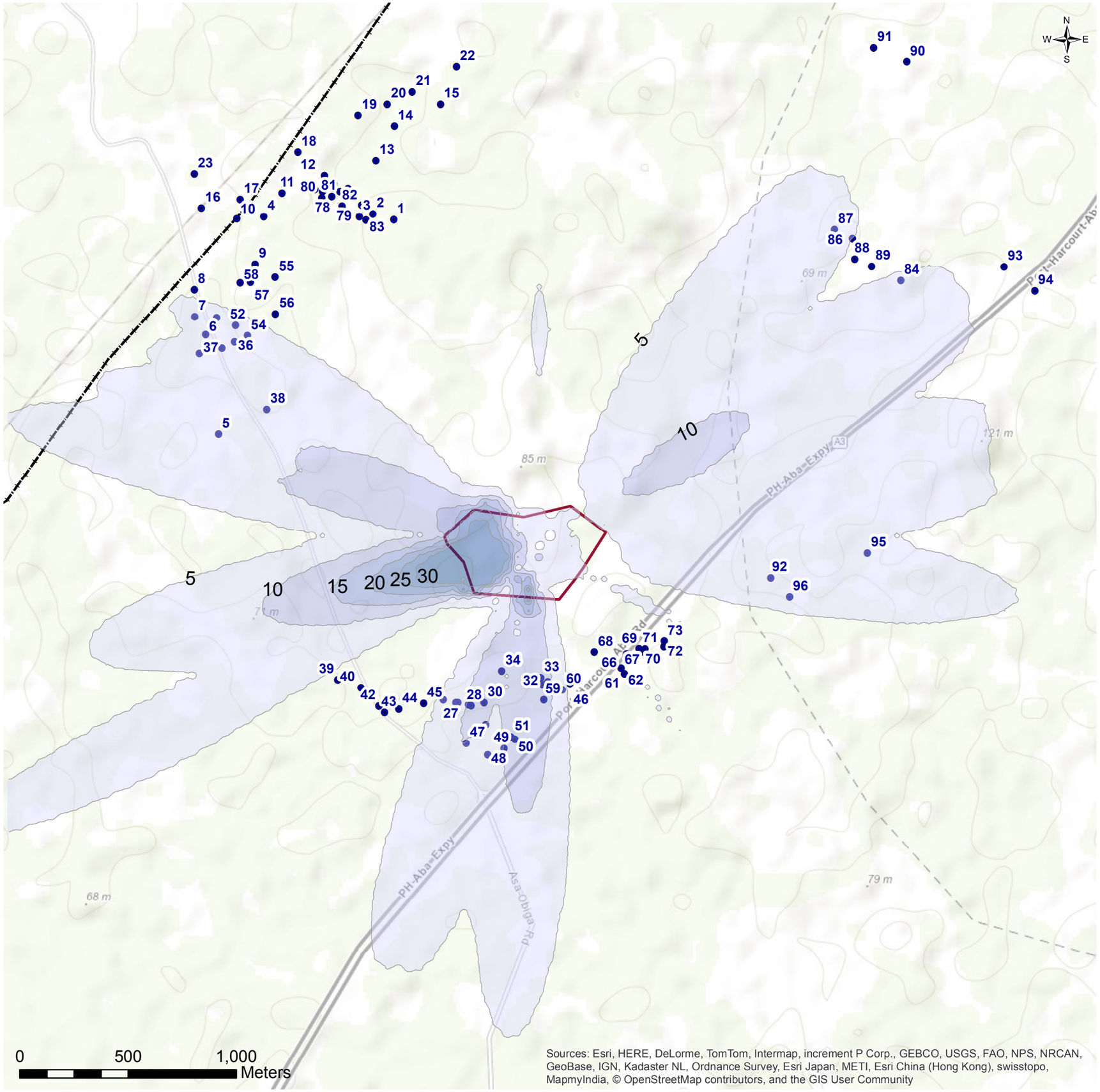


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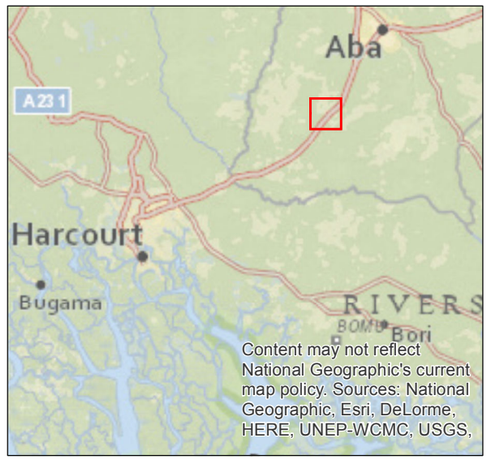
# FIGURE 6

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Hourly mean nitrogen dioxide process contributions**

- 5 - 10 µg/m³
- 10 - 15 µg/m³
- 15 - 20 µg/m³
- 20 - 25 µg/m³
- 25 - 30 µg/m³
- >30 µg/m³

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Hourly mean nitrogen dioxide process contributions (100th percentile), Phase 1, 2012 meteorological data

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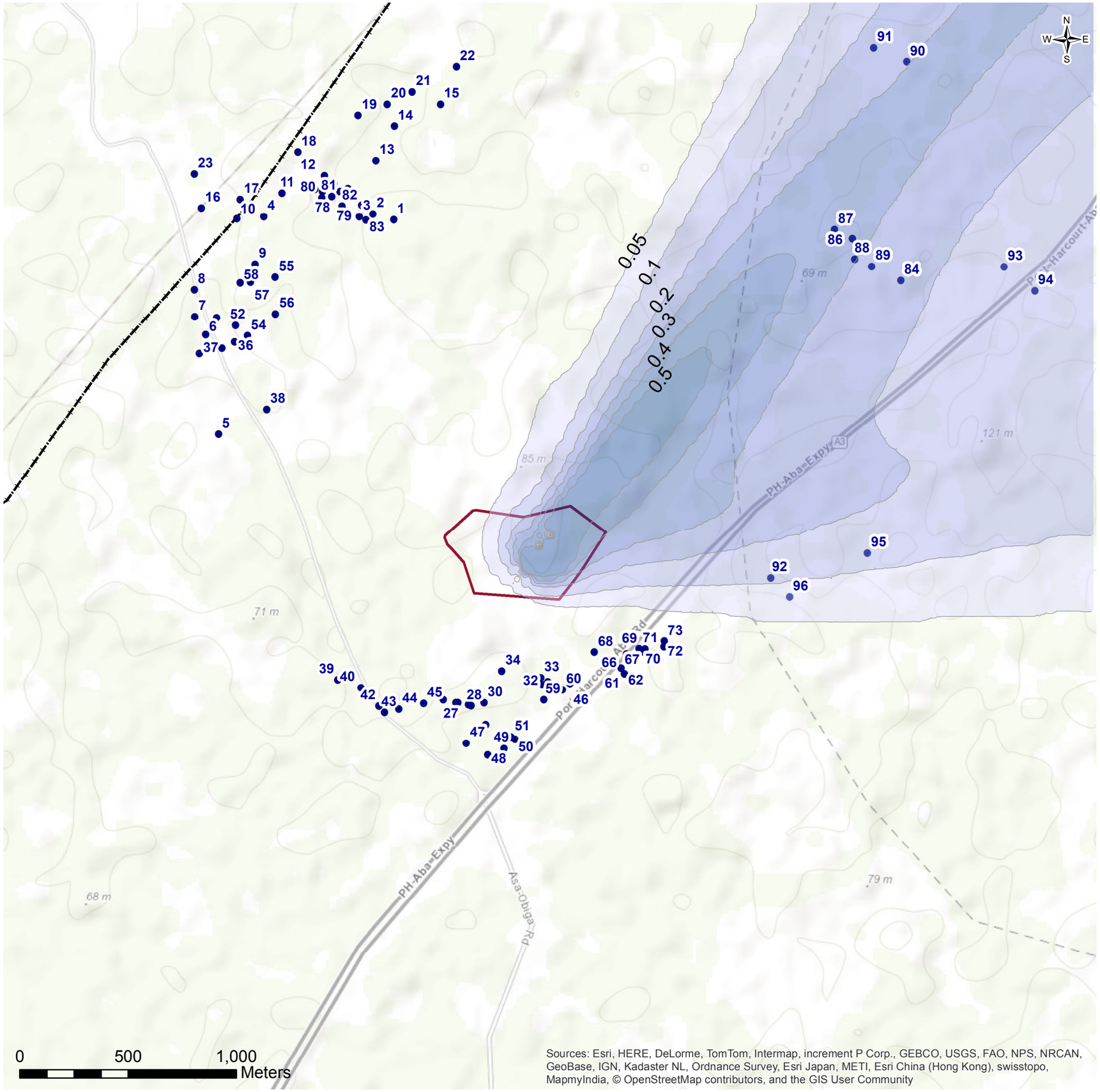


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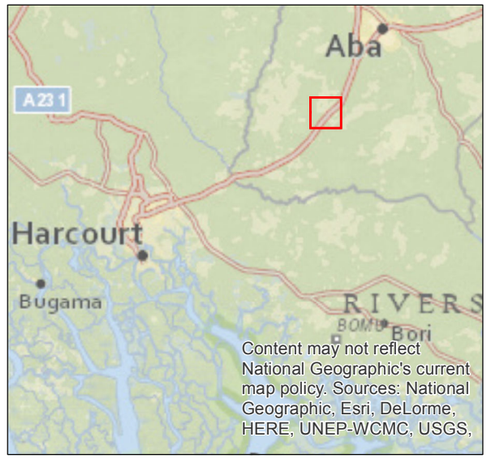
# FIGURE 7

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Annual mean nitrogen dioxide process contributions**

- 0.05 - 0.1 µg/m³
- 0.1 - 0.2 µg/m³
- 0.2 - 0.3 µg/m³
- 0.3 - 0.4 µg/m³
- 0.4 - 0.5 µg/m³
- >0.5 µg/m³

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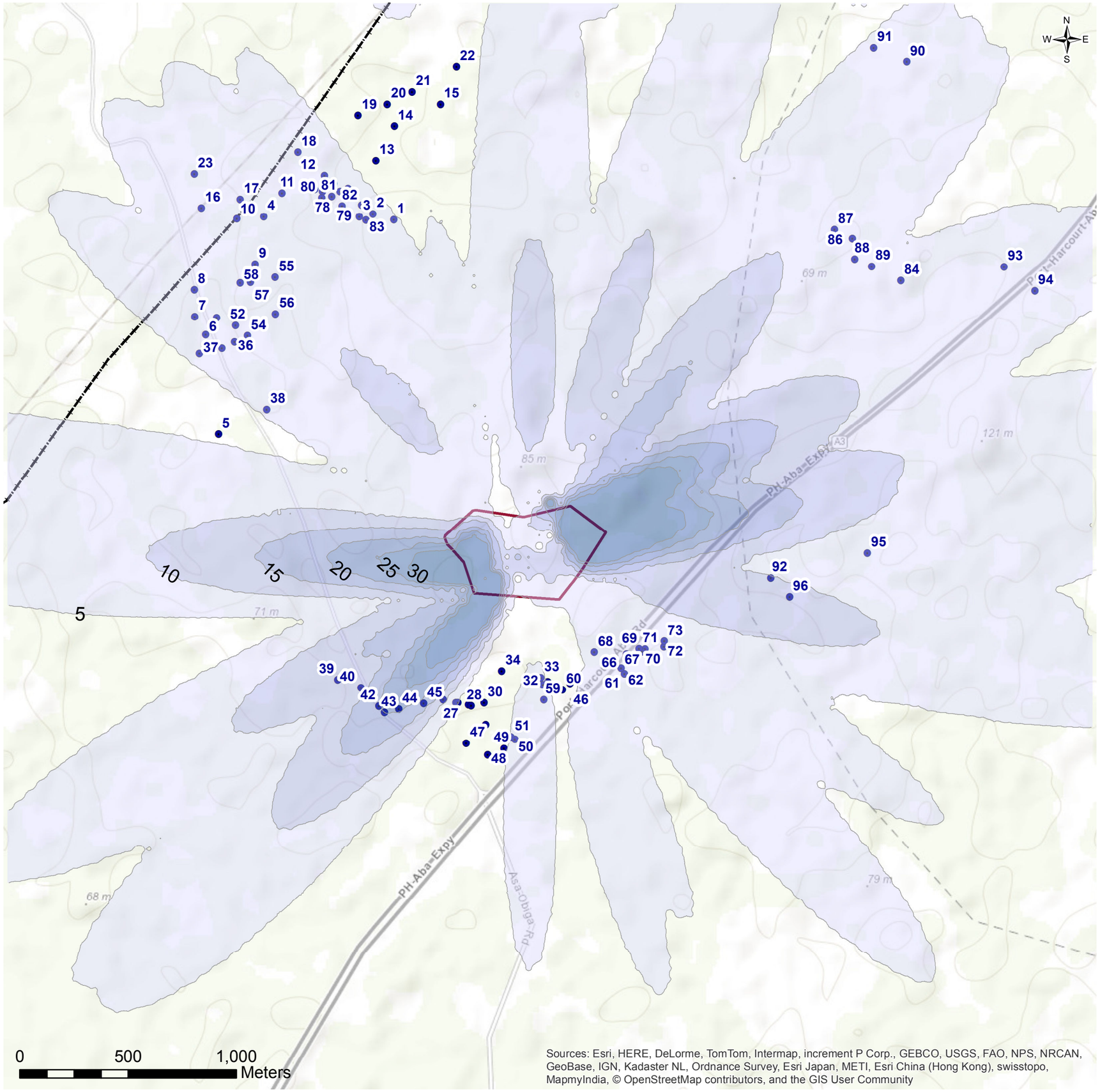


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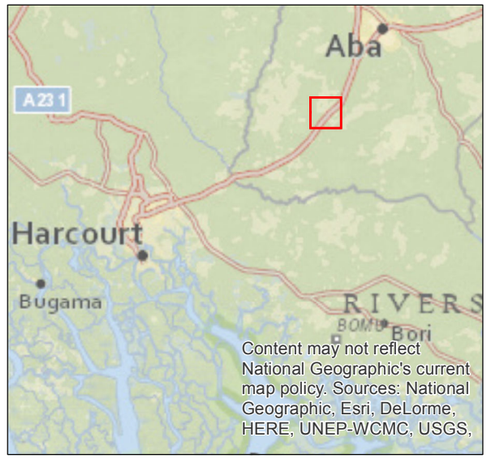
# FIGURE 8

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Hourly mean nitrogen dioxide process contribution**

- 5 - 10 µg/m³
- 10 - 15 µg/m³
- 15 - 20 µg/m³
- 20 - 25 µg/m³
- 25 - 30 µg/m³
- >30 µg/m³

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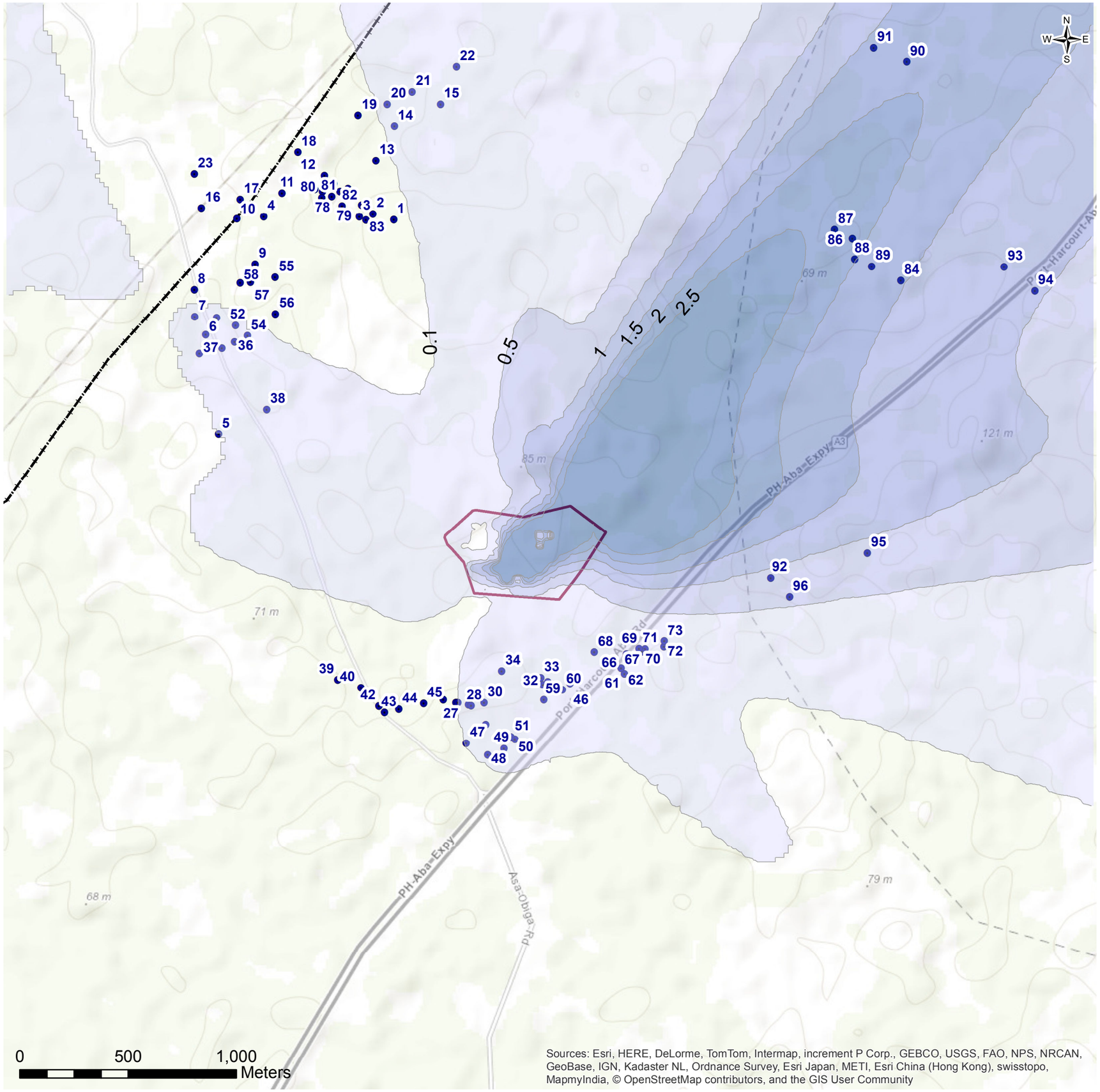


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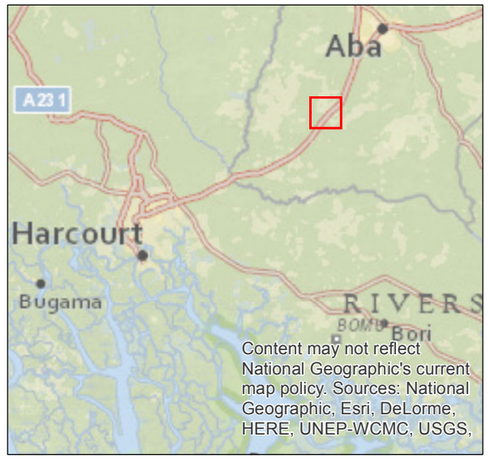
# FIGURE 9

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Annual mean nitrogen dioxide process contributions**

- 0.1 - 0.5 µg/m³
- 0.5 - 1 µg/m³
- 1 - 1.5 µg/m³
- 1.5 - 2 µg/m³
- 2 - 2.5 µg/m³
- >2.5 µg/m³

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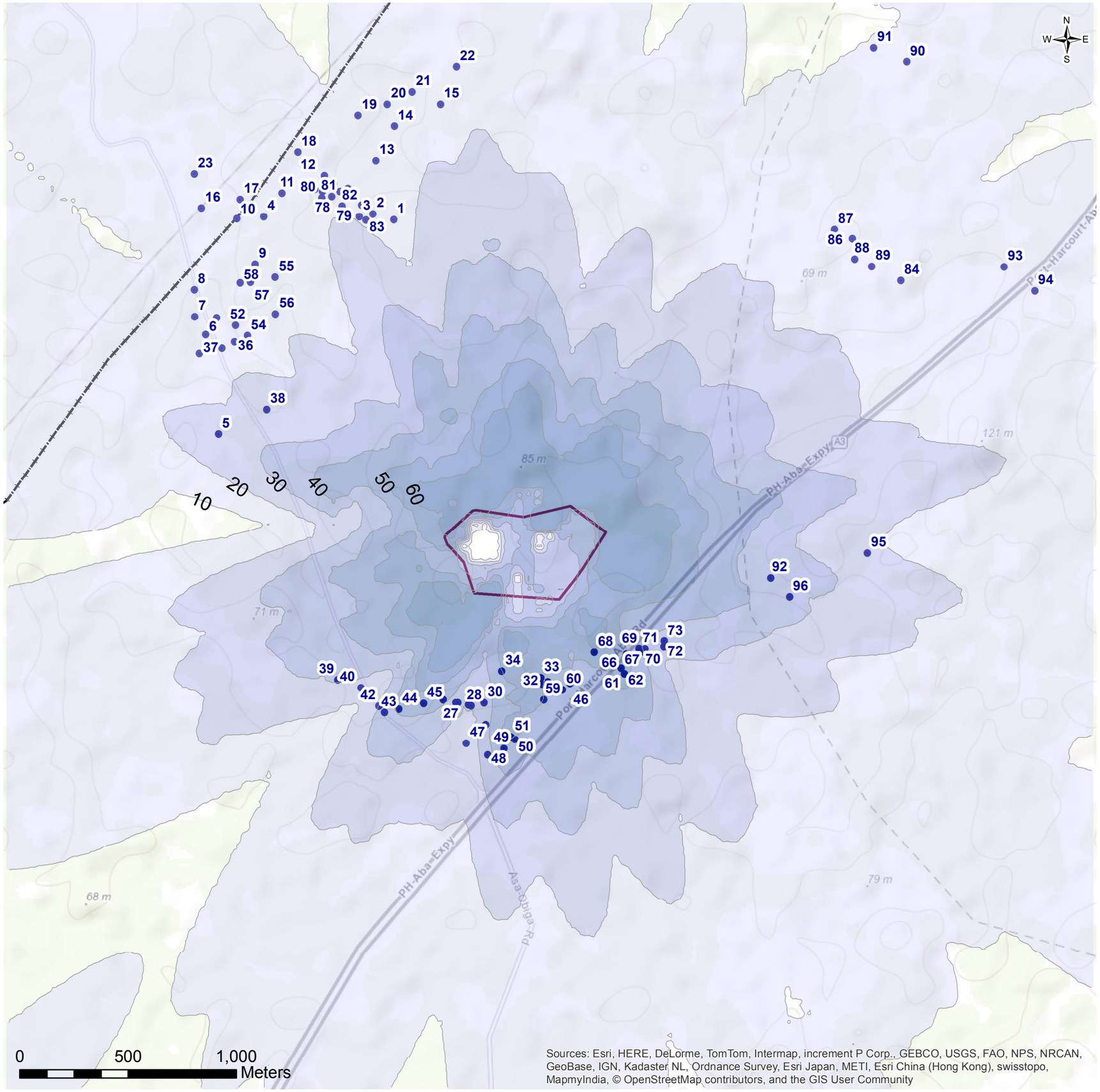


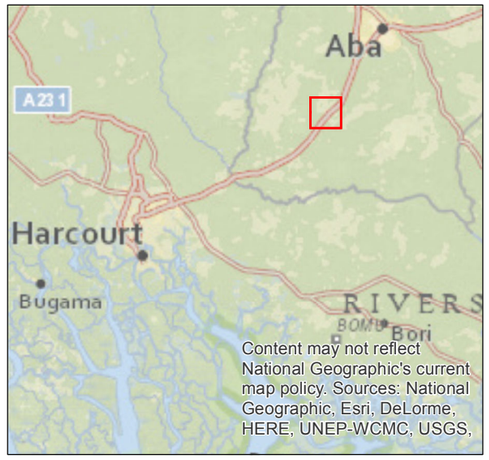

## FIGURE 10

### Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Hourly mean nitrogen dioxide process contributions**

- 10 - 20 µg/m³
- 20 - 30 µg/m³
- 30 - 40 µg/m³
- 40 - 50 µg/m³
- 50 - 60 µg/m³
- >60 µg/m³

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Hourly mean nitrogen dioxide process contributions (100th percentile), Phase 3a, 2011 meteorological data

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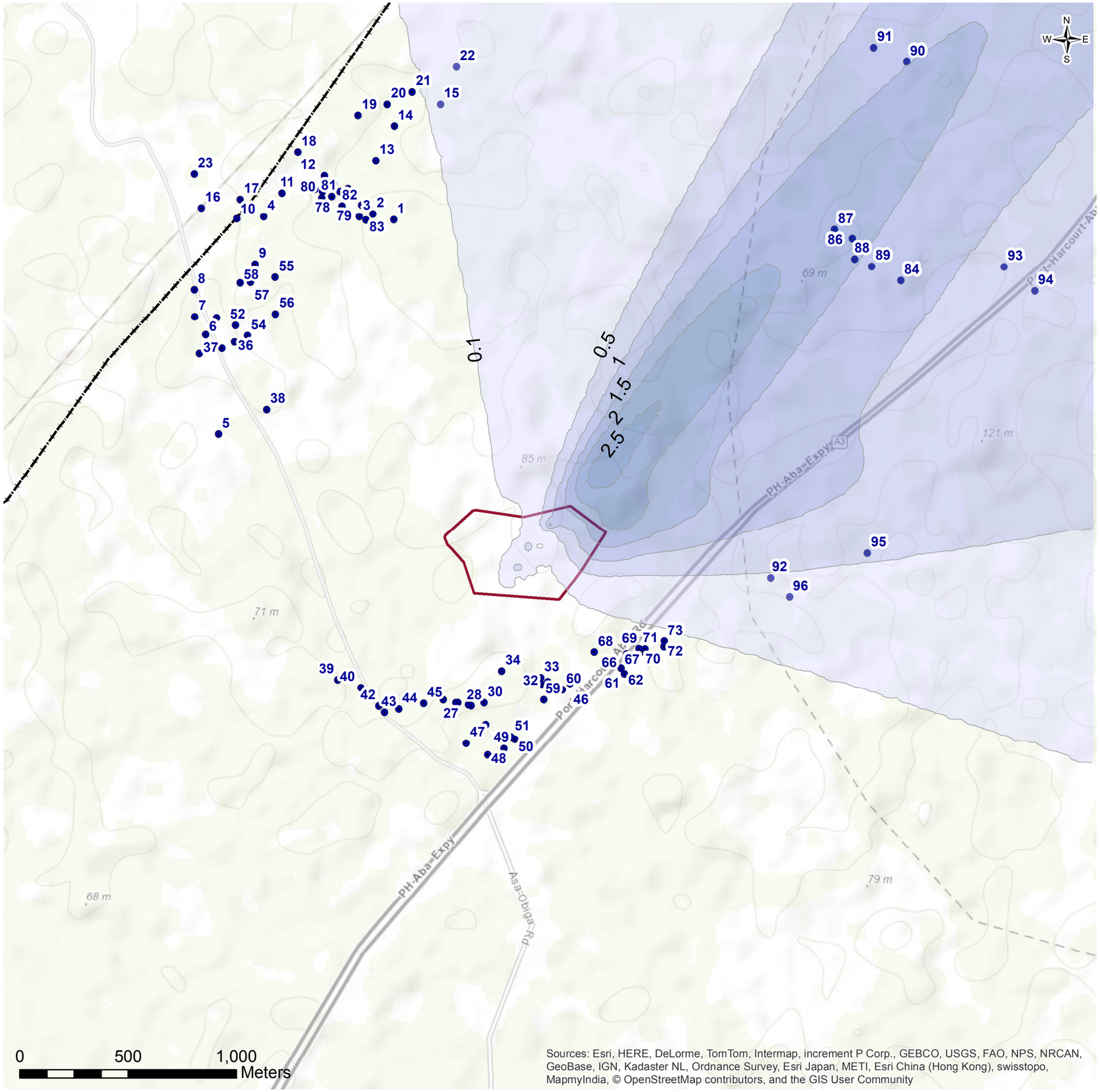


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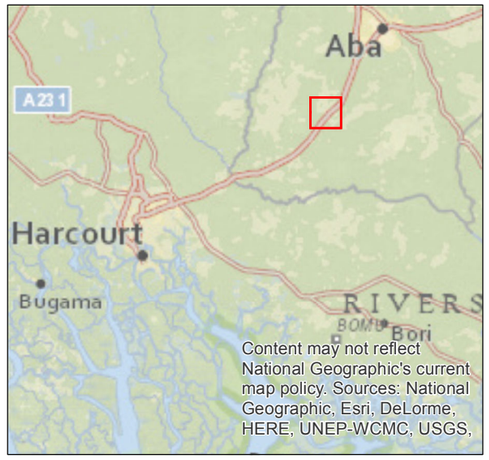
# FIGURE 11

## Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Annual mean nitrogen dioxide process contributions**

- 0.1 - 0.5 µg/m³
- 0.5 - 1 µg/m³
- 1 - 1.5 µg/m³
- 1.5 - 2 µg/m³
- 2 - 2.5 µg/m³
- >2.5 µg/m³

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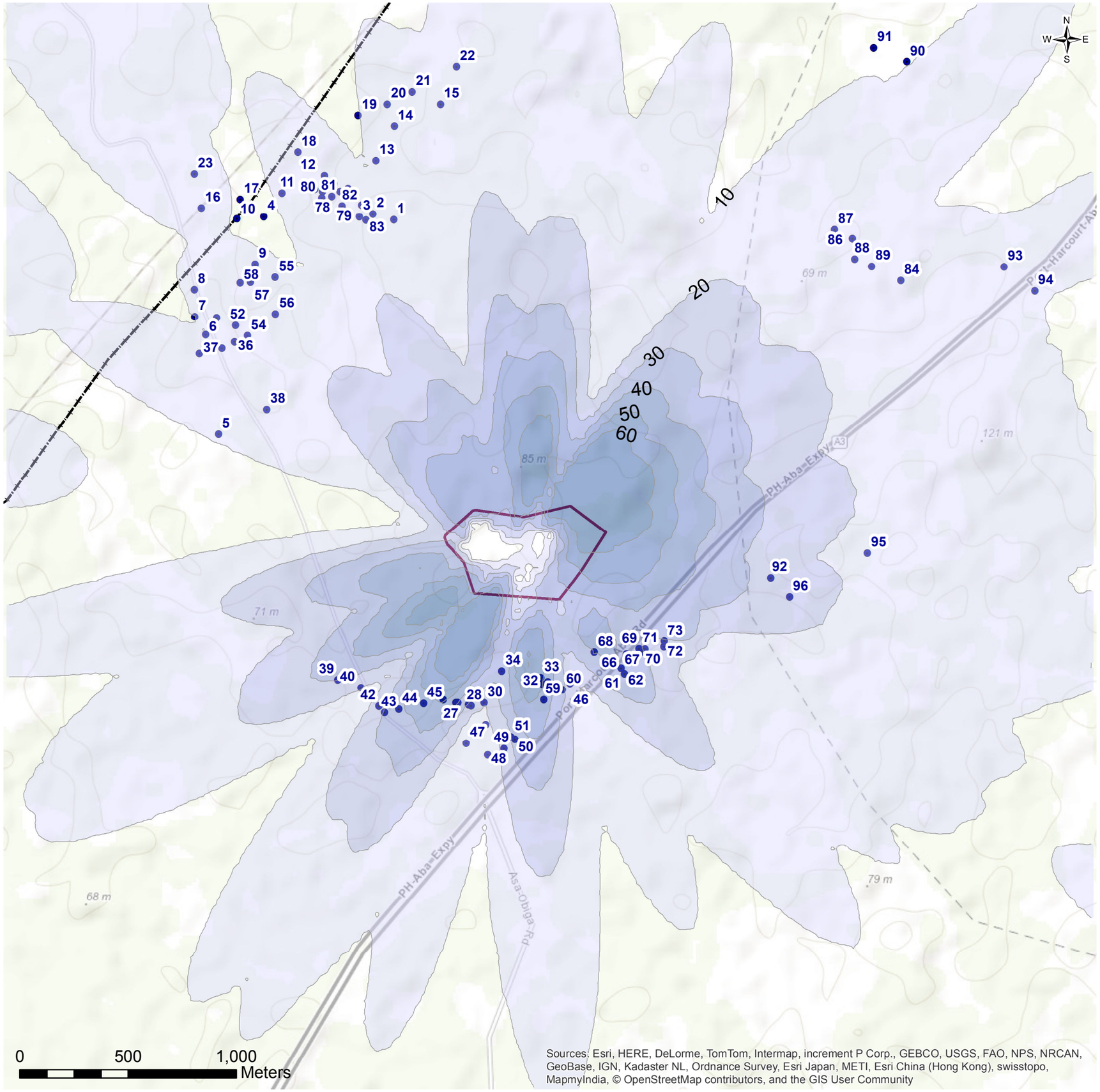


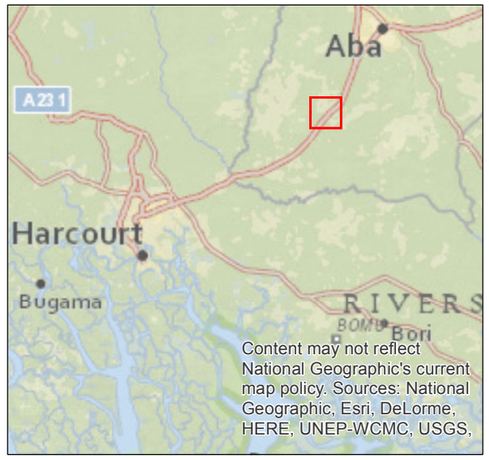

## FIGURE 12

### Legend

- Modelled sensitive receptor locations
- Site Boundary
- Rail Line

**Hourly mean nitrogen dioxide process contributions**

- 10 - 20 µg/m³
- 20 - 30 µg/m³
- 30 - 40 µg/m³
- 40 - 50 µg/m³
- 50 - 60 µg/m³
- >60 µg/m³

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Hourly mean nitrogen dioxide process contributions (100th percentile), Phase 3b, 2011 meteorological data

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## Appendix VIII – Noise Technical Appendix

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# Oma Independent Power Project

# Noise Technical Report

**March 2015**

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Version 16; October 2013

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**Client:** Geometric Power Limited
Document title: Noise Technical Report
Project No: KU090500

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# Contents


| | | |
|---|---|---|
| **1** | **Introduction** | **1** |
| 1.1 | Noise | 1 |
| 1.2 | Noise Descriptors | 1 |
| 1.3 | Nomenclature | 2 |
| 1.4 | Decibel Addition | 3 |
| 1.5 | Human Sensitivity to Change | 4 |
| 1.6 | Free-field and Façade Incident Noise Levels | 4 |
| **2** | **Potential Noise Impacts** | **5** |
| **3** | **Noise Criteria** | **6** |
| **4** | **Noise Predictions** | **7** |
| 4.1 | Methodology | 7 |
| 4.1.1 | Noise Modelling | 7 |
| 4.1.2 | Noise Sources | 8 |
| 4.2 | Input Data | 8 |
| 4.2.1 | Site Layout | 8 |
| 4.2.2 | Sound Power Levels | 9 |
| 4.3 | Noise sensitive receptors | 10 |
| **5** | **Assessment** | **13** |
| **6** | **Mitigation** | **17** |
| **7** | **Conclusions** | **20** |
| **Appendix A** | **Figures** | **7-1** |
| **Appendix B** | **Octave Band Sound Power Levels** | **7-2** |

# 1 Introduction

This report assesses the likely significant operational impacts of the Oma Project with respect to noise.

Noise disturbance is frequently raised as a significant issue by local communities concerned about development, and is often the focus of complaints relating to operations. In some situations, it can lead to adverse health impacts. It is therefore appropriate to consider, and if necessary mitigate, the potential noise impacts that the Project may have.

## 1.1 Noise

Noise is defined as unwanted sound, and the normal unit of measurement is the decibel (dB(A)). Sound pressure levels range from the threshold of hearing at 0 dB(A) to levels of over 130 dB(A) at which point noise becomes painful.

Sound consists of vibrations transmitted to the ear as rapid variations in air pressure. The more rapid the fluctuation, the higher the frequency of the sound. Frequency is the number of pressure fluctuations per second and is expressed in Hertz (Hz).

The sensitivity of the human ear varies with frequency. To allow for this phenomenon, sound level meters are often equipped with a set of filters that modify the response of the sound level meter in a similar way to the human ear; these filters are referred to as the 'A-weighting network'. The 'dB(A)' notation is used to indicate when noise levels have been filtered using the A-weighting network. It has been found that changes in noise level when measured in dB(A) correlate better with changes in subjective reaction than to changes in noise measured without using the A-weighting network.

Some common levels of noise on the A-weighted scale are given in Table 1.1 below.

***Table 1.1 Common Levels of Noise***

| Sound Pressure Level (dBA) | Typical Environment | Average subjective description |
|---|---|---|
| 140 | 30m from military aircraft takeoff | Intolerable |
| 100 | Underground station platform | Very noisy |
| 90 | Heavy lorries at 6m | Very noisy |
| 60 | Restaurant | Noisy |
| 50 | General office | Quiet |
| 20 | Background in TV studios | Very quiet |

*After Sharland,(1972)*

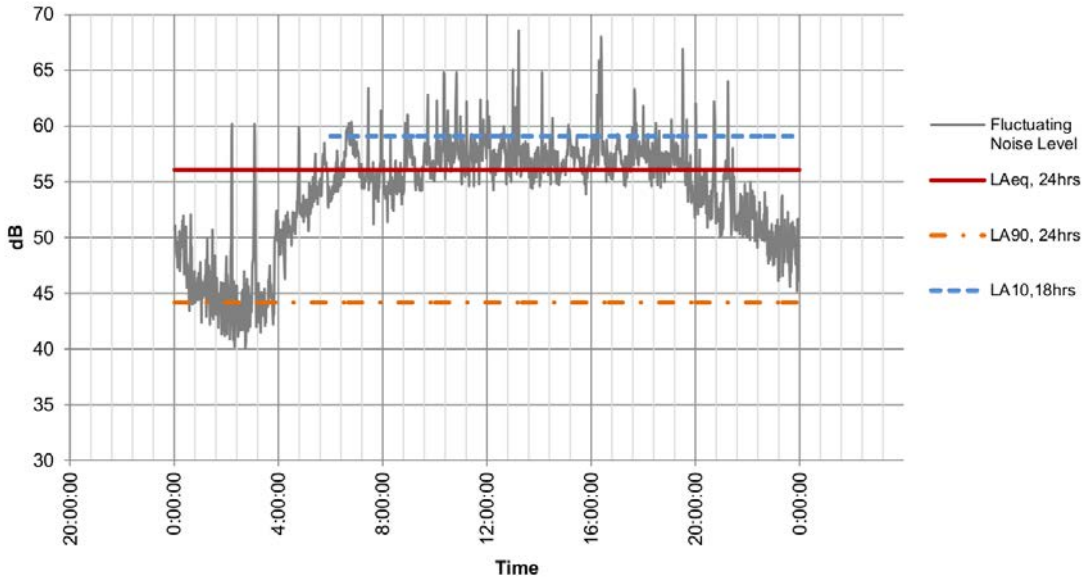
## 1.2 Noise Descriptors

The subjective response to noise is dependent not only upon the sound pressure level and its frequency but also on its duration and the time of day it occurs. Noise levels fluctuate in response to events, for instance with aircraft passing overhead or changes in the quantity and speed of road traffic on nearby roads. For this reason environmental noise is often described in terms of an equivalent continuous sound pressure level, which can be thought of as a constant noise level over a time period (T) that contains the same sound energy as the fluctuating noise level. The notation

for this noise descriptor is $L_{Aeq,T}$ and this concept is shown graphically in Plate 1 below.

The $L_{A90,T}$ statistical noise parameter, which is defined as the level exceeded for 90% of the measurement period (T), is often used to describe background noise levels. This can be thought of as representing the underlying level of noise present during the quieter parts of the measurement.

***Plate 1 Illustration of Statistical Noise Descriptors***




## 1.3 Nomenclature

The nomenclature used to represent statistical acoustic quantities can appear complicated, however once understood it is logical and efficient. Take for instance the upper noise level recommended by the World Health Organisation[1] for balconies and outdoor living areas of 55 dB $L_{Aeq,16hrs}$:

The above descriptor is comprised as follows:

1) The first part of the statistical descriptor identifies its numeric value. This value is usually given as a whole number or to one decimal place. Where values are given to one decimal place, this is normally required for compliance with a particular standard or convention, but it does not necessarily imply that the values are accurate to one decimal place.

2) The second group of characters indicate that the units of the noise descriptor are decibels.

[1] Guidelines for Community Noise. Editors B Berglund, T Lindvall, D H Schwela. World Health Organization, Geneva :1999

3) The third grouping ('L') indicates that the quantity is a sound pressure level. Other less common quantities are sound intensity level ($L_I$) and sound power level ($L_W$).

4) The fourth grouping ('A') denotes that the sound pressure level is evaluated using the A-weighted filter network. There are two competing conventions regarding the position of this identifier, either immediately after the 'L' as shown in the example above, or alternatively in brackets following the units. Therefore whilst appearing different, 55 dB $L_{Aeq,16hrs}$ and 55 dB(A) $L_{eq,16hrs}$ are equivalent and may be used interchangeably. Which convention is used is a matter of preference; however it is considered good practice to remain consistent within a document for the convenience of the reader.

5) The fifth grouping of characters identify the statistical index. In this example, the letters indicate that the quantity is in terms of the **eq**uivalent continuous noise level (eq), which has some similarities with the concept of an average noise level over a time period. Other common quantities include:

   - *$L_{DEN}$ which is the A-weighted equivalent continuous noise level, measured over the 24 hour period, with a 10 dB penalty added to the levels at night and a 5 dB penalty added to the levels in the evening to reflect people's extra sensitivity to noise during these periods.*
   - *$L_{day}$ which is the A-weighted equivalent continuous noise level, assessed over an annual average daytime period (07.00-19.00).*
   - *$L_{evening}$ which is the A-weighted equivalent continuous noise level, assessed over an annual average evening period (19.00-23.00).*
   - *$L_{night}$ which is the A-weighted equivalent continuous noise level, assessed over an annual average night-time period (23.00-07.00).*

6) The sixth and final quantity shown after the statistical index is the duration over which the quantity is evaluated. This is typically represented in minutes or hours, e.g. 15min, 16hrs.

## 1.4 Decibel Addition

If the sound levels from two or more sources have been measured or predicted separately, and the combined sound level is required, the sound levels must be added together. However, due to the fact the decibel is a logarithmic value they cannot be added together using normal arithmetic.

Table 1.2 below provides a quick guide to adding two sound levels together. First the difference between the higher and lower noise level must be calculated, and then the corresponding amount in the right hand side of the table must be added to the higher of the two noise levels.

***Table 1.2 Guide to decibel addition***

| Difference between noise levels, dB | Amount to be added to higher level, dB |
|---|---|
| 0 | 3 |
| 1 | 2.5 |
| 2 | 2.1 |
| 3 | 1.8 |
| 4 | 1.5 |
| 5 | 1.2 |
| 10 | 0.4 |
| 15 | 0.1 |

For example, when adding the values of 50.0 dB(A) and 55.0 dB(A) together, the difference between them is 5.0 dB(A) and therefore 1.2 dB(A) should be added to the higher value. The resulting sound level would be 56.2 dB(A).

## 1.5 Human Sensitivity to Change

Generally, a change of 3 dB(A) in fluctuating environmental noise is the minimum change perceptible to a human. However, there is research that suggests with respect to road traffic noise, immediately following a sudden change in traffic flow or road alignment people may find benefits or disbenefits when noise changes are as small as 1 dB(A). A change of 1 dB(A) is equivalent to an increase in traffic flow of 25 per cent or a decrease in traffic flow of 20 per cent. These impacts last for a number of years, however, in the longer term, perceived noise nuisance may tend towards the steady state level associated with the new source, which is generally lower.

## 1.6 Free-field and Façade Incident Noise Levels

Due to the effects of reflection, sound pressure levels measured close to large reflecting surfaces orientated near perpendicular to the direction the sound waves are traveling are higher than those that are measured away from reflective surfaces.

For sound propagation largely in the vertical direction (e.g. from an airborne aircraft towards the ground), the ground itself causes reflection. Unless stated otherwise, the airborne aircraft noise levels presented in this chapter include the effects of ground reflection, at a height of 1.5m above ground level.

For sound propagation largely in the horizontal direction (e.g. from ground operations), sound pressure levels measured 1m from a large solid, reflecting surface are termed ‘façade incident’ levels, whilst those measured at least 3m away from any reflective surfaces (other than the ground) are termed ‘free-field’. Façade incident levels are typically up to 3 dB higher than free-field levels and therefore it is important to know the conditions under which a noise measurement or prediction has been undertaken. Unless stated otherwise, the noise levels presented in this chapter are free-field levels which do not account for the effects of reflection from building facades or other large vertical surfaces.

# 2 Potential Noise Impacts

The operation of the equipment associated with the Project has the potential to lead to noise impacts at residences, schools, healthcare facilities and other nearby sensitive receptors.

Depending on the magnitude of the impact, and the activities being conducted at the receptor, the following effects may result:

- *Small changes in behaviour such as turning the volume up, speaking more loudly, occasionally closing windows and a perceived reduction in quality of life.*
- *Material changes in behaviour such as avoiding certain activities during noisy periods, keeping windows closed most of the time, difficulty concentrating on tasks, reduced speech intelligibility and diminished quality of life.*
- *Health impacts such as annoyance, reduced cognitive performance, sleep disturbance (arousal, motility, sleep quality and reported awakening), the autonomous release of stress hormones, increased risk of hypertension (high blood pressure) and ischaemic heart diseases (including myocardial infarction).*

# 3 Noise Criteria

The financial lenders for the Project include organisations applying International Finance Corporation (IFC) Performance Standards.

The IFC has published Environmental, Health, and Safety (EHS) Guidelines for Thermal Power Plants which set out industry-specific examples of good international industry practice. In respect of noise, these guidelines note that amongst the principal sources of noise in thermal power plants are turbine generators and auxiliaries, boilers and auxiliaries, fans and ductwork, pumps, compressors, piping, valves and cooling towers.

Noise impacts, control measures, and recommended ambient noise levels for thermal power plants are presented in Section 1.7 of the General EHS Guidelines. These Noise Level Guidelines are presented in Table 3.1 below. It is desirable that noise levels should not exceed these values, or result in a maximum increase in 'background' levels of 3dB at the nearest receptor location.

***Table 3.1 IFC Noise Level Guidelines (dB)***

| Receptor | Daytime 07:00-22:00 hrs ($L_{Aeq\ 1hr}$) | Night-time 22:00-07:00 hrs ($L_{Aeq\ 1hr}$) |
|---|---|---|
| Residential; institutional; educational. | 55 | 45 |
| Industrial; commercial | 70 | 70 |

The terminology used in the IFC document can lead to confusion. Whilst not explicit, the guidelines are commonly applied to the noise from the development only and not to the cumulative level of baseline plus development related noise. The guidelines are also interpreted as being relevant to the long-term operational noise emissions from the Project, rather than the short term construction noise levels.

The IFC EHS guidelines also present examples of noise reduction options that should be considered where noise levels exceed these guideline values, along with recommendations for noise monitoring to be carried out either to establish existing ambient noise levels or to verify operational noise levels.

The noise guidelines presented in Section 1.7 of the General EHS Guidelines are based on the 1999 World Health Organisation (WHO) Guidelines for Community Noise.

In terms of vibration the General IFC EHS guidelines do not stipulate any environmental vibration criteria.

# 4 Noise Predictions

This report considers noise emissions arising from the operation of the following plant associated with the three Phases of the Project which, briefly, comprise:

Phase 1:

- *Four General Electric (GE) 'Frame 9' 113MW gas turbines operating in simple cycle mode.*
- *Six electrical transformers.*
- *Associated infrastructure and buildings.*

Phase 2:

- *Six GE 'Frame 9' 113MW gas turbines operating in simple cycle mode.*
- *Nine electrical transformers.*
- *Associated infrastructure and buildings.*

Phase 3:

- *Six GE 'Frame 9' 113MW gas turbines operating simultaneously in combined cycle mode with the exhaust gases being directed through six waste heat boilers for energy recovery.*
- *Two steam turbines, situated in dedicated buildings.*
- *Two air cooled condenser arrays.*
- *11 electrical transformers.*
- *Associated infrastructure and buildings.*

All of the scenarios consider operation under steady-state conditions, rather than during start-up, maintenance or emergency conditions, In particular, pulsing cleaning to clear debris from the gas turbine air intakes has not been considered; this activity can lead to high noise levels, but is short in duration.

## 4.1 Methodology

### 4.1.1 Noise Modelling

Noise modelling software provides a way of constructing a three-dimensional computer model of terrain, ground characteristics and noise sources which enables the prediction of noise at any point within the modelled area.

In order to compute the environmental noise emission level from plant items and operations at the representative noise sensitive receptors, noise emission modelling was undertaken using the CadnaA noise prediction software. The software was configured to use the noise prediction methodology set out in ISO9613[2], which is suitable for the prediction of noise levels in the community from sources of known sound emission.

The noise prediction method described in part 2 of ISO9613 is general, and is suitable for a wide range of engineering applications where the noise level outdoors

[2] International Standard: ISO 9613-2: 1996(E): Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation.

is of interest. The noise source(s) may be moving or stationary and the method considers the following major mechanisms of noise attenuation:

- *Geometrical divergence (also known as distance loss or geometric damping);*
- *Atmospheric absorption;*
- *Ground effect;*
- *Reflection from surfaces; and*
- *Screening by obstacles.*

The method predicts noise levels under metrological conditions favourable to noise propagation from the sound source to the receiver, such as downwind propagation, or equivalently, propagation under a moderate ground based temperature inversion as commonly occurs at night.

### 4.1.2 Noise Sources

The key noise sources associated with the three Phases of the Project are:

- ***Gas Turbines****: The gas turbines generate noise as a result of the flow of air and combustion gas. Noise is emitted from the gas turbine casings, and from the associated air intakes and exhausts. In simple cycle (also known as 'open cycle') mode the exhaust gases are discharged via 40m tall vertical flues (fitted with attenuators) connected to the gas turbine exhausts. In combined cycle mode, a significant proportion of the exhaust gas is directed through Waste Heat Boilers (WHB) and then exits through additional 40m tall vertical flues. The WHBs generate steam to feed the Phase 3 steam turbines.*

- ***Air Inlet Filters****: Air to the gas turbines is filtered before entering the inlet plenum to minimise the potential for pollen, dust and sand to cause damage. The filters collect particulates in the air, and must be cleaned periodically by high-pressure air pulses, which blow the particles off the filter surface.*

- ***Electrical Transformers****: Noise from electrical transformers is caused by magnetostriction (where the metal sheets forming the core extend and contract in response to the alternating magnetic field), and from the cooling system.*

- ***Air Cooled Condensers*** *(ACC): ACCs are heat exchangers that use the ambient air to cool and condense steam which has been through the steam turbine, in order for it to be recirculated to the waste heat boilers. Each ACC comprises an array of large fans, which blow cool air over finned tubes containing the steam. Each fan and its associated finned tubes is referred to as a cell. Noise is generated by the fan gearbox, fan blades and the movement of air across the heat exchange surface.*

- ***Steam Turbines****: Steam turbines convert thermal energy in the form of pressurised steam to mechanical work and ultimately, electrical power through a generator. Noise is generated in the turbine by rotating parts and pressure changes in the steam.*

## 4.2 Input Data

### 4.2.1 Site Layout

The site layout, position and the height of buildings / plant in the noise model are derived from drawingF2013021T-Z04 Rev 09 by China power Construction

Engineering Consulting Central Sothern Co. Ltd., which is included in Appendix A of this document for convenience.

The ground level in and around the site is assumed to be generally flat, and therefore no topographic screening effects have been considered in the noise model. The intervening ground between the Project and the closest dwellings is generally natural scrub land, and therefore is considered to be acoustically porous.

### 4.2.2 Sound Power Levels

At this time, detailed noise emission data for the proposed equipment selections is not available. Therefore, the following A-weighted sound power levels have been used in the noise predictions, which are based upon empirical formulae in technical literature, noise measurements of similar equipment, or other manufacturer's data for similar equipment. These values were agreed with Geometric Power prior to commencement of this noise assessment. The detailed 1/1 octave band data which comprises each broadband value is provided in Appendix B.

***Table 4.1 A-weighted sound power levels for equipment***

| Equipment | Representation in Model | Sound Power Level, dB(A) | Source of Noise Data |
|---|---|---|---|
| Gas Turbine Casing | Omnidirectional Point Sources at 5m a.g.l. | 108.4 | Measured noise spectrum for GE LM6000 gas turbine scaled to 85 dB(A) at 1m. |
| Gas Turbine Generator | Omnidirectional Point Sources at 5m a.g.l. | 108.4 | As per Gas Turbine Casing |
| Gas Generator Air Intake | Point source at 6m a.g.l. in front of vertical reflecting plane. | 95.6 | Measured data for GE LM6000 gas turbine. |
| Silenced Flue Gas Stack | Point source at 40m above ground level, adjusted for stack directivity towards ground. | 99.9 | Measured data for GE LM6000 gas turbine. |
| GTG Transformer | Point source at 5m above ground level. | 102.5 | NEMA empirical method (Standard Transformer 140MVA) |
| STG Transformer | Point source at 5m above ground level, adjusted for directivity towards ground. | | |
| WHB Stack | Point source at 40m above ground level, adjusted for directivity towards ground. | 99.9 | As Per Silenced Flue Gas Stack |
| Air Cooled Condenser Array | Horizontal area source situated 5m above ground level. | 105 | Based on experience and data from previous projects |
| Air Fin Fan Cooler | Axial fan 5m3/s at 200Pa | 78.2 | Library |

These sound emission levels should be considered maximum permissible values for equipment as the design progresses to ensure that the environmental effects are no worse than stated in this assessment.

## 4.3 Noise sensitive receptors

A total of 102 potentially noise sensitive receptors were identified in the vicinity of the IPP development site, as detailed in Table 4.2. The modelled receptor locations are shown in Figure 1. Noise levels were predicted at these specific locations.

***Table 4.2 Modelled Sensitive Receptor Locations***

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 1 | Near town of Ogwe | NNW | 1.7 | 308954 | 553098 |
| 2 | Near town of Ogwe | NNW | 1.7 | 308858 | 553124 |
| 3 | Near town of Ogwe | NNW | 1.8 | 308795 | 553112 |
| 4 | Near town of Ogwe | NNW | 2.0 | 308354 | 553112 |
| 5 | Near town of Ogwe | NW | 1.5 | 308145 | 552107 |
| 6 | Near town of Ogwe | NW | 1.8 | 308085 | 552567 |
| 7 | Near town of Ogwe | NW | 1.9 | 308035 | 552650 |
| 8 | Near town of Ogwe | NW | 2.0 | 308033 | 552774 |
| 9 | Near town of Ogwe | NW | 1.9 | 308314 | 552892 |
| 10 | Near town of Ogwe | NNW | 2.1 | 308229 | 553102 |
| 11 | Near town of Ogwe | NNW | 2.0 | 308438 | 553220 |
| 12 | Near town of Ogwe | NNW | 2.0 | 308634 | 553302 |
| 13 | Near town of Ogwe | NNW | 2.0 | 308871 | 553372 |
| 14 | Near town of Ogwe | NNW | 2.1 | 308957 | 553531 |
| 15 | Near town of Ogwe | NNW | 2.1 | 309170 | 553633 |
| 16 | Near town of Ogwe | NW | 2.2 | 308065 | 553151 |
| 17 | Near town of Ogwe | NW | 2.1 | 308245 | 553192 |
| 18 | Near town of Ogwe | NNW | 2.2 | 308511 | 553410 |
| 19 | Near town of Ogwe | NNW | 2.2 | 308789 | 553580 |
| 20 | Near town of Ogwe | NNW | 2.2 | 308924 | 553633 |
| 21 | Near town of Ogwe | NNW | 2.2 | 309039 | 553690 |
| 22 | Near town of Ogwe | N | 2.3 | 309243 | 553805 |
| 23 | Near town of Ogwe | NW | 2.4 | 308033 | 553310 |
| 24 | Near town of Asa | SSW | 0.8 | 309182 | 550881 |
| 25 | Near town of Asa | SSW | 0.7 | 309241 | 550866 |
| 26 | Near town of Asa | SSW | 0.7 | 309250 | 550866 |
| 27 | Near town of Asa | SSW | 0.7 | 309298 | 550858 |
| 28 | Near town of Asa | SSW | 0.7 | 309311 | 550853 |
| 29 | Near town of Asa | S | 0.8 | 309379 | 550766 |
| 30 | Near town of Asa | S | 0.7 | 309371 | 550867 |
| 31 | Near town of Asa | S | 0.6 | 309644 | 550950 |
| 32 | Near town of Asa | S | 0.6 | 309666 | 550963 |
| 33 | Near town of Asa | S | 0.6 | 309632 | 550982 |
| 34 | Near town of Asa | S | 0.5 | 309453 | 551012 |
| 35 | Near town of Ogwe | NW | 1.7 | 308160 | 552505 |

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 36 | Near town of Ogwe | NW | 1.7 | 308218 | 552533 |
| 37 | Near town of Ogwe | NW | 1.8 | 308056 | 552480 |
| 38 | Near town of Ogwe | NW | 1.4 | 308367 | 552221 |
| 39 | Near town of Asa | SW | 1.0 | 308695 | 550973 |
| 40 | Near town of Asa | SW | 1.0 | 308803 | 550936 |
| 41 | Near town of Asa | SW | 1.0 | 308831 | 550891 |
| 42 | Near town of Asa | SSW | 1.0 | 308885 | 550852 |
| 43 | Near town of Asa | SSW | 1.0 | 308911 | 550822 |
| 44 | Near town of Asa | SSW | 0.9 | 308977 | 550837 |
| 45 | Near town of Asa | SSW | 0.8 | 309092 | 550863 |
| 46 | Near town of Asa | SSW | 0.6 | 309767 | 550956 |
| 47 | Near town of Asa | S | 0.9 | 309288 | 550680 |
| 48 | Near town of Asa | S | 0.9 | 309388 | 550626 |
| 49 | Near town of Asa | S | 0.9 | 309464 | 550655 |
| 50 | Near town of Asa | S | 0.8 | 309513 | 550698 |
| 51 | Near town of Asa | S | 0.8 | 309496 | 550710 |
| 52 | Near town of Ogwe | NW | 1.7 | 308223 | 552611 |
| 53 | Near town of Ogwe | NW | 1.8 | 308136 | 552646 |
| 54 | Near town of Ogwe | NW | 1.7 | 308278 | 552563 |
| 55 | Near town of Ogwe | NNW | 1.7 | 308406 | 552833 |
| 56 | Near town of Ogwe | NNW | 1.6 | 308408 | 552663 |
| 57 | Near town of Ogwe | NNW | 1.8 | 308293 | 552810 |
| 58 | Near town of Ogwe | NNW | 1.8 | 308245 | 552807 |
| 59 | Near town of Asa | S | 0.7 | 309647 | 550880 |
| 60 | Near town of Asa | S | 0.6 | 309733 | 550926 |
| 61 | Port Harcourt Aba Road | SSE | 0.7 | 310044 | 550982 |
| 62 | Port Harcourt Aba Road | SSE | 0.7 | 310019 | 551000 |
| 63 | Port Harcourt Aba Road | SSE | 0.7 | 310077 | 551086 |
| 64 | Port Harcourt Aba Road | SSE | 0.7 | 310050 | 551061 |
| 65 | Port Harcourt Aba Road | SSE | 0.6 | 310027 | 551079 |
| 66 | Port Harcourt Aba Road | SSE | 0.6 | 310029 | 551090 |
| 67 | Port Harcourt Aba Road | SSE | 0.7 | 310004 | 551027 |
| 68 | Port Harcourt Aba Road | SSE | 0.5 | 309880 | 551099 |
| 69 | Port Harcourt Aba Road | SSE | 0.7 | 310114 | 551113 |
| 70 | Port Harcourt Aba Road | SSE | 0.7 | 310100 | 551101 |
| 71 | Port Harcourt Aba Road | SSE | 0.7 | 310087 | 551114 |
| 72 | Port Harcourt Aba Road | SE | 0.8 | 310202 | 551124 |
| 73 | Port Harcourt Aba Road | SE | 0.7 | 310203 | 551151 |
| 74 | Near town of Ogwe | NNW | 2.0 | 308590 | 553239 |
| 75 | Near town of Ogwe | NNW | 1.9 | 308624 | 553228 |
| 76 | Near town of Ogwe | NNW | 1.9 | 308677 | 553265 |

| Receptor Description | | | | Location | |
|---|---|---|---|---|---|
| Reference | Location | Direction from site | Distance from site (km) | E | N |
| 77 | Near town of Ogwe | NNW | 1.9 | 308743 | 553242 |
| 78 | Near town of Ogwe | NNW | 1.9 | 308706 | 553228 |
| 79 | Near town of Ogwe | NNW | 1.8 | 308805 | 553166 |
| 80 | Near town of Ogwe | NNW | 1.9 | 308622 | 553199 |
| 81 | Near town of Ogwe | NNW | 1.9 | 308667 | 553206 |
| 82 | Near town of Ogwe | NNW | 1.8 | 308715 | 553161 |
| 83 | Near town of Ogwe | NNW | 1.7 | 308825 | 553096 |
| 84 | Near town of Obehie | NE | 2.2 | 311295 | 552818 |
| 85 | Near town of Obehie | NE | 2.2 | 311204 | 552934 |
| 86 | Near town of Obehie | NE | 2.1 | 311072 | 553011 |
| 87 | Near town of Obehie | NE | 2.1 | 310989 | 553051 |
| 88 | Near town of Obehie | NE | 2.1 | 311084 | 552916 |
| 89 | Near town of Obehie | NE | 2.1 | 311161 | 552882 |
| 90 | Near town of Obehie | NNE | 2.9 | 311323 | 553827 |
| 91 | Near town of Obehie | NNE | 2.9 | 311170 | 553893 |
| 92 | East of site beyond Aba Road | E | 1.1 | 310695 | 551442 |
| 93 | Near town of Obehie | NE | 2.6 | 311773 | 552881 |
| 94 | Near town of Obehie | NE | 2.7 | 311914 | 552770 |
| 95 | East of site beyond Aba Road | E | 1.6 | 311142 | 551558 |
| 96 | East of site beyond Aba Road | E | 1.2 | 310782 | 551355 |
| 97 | NW of Obehie | NNE | 4.1 | 309840 | 555584 |
| 98 | NW of Obehie | NNE | 4.1 | 310289 | 555605 |
| 99 | NW of Obehie | NE | 4.2 | 310745 | 555530 |
| 100 | NW of Obehie | NE | 4.2 | 310878 | 555475 |
| 101 | NW of Obehie | NE | 4.1 | 311008 | 555365 |
| 102 | NW of Obehie | NE | 4.1 | 311124 | 555285 |

# 5 Assessment

The noise levels predicted at receptors for each of the three development phases are given in Table 5.1 below, and shown on Figures 2 to 4. The noise emissions of the development will not alter between night and day, and therefore the predicted levels have been compared to the IFC night-time criterion for residential properties of 45 dB $L_{Aeq,1h}$. Where this level is likely to be exceeded, the cell has been shaded red for convenience.

***Table 5.1 Predicted operational noise levels, $L_{Aeq,T}$ dB***

| Receptor | | Predicted noise level, $L_{Aeq,1h}$ dB | | |
|---|---|---|---|---|
| Reference | Location | Phase 1 | Phase 2 | Phase 3 |
| 68 | Port Harcourt Aba Road | **48.2** | **50.5** | **50.6** |
| 66 | Port Harcourt Aba Road | **46.7** | **48.7** | **48.8** |
| 65 | Port Harcourt Aba Road | **46.6** | **48.5** | **48.7** |
| 71 | Port Harcourt Aba Road | **46.4** | **48.2** | **48.4** |
| 33 | Near town of Asa | **46.2** | **49.1** | **49.3** |
| 34 | Near town of Asa | **46.2** | **49.3** | **49.7** |
| 63 | Port Harcourt Aba Road | **46.2** | **48.0** | **48.2** |
| 64 | Port Harcourt Aba Road | **46.2** | **48.1** | **48.3** |
| 67 | Port Harcourt Aba Road | **46.1** | **48.1** | **48.3** |
| 69 | Port Harcourt Aba Road | **46.1** | **47.9** | **48.1** |
| 70 | Port Harcourt Aba Road | **46.1** | **47.9** | **48.1** |
| 32 | Near town of Asa | **45.9** | **48.9** | **49.2** |
| 46 | Near town of Asa | **45.8** | **48.6** | **48.8** |
| 31 | Near town of Asa | **45.7** | **48.5** | **48.7** |
| 62 | Port Harcourt Aba Road | **45.6** | **47.6** | **47.8** |
| 73 | Port Harcourt Aba Road | **45.4** | **47.1** | **47.3** |
| 60 | Near town of Asa | **45.3** | **48.2** | **48.5** |
| 61 | Port Harcourt Aba Road | **45.2** | **47.2** | **47.4** |
| 72 | Port Harcourt Aba Road | **45.2** | **46.9** | **47.1** |
| 59 | Near town of Asa | 44.6 | **47.3** | **47.5** |
| 30 | Near town of Asa | 43.6 | **46.4** | **46.9** |
| 27 | Near town of Asa | 43.1 | **45.8** | **46.4** |
| 28 | Near town of Asa | 43.1 | **45.8** | **46.4** |
| 26 | Near town of Asa | 42.4 | **45.4** | **46.0** |
| 25 | Near town of Asa | 42.3 | **45.3** | **45.9** |
| 29 | Near town of Asa | 42.3 | 45.0 | **45.5** |
| 24 | Near town of Asa | 41.3 | 44.4 | **45.2** |
| 51 | Near town of Asa | 42.0 | 44.6 | 45.0 |
| 50 | Near town of Asa | 41.9 | 44.4 | 44.8 |
| 49 | Near town of Asa | 41.3 | 43.8 | 44.2 |
| 47 | Near town of Asa | 41.0 | 43.5 | 44.0 |
| 92 | East of site beyond Aba Road | 41.0 | 42.4 | 42.4 |
| 48 | Near town of Asa | 40.8 | 43.3 | 43.7 |
| 45 | Near town of Asa | 40.2 | 43.3 | 44.2 |

| Receptor | | Predicted noise level, $L_{Aeq,1h}$ dB | | |
|---|---|---|---|---|
| Reference | Location | Phase 1 | Phase 2 | Phase 3 |
| 96 | East of site beyond Aba Road | 40.0 | 41.5 | 41.5 |
| 44 | Near town of Asa | 38.7 | 41.9 | 42.8 |
| 42 | Near town of Asa | 37.4 | 40.9 | 41.9 |
| 43 | Near town of Asa | 37.3 | 40.9 | 41.9 |
| 95 | East of site beyond Aba Road | 36.9 | 38.2 | 38.2 |
| 40 | Near town of Asa | 36.8 | 40.4 | 41.5 |
| 41 | Near town of Asa | 36.8 | 40.5 | 41.6 |
| 38 | Near town of Ogwe | 36.5 | 38.6 | 39.4 |
| 39 | Near town of Asa | 36.2 | 39.5 | 40.8 |
| 56 | Near town of Ogwe | 36.1 | 37.7 | 38.2 |
| 54 | Near town of Ogwe | 35.6 | 37.4 | 38.0 |
| 5 | Near town of Ogwe | 35.5 | 37.1 | 37.8 |
| 52 | Near town of Ogwe | 35.3 | 37.1 | 37.5 |
| 36 | Near town of Ogwe | 35.2 | 37.1 | 37.6 |
| 55 | Near town of Ogwe | 35.1 | 36.6 | 37.0 |
| 1 | Near town of Ogwe | 34.9 | 36.4 | 36.9 |
| 57 | Near town of Ogwe | 34.9 | 36.3 | 36.7 |
| 35 | Near town of Ogwe | 34.8 | 36.8 | 37.3 |
| 58 | Near town of Ogwe | 34.7 | 36.2 | 36.7 |
| 53 | Near town of Ogwe | 34.6 | 36.4 | 36.8 |
| 83 | Near town of Ogwe | 34.5 | 36.1 | 36.6 |
| 2 | Near town of Ogwe | 34.4 | 36.0 | 36.5 |
| 6 | Near town of Ogwe | 34.4 | 36.3 | 36.7 |
| 9 | Near town of Ogwe | 34.4 | 35.9 | 36.3 |
| 3 | Near town of Ogwe | 34.3 | 35.9 | 36.4 |
| 79 | Near town of Ogwe | 34.0 | 35.6 | 36.1 |
| 7 | Near town of Ogwe | 33.9 | 35.8 | 36.2 |
| 37 | Near town of Ogwe | 33.9 | 36.1 | 36.6 |
| 8 | Near town of Ogwe | 33.8 | 35.5 | 35.9 |
| 82 | Near town of Ogwe | 33.8 | 35.4 | 35.8 |
| 77 | Near town of Ogwe | 33.4 | 35.0 | 35.4 |
| 78 | Near town of Ogwe | 33.4 | 35.0 | 35.4 |
| 81 | Near town of Ogwe | 33.4 | 35.0 | 35.4 |
| 80 | Near town of Ogwe | 33.3 | 34.9 | 35.3 |
| 75 | Near town of Ogwe | 33.2 | 34.8 | 35.2 |
| 88 | Near town of Obehie | 33.2 | 34.7 | 34.7 |
| 13 | Near town of Ogwe | 33.1 | 34.7 | 35.0 |
| 76 | Near town of Ogwe | 33.1 | 34.7 | 35.1 |
| 10 | Near town of Ogwe | 33.0 | 34.5 | 34.9 |
| 74 | Near town of Ogwe | 33.0 | 34.6 | 35.0 |
| 89 | Near town of Obehie | 33.0 | 34.5 | 34.3 |
| 4 | Near town of Ogwe | 32.9 | 34.6 | 35.0 |
| 11 | Near town of Ogwe | 32.8 | 34.4 | 34.7 |

| Receptor | | Predicted noise level, $L_{Aeq,1h}$ dB | | |
|---|---|---|---|---|
| Reference | Location | Phase 1 | Phase 2 | Phase 3 |
| 12 | Near town of Ogwe | 32.8 | 34.4 | 34.8 |
| 84 | Near town of Obehie | 32.6 | 34.1 | 33.8 |
| 85 | Near town of Obehie | 32.6 | 34.1 | 34.0 |
| 14 | Near town of Ogwe | 32.4 | 34.0 | 34.3 |
| 16 | Near town of Ogwe | 32.4 | 33.9 | 34.1 |
| 87 | Near town of Obehie | 32.3 | 33.6 | 33.7 |
| 17 | Near town of Ogwe | 32.2 | 33.9 | 34.2 |
| 86 | Near town of Obehie | 32.1 | 33.5 | 33.5 |
| 18 | Near town of Ogwe | 32.0 | 33.6 | 33.9 |
| 19 | Near town of Ogwe | 31.8 | 33.4 | 33.7 |
| 20 | Near town of Ogwe | 31.8 | 33.4 | 33.6 |
| 15 | Near town of Ogwe | 31.5 | 33.0 | 33.3 |
| 23 | Near town of Ogwe | 31.5 | 33.0 | 33.2 |
| 21 | Near town of Ogwe | 31.3 | 32.7 | 32.9 |
| 22 | Near town of Ogwe | 30.7 | 32.2 | 32.4 |
| 93 | Near town of Obehie | 30.4 | 31.9 | 31.5 |
| 94 | Near town of Obehie | 30.1 | 31.6 | 31.2 |
| 90 | Near town of Obehie | 28.4 | 29.8 | 29.5 |
| 91 | Near town of Obehie | 28.4 | 29.8 | 29.5 |
| 102 | NW of Obehie | 23.5 | 24.8 | 24.0 |
| 101 | NW of Obehie | 23.4 | 24.7 | 23.9 |
| 100 | NW of Obehie | 23.3 | 24.6 | 23.7 |
| 97 | NW of Obehie | 23.2 | 24.6 | 23.7 |
| 99 | NW of Obehie | 23.2 | 24.6 | 23.7 |
| 98 | NW of Obehie | 23.0 | 24.4 | 23.5 |

It can be seen that the highest noise levels are predicted for receptors to the south of the Project in the Port Harcourt Aba Road area.

All of the predicted noise levels are below the recommended daytime ambient noise levels are presented in Section 1.7 of the General EHS Guidelines for residential, institutional and educational facilities. However the recommended night-time ambient noise levels will be exceeded in all three phases of operation:

- *During Phase 1, it is expected that the night noise criterion will be exceeded at 19 properties, by between 0.2 - 3.2 dB.*
- *During Phase 2, it is expected that the night noise criterion will be exceeded at 25 properties, by between 0.3 – 5.5 dB*
- *During Phase 3, it is expected that the night noise criterion will be exceeded at 27 properties, by between 0.2 – 5.6 dB*

As the recommended noise levels set out in the General EHS Guidelines are predicted to be exceeded, it is appropriate to consider the effects of the predicted noise levels and mitigation measures that may be employed to reduce noise emissions from the Project.

The National Physical Laboratory (UK) undertook a review and feasibility study of health effect based noise assessment methods[3] which considered the WHO guideline levels (on which the IFC guidelines are based) to be "*the lower threshold levels below which residual noise impacts can probably be considered as negligible…. they can therefore be considered as 'desirable' and ideal targets*". The study notes that, according to the most recent study at the time (Sargent, 93), around 65% of the UK population were exposed to night-time noise levels exceeding 45 $L_{Aeq}$. In summarising the WHO guidelines it states: "*It is important to make clear at this point that exceedances do not necessarily imply an over-riding need for noise control, merely that the relative advantages and disadvantages of noise control action should be weighed in the balance*".

Since the General EHS Guidelines were published, the WHO has set out Night Noise Guidelines for Europe (2009). The night noise guidelines are in terms of $L_{night,outside}$ which is the equivalent continuous noise level over the course of a night[4]. These guidelines identify that there is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,outside}$ are harmful to health. These guidelines therefore equate 40 dB $L_{night,outside}$ to the Lowest Observed Adverse Effect Level (LOAEL) for night noise.

Above 55 dB $L_{night,outside}$, the situation is considered increasingly dangerous for public health: adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed, and there is evidence that the risk of cardiovascular disease increases. Correspondingly, the night noise guidelines put forward an Interim Target of 55 dB $L_{night,outside}$ for situations where the LOAEL cannot be achieved. This is considered to be an appropriate Significant Observed Adverse Effect Level (SOAEL) for this assessment.

The highest noise levels predicted as a result of the Project are above the LOAEL of 40 dB $L_{night,outside}$, but are below the SOAEL of 55 dB $L_{night,outside.}$ Noise levels in this range (40-55 dB $L_{night,outside}$) are associated with increased likelihood of adverse health effects including self-reported sleep disturbance, environmental insomnia, increased use of somnifacient drugs and sedatives, and changes in behaviour. The most common change in behaviour is to close bedroom windows whilst sleeping, which may cause other issues with overheating and fresh air which impact on quality of sleep. It is therefore best practice to mitigate, as far as possible, noise levels above the adopted LOAEL of 40 dB $L_{night,outside.}$

[3] NPL Report CMAM 16, Health Effect Based Noise Assessment Methods: A Review and Feasibility Study, Nicole D Porter and Bernard F Berry, 1998

[4] $L_{night,outside}$ is the night-time noise indicator ($L_{night}$) of Directive 2002/49/EC of 25 June 2002: the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year; in which: the night is eight hours (usually 23.00 – 07.00 local time).

# 6 Mitigation

It has been assumed that, other than high-performance silencers (attenuators) on the gas turbine air intakes and flues (including the waste heat boiler flues in Phase 3), that no other specific noise mitigation measures are included in the basic design or layout of the Project.

With respect to noise mitigation of thermal power plants, the IHS Guidelines recommend consideration of the following:

1) Siting new facilities with consideration of distances from the noise sources to the receptors (e.g., residential receptors, schools, hospitals, religious places) to the extent possible. If the local land use is not controlled through zoning or is not effectively enforced, examine whether residential receptors could come outside the acquired plant boundary. In some cases, it could be more cost effective to acquire additional land as buffer zone than relying on technical noise control measures, where possible;
2) Use of noise control techniques such as: using acoustic machine enclosures; selecting structures according to their noise isolation effect to envelop the building; using mufflers or silencers in intake and exhaust channels; using sound absorptive materials in walls and ceilings; using vibration isolators and flexible connections (e.g., helical steel springs and rubber elements); applying a carefully detailed design to prevent possible noise leakage through openings or to minimize pressure variations in piping;
3) Modification of the plant configuration or use of noise barriers such as berms and vegetation to limit ambient noise at plant property lines, especially where sensitive noise receptors may be present.

At this stage of the Project, selecting a new site for the thermal power plant is not a feasible solution. Similarly, acquiring the dwellings at which noise levels over 45 dB $L_{Aeq,1hour}$ at night is a disproportionate response to the magnitude of the noise impact and the likely effects and resettlement of dwellings is considered by Geometric Power as a last resort. Therefore this assessment considers items (2) the use of noise control techniques and (3) modification of the plant configuration in more detail.

Table 6.1 below shows the relative contributions of noise sources at Receptor 68, which is identified as being the worst affected in all three phases.

***Table 6.1 Contribution of Phase 3 Noise Sources at Receptor 68***

| Source | Phase 3 Sound Pressure Level Contribution, dB(A) |
|---|---|
| Gas Turbine 06 | 38.6 |
| Generator 06 | 38.6 |
| Gas Turbine 05 | 38.4 |
| Generator 05 | 38.4 |
| Gas Turbine 04 | 38.1 |
| Generator 04 | 38.0 |
| Gas Turbine 03 | 37.6 |
| Generator 03 | 37.5 |
| GTG Transformer 06 | 37.2 |
| Gas Turbine 02 | 37.1 |

| Source | Phase 3 Sound Pressure Level Contribution, dB(A) |
|---|---|
| Generator 02 | 37.0 |
| GTG Transformer 05 | 37.0 |
| GTG Transformer 04 | 36.8 |
| Gas Turbine 01 | 36.5 |
| GTG Transformer 03 | 36.3 |
| GTG Transformer 02 | 35.8 |
| Air Cooled Condenser Array | 35.3 |
| GTG Transformer 01 | 35.2 |
| STG Transformer 02 | 34.7 |
| Generator 01 | 33.9 |
| STG Transformer 01 | 32.1 |
| WHB Stack 06 | 31.1 |
| WHB Stack 05 | 31.0 |
| WHB Stack 04 | 30.7 |
| WHB Stack 03 | 30.3 |
| WHB Stack 02 | 29.8 |
| WHB Stack 01 | 29.3 |
| Gas Turbine Air Intake 06 | 28.8 |
| Gas Turbine Air Intake 05 | 28.6 |
| Gas Turbine Air Intake 04 | 28.3 |
| Gas Turbine Air Intake 03 | 27.9 |
| Gas Turbine Air Intake 02 | 27.4 |
| Gas Turbine Air Intake 01 | 26.8 |
| Air Fin Fan Cooler 06A | 11.4 |
| Air Fin Fan Cooler 06B | 11.4 |
| Air Fin Fan Cooler 05A | 11.3 |
| Air Fin Fan Cooler 05B | 11.3 |
| Air Fin Fan Cooler 04A | 11.1 |
| Air Fin Fan Cooler 04B | 11.1 |
| Air Fin Fan Cooler 03A | 10.8 |
| Air Fin Fan Cooler 03A | 10.8 |
| Air Fin Fan Cooler 02A | 10.4 |
| Air Fin Fan Cooler 02B | 10.4 |
| Air Fin Fan Cooler 01A | 9.9 |
| Air Fin Fan Cooler 01B | 7.3 |
| **Total** | **50.6** |

It can be seen that noise emanated from the gas turbine / generator casings, and from the GTG transformers, cause the greatest contributions to noise at receptor 68.

NEMA indicates that noise from transformers can be reduced by up to 10 dB by using quieted transformers. Effectively reducing noise from the gas turbine / generator casings is potentially more challenging, and would require placing the turbines and generators in enclosures or a building offering a good level of sound insulation to achieve noise levels below 45 dB $L_{Aeq,1hour}$ at all receptors. This may have significant cost and operational impacts.

Alternatively, a combination of noise barriers around units and along the southern boundary could be investigated. The noise barriers would need to be substantially taller than the gas turbine units. Initial modelling has shown that a 12.5m high noise barrier along the southern perimeter, returning a short distance along the east

perimeter, will have beneficial effects at some receptors. However, with this indicative barrier design, there would still be 14 properties at which noise levels exceed 45 dB $L_{Aeq,1hour}$ (by up to 2.5 dB).

As an alternative, a sound insulation grant scheme could be administered for properties exposed to noise levels over 45 dB $L_{Aeq,1hour}$ as a result of the Project. These grants would be provided to cover the installation of air-conditioning, or acoustic ventilators (which allow airflow but reduce noise ingress to a greater extent than open windows) to bedrooms. This would not achieve the IFC external noise criteria at night, but would ameliorate the potential adverse health effects that they are intended to prevent.

The properties at which noise levels are predicted to exceed 45 dB $L_{Aeq,1hour}$ are shown in Figure 4.

# 7 Conclusions

This report assesses the likely significant operational impacts of the Project with respect to noise.

A three-dimensional noise model has been used to predict daytime and night-time noise levels due to the operation of all three Phases. The predicted noise levels indicated that the IFC night-time noise criterion for residential properties of 45 dB $L_{Aeq,1hour}$ will be exceeded at 19 receptors in Phase 1, 25 receptors in Phase 2 and 27 receptors in Phase 3. The criterion will be exceeded by between 0.2 and 5.6 dB.

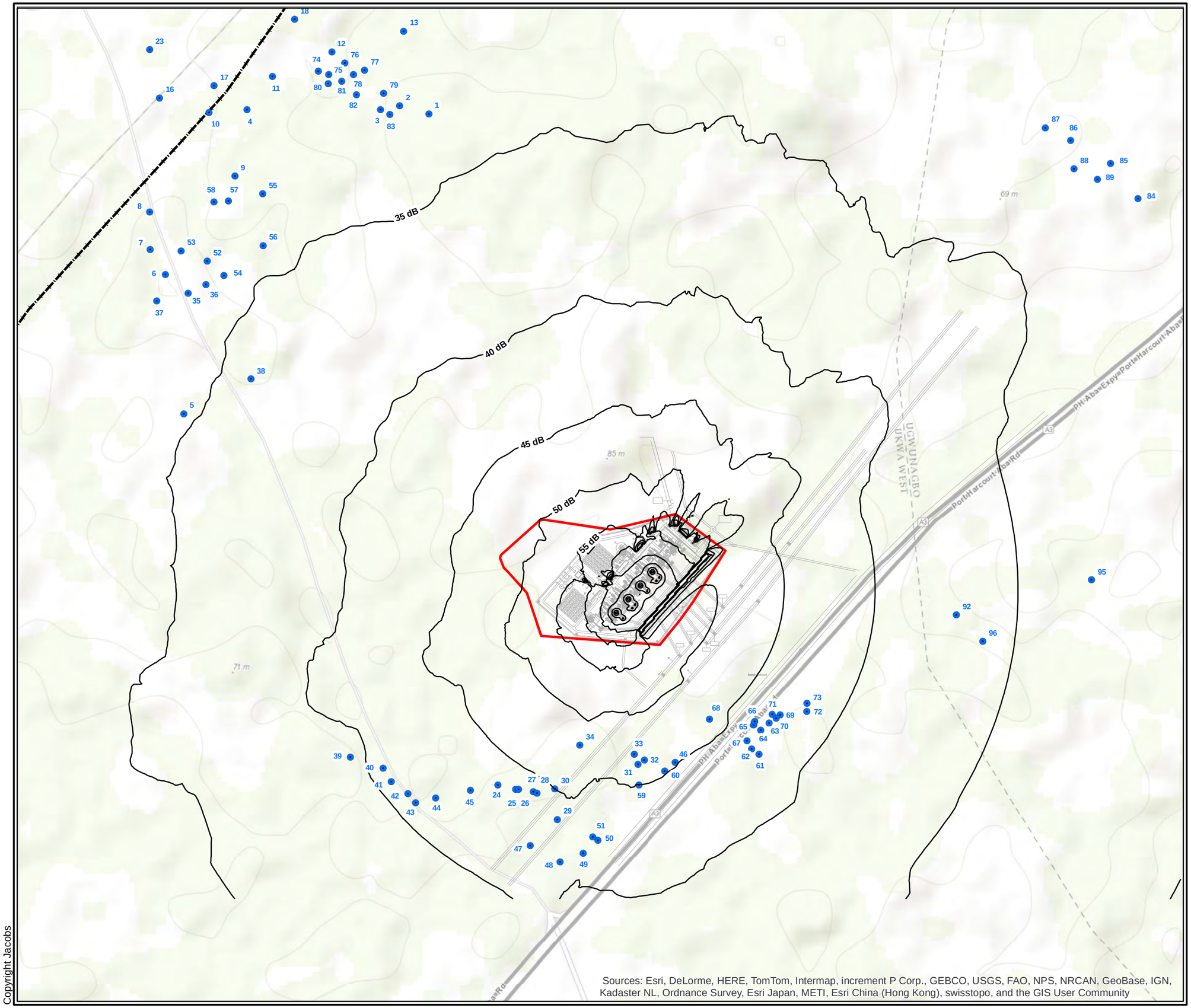
Three potential mitigation strategies have been identified, with different levels of effectiveness, cost and operational impact. These strategies are summarised in Table 7.1 below:

***Table 7.1 Summary of Noise Mitigation Strategies***

| Mitigation Strategy | Effectiveness | Cost and Operational Impact |
|---|---|---|
| Place gas turbines and generators in enclosures or buildings offering good sound insulation ($R_w$ 20 dB or better).<br><br>Specifying transformers with a sound power level (including fans) not exceeding 92.5 dB $L_{WA}$ (ref $1x10^{-12}$ W). | Highly effective. Noise levels less than 45 dB $L_{Aeq,1hour}$ will be achieved at all sensitive receptors. | Highest cost and operational / design impacts. |
| Construction of a solid noise barrier (and/or bund) along the southern perimeter of the site, and local barriers around turbines and generators. | Moderate effect; some noise reductions, but noise levels at 14 receptors will still exceed 45 dB $L_{Aeq,1hour}$, by up to 2.5 dB. | High cost, some operational and design impacts. |
| A sound insulation grant scheme for residential properties where noise levels are shown to exceed 45 dB $L_{Aeq,1hour}$ at night. | External noise levels will be unaltered, but the sound insulation measures will enable occupants to sleep comfortably with windows closed. | Lowest cost, no operational impact other than administering grant scheme. |

It is recommended that consultation with the Lender Group over the most appropriate mitigation strategy for the Project be undertaken, and the selected strategy implemented.

# Appendix A Figures




Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

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## Legend

- Noise Receptors
- Site Boundary
- Noise Contour
- Rail Line

REVISION: A

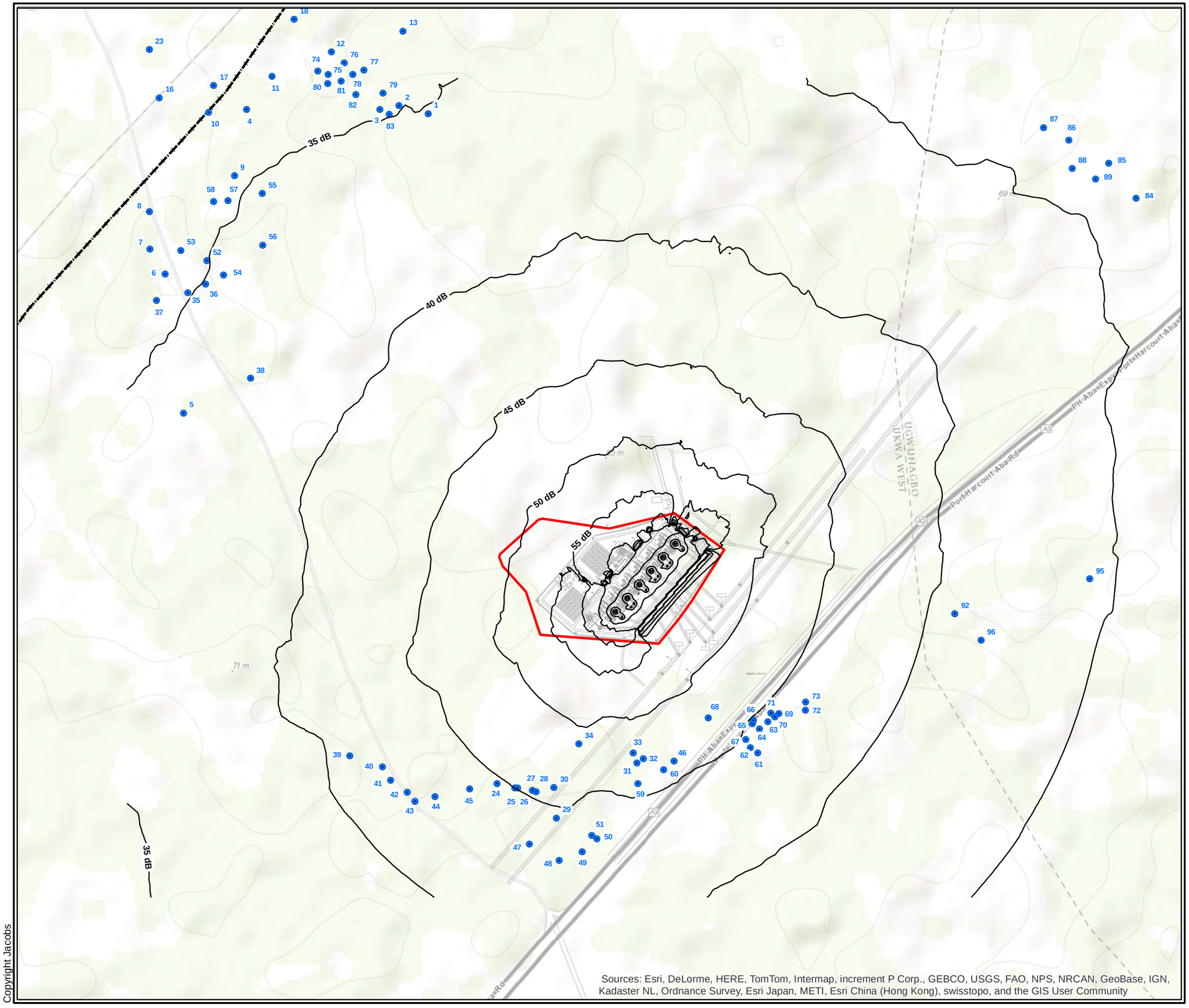
MXD: 001/g003

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 1

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

JACOBS

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## Legend

- Noise Receptors
- Site Boundary
- Noise Contour
- Rail Line

REVISION: A

MXD: 001/g004

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 2

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

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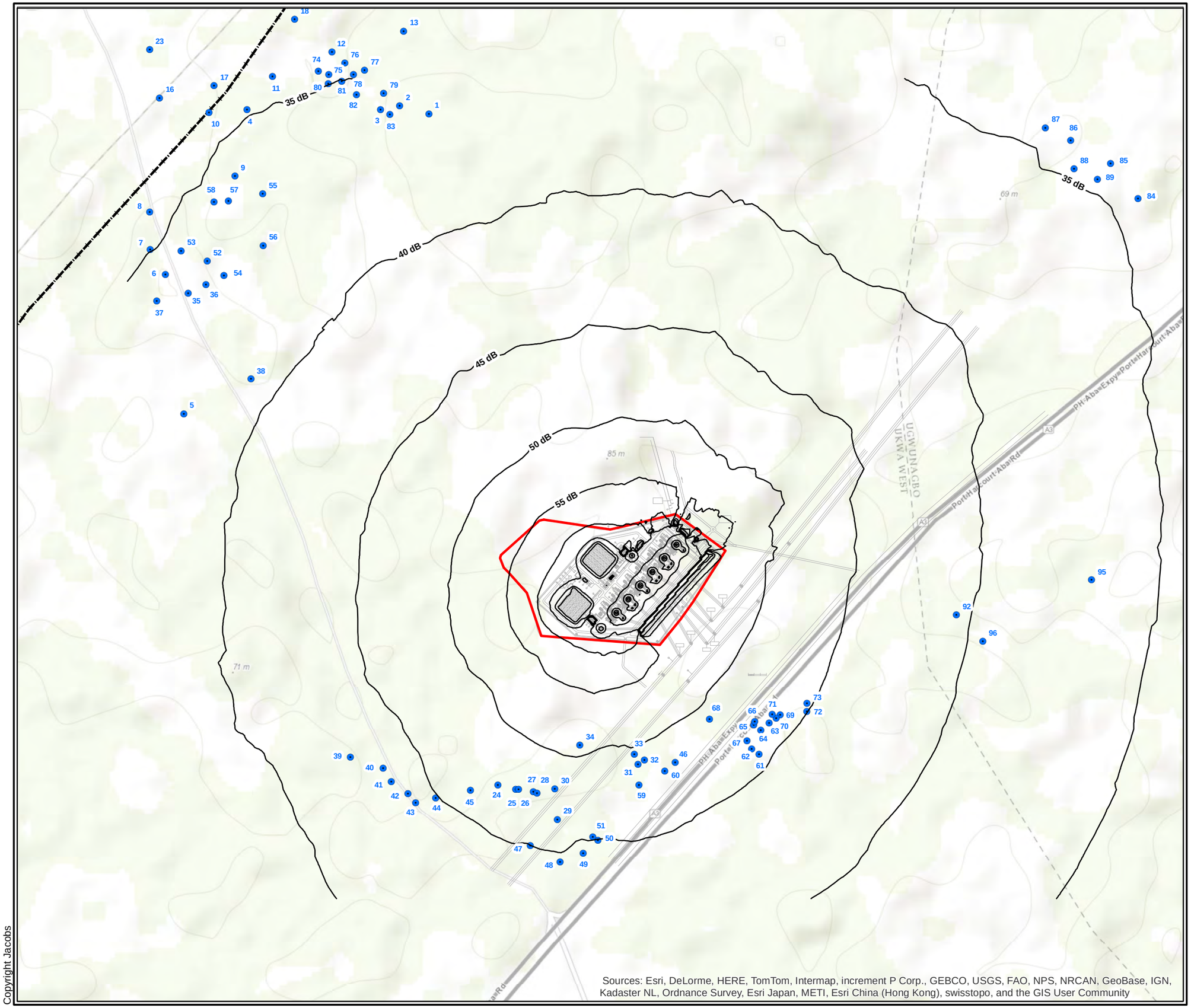


Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

## Legend

- Noise Receptors
- Site Boundary
- Noise Contour
- Rail Line

REVISION: A

MXD: 001/g005

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 3

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

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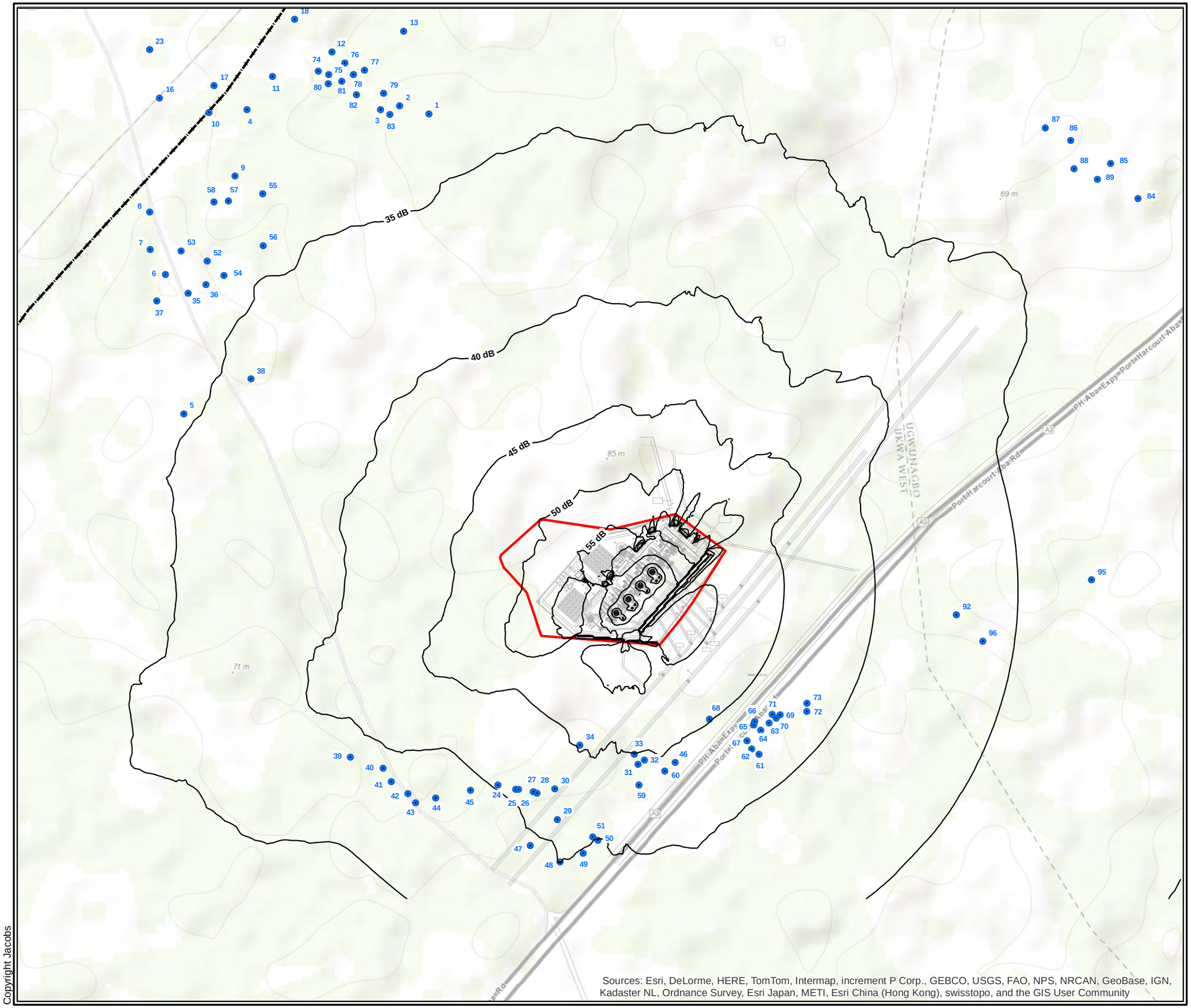


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## Legend

- Noise Receptors
- Site Boundary
- Noise Contour
- Rail Line

REVISION: A

MXD: 001/g006

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 1 (Mitigated)

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

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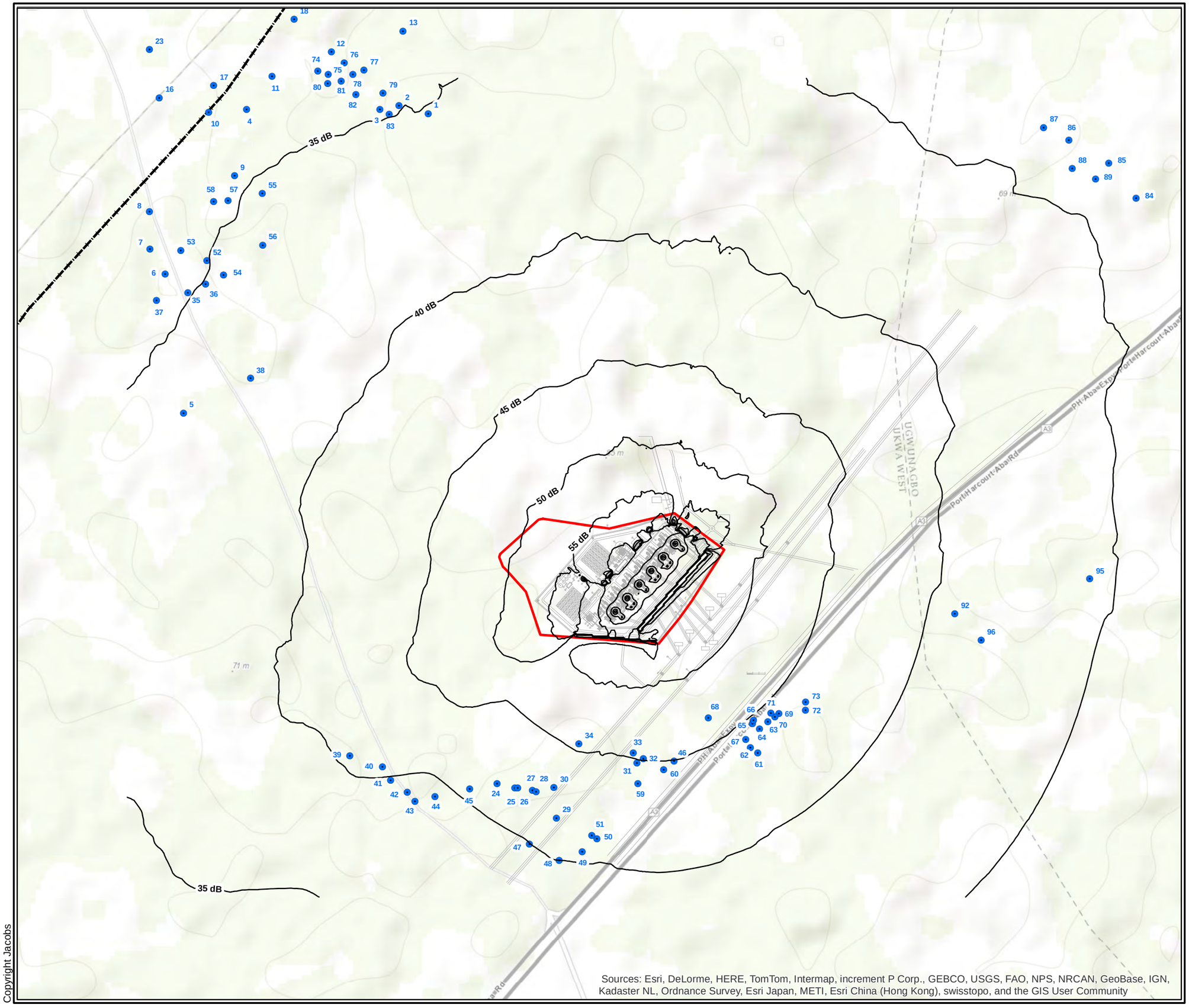


Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

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## Legend

- Noise Receptors
- Site Boundary
- Noise Contour
- Rail Line

REVISION: A

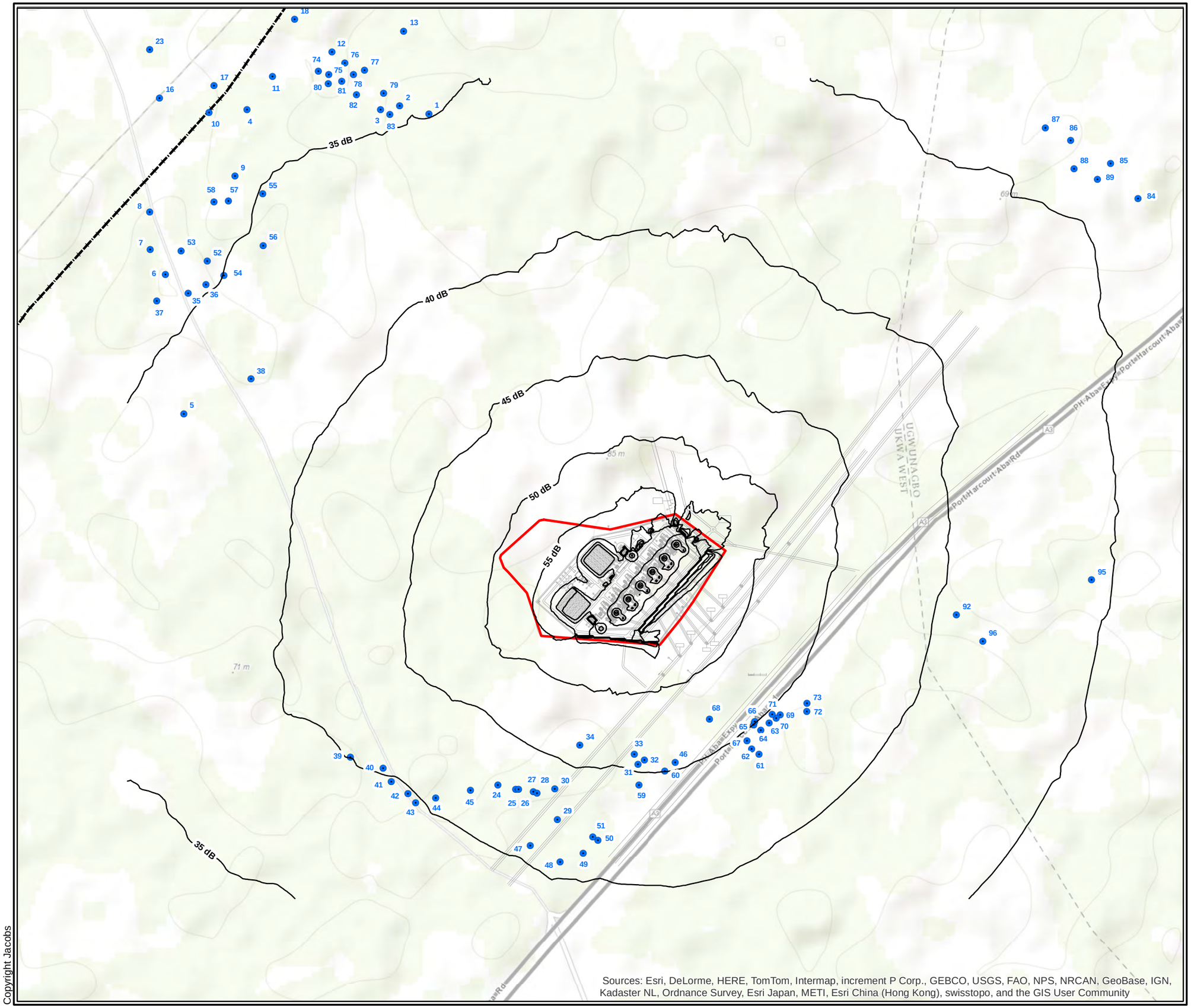
MXD: 001/g007

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 2 (Mitigated)

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

JACOBS




## Legend

- Noise Receptors
- Site Boundary
- Rail Line
- Noise Contour

REVISION: A

MXD: 001/g008

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 3 (Mitigated)

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

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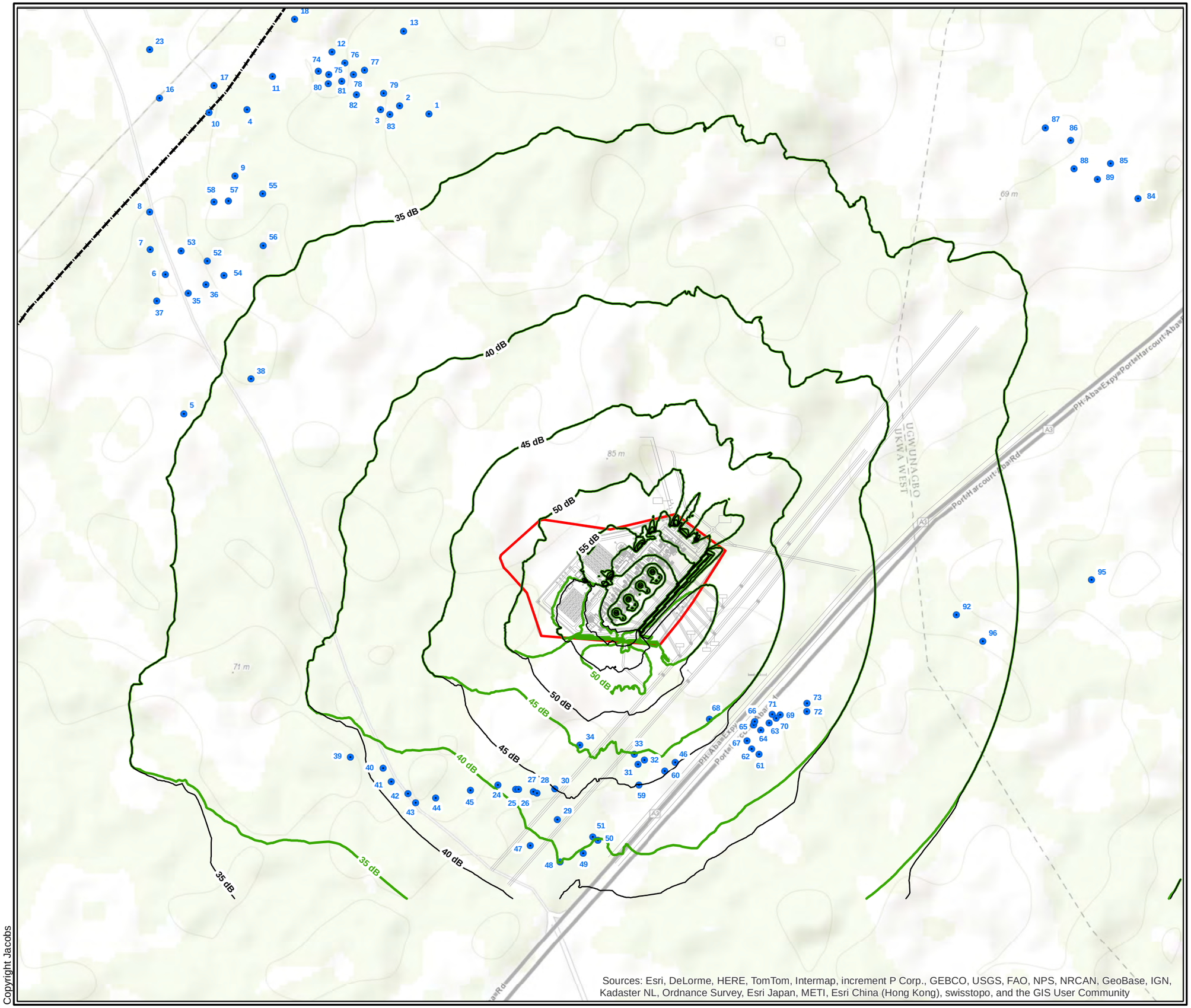


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## Legend

- Noise Receptors
- Site Boundary
- Rail Line
- Predicted Steady State Operational Noise Contours
- Predicted Steady State Operational Noise Contours (Mitigated)

REVISION: A

MXD: 001/g009

# Oma Power Station

## Predicted Steady State Operational Noise Levels Phase 1 & Phase 1 Mitigated

| | |
|---|---|
| SCALE 1:12,000 @ A3 | PROJECT CODE JE30749 |
| CONTENT SW | DRAWN JA |
| CHECKED SW | DATE 08/08/2014 |

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# Appendix B Octave Band Sound Power Levels

| Equipment | Octave Band Centre Frequency, Hz | | | | | | | | A |
|---|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| Gas Turbine Casing | 105.5 | 111.5 | 104.5 | 100.5 | 96.5 | 99.5 | 101.5 | 104.5 | 108.4 |
| Gas Generator Air Intake | 110.8 | 98.8 | 78.8 | 78.8 | 84.8 | 89.8 | 89.8 | 86.8 | 95.6 |
| Silenced Flue Gas Stack | 108 | 113 | 103 | 91 | 84 | 87 | 83 | 82 | 99.9 |
| GTG Transformer | 105.1 | 107.1 | 102.1 | 102.1 | 96.1 | 91.1 | 86.1 | 79.1 | 102.5 |
| STG Transformer | 105.1 | 107.1 | 102.1 | 102.1 | 96.1 | 91.1 | 86.1 | 79.1 | 102.5 |
| WHB Stack | 100.5 | 98.5 | 98.5 | 99.5 | 99.5 | 98.5 | 95.5 | 89.5 | 104.6 |
| Generator | 105.5 | 111.5 | 104.5 | 100.5 | 96.5 | 99.5 | 101.5 | 104.5 | 108.4 |
| Air Cooled Condenser Array | - | - | - | 108.2 | - | - | - | - | 105 |
| Air Fin Fan Cooler | 80.2 | 80.1 | 78.6 | 76.2 | 73 | 68.8 | 64 | 57.1 | 78.2 |

# Appendix IX – Focus Group Discussions 2015

# ESIA STUDY OF THE PROPOSED OMA INDEPENDENT POWER PLANT PROJECT, ABIA STATE
# MINUTES OF MEETING

**OBEHIE COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTES OF MEETING**

**VENUE: Eze's Palace, Obehie in Ukwa West LGA of Abia State**

**DATE: August 17, 2015**

## I. Opening Remarks/Attendance/Introduction

The meeting started at exactly 9:46am with the opening prayer said by the Eze of Obehie Community, Prince Stephen Oforji. The Eze and his Council of Chiefs as well as other members of the community welcomed the socio economics survey team while the spokesperson (Mr. Onyinye Agomuo) of the community introduced each member of the community that gathered for the meeting. Thereafter, the led consultant of Creekline Consult Ltd community survey team, Mr. Alphonsus Isusu, introduced the team members.

The community was represented during the Focus Group Discussions by the Eze, Village heads, Chiefs, Women leaders, Youth leaders and community members/other stake holders.

The study team was formally welcomed by presentation of kola-nut by the host community as a tradition and mark of respect for visitors. As tradition demands, the kola-nut was blessed by the Eze of the community, Prince Stephen Oforji, before it was broken and passed round for eating.

Attendance was taken by Opha Odafe James for Creekline Consult Limited (Community Survey Team)

## II. Creekline Consult Limited Presentation (Community Survey Team) Presentation

The lead consultant of Creekline Consult Ltd, Mr. Alphonsus Isusu, gave the presentation in this segment. He started the presentation by saying that although Geometric Power Limited are co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to achieve the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The Eze was quick to point out some malfunction water projects in the community while calling on the company (OMA Power Independent Company Limited) to come to their aid. At this point, Mr. Alphonsus, the team lead told the community that, the essence of our coming is to interact with the community, know some of their challenges, how they co-exist as a community, their fears if any as it concerns the proposed project and take their message back to the project proponent (OMA Power).

The session was further divided into three (3) Focus Groups for discussion namely, Elders Group, Women Group and Youth Group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

Chief Joshua Elendu asked to know how the project will benefit the community while Mrs Mercy Obi want to know how the woman will benefit from the project too. Also, one of the youth, Mr Amaechi Ogukpu asked what area specifically will the project benefit the community youth. Again, one Mr. Desmond Robert want to know how the company (OMA) will manage the pipeline project to avoid explosion since it's pipeline that will be carrying the gas to the plant.

The team lead from Creekline Consult, Mr Alphonsus Isusu responded by saying that every project has its benefit(s) and believe that the project is capable of providing job opportunities to some of the community members, skill acquisition program may be initiated for the women while those of the youth who have the requisite qualification may be employed.

However, Creekline Consult is not assuring the community of all these benefits but believe that the community will benefit from the project when in operation. Meanwhile, in responding to Mr Desmond Robert, one of the survey team member (Mr Odafe James) said that, it is believed that OMA Power Company will use the best available technology to forestall any explosion while enjoining the community to help in policing the pipeline when in operation as a stakeholder to avoid sabotage.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Eze and his cabinet and other members of the community present, allaying their fears/concerns about failed promises by other companies, and assured the community that OMA Power all things being equal will carry out its corporate social responsibilities in the community.

The meeting ended at exactly 1:03pm.

**NGWAIYIEKWE COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTES OF MEETING**

**VENUE: Eze's Palace, Ngwaiyikwe in Ukwa West LGA of Abia State**

**DATE: August 17, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at exactly 1:35pm with the opening prayer by His Royal Highness (Eze) Moses Ugochukwu Eze of Ngwaiyikwe community. The Eze express his happiness to seeing the team, saying that a pre-information was given to him on our coming and said he is delightful to see the team. He further welcomed the socio economics survey team. MrOdoIhejirika, the spokesperson of the community introduced each members of the community gathered for the meeting. Thereafter, the led consultant of Creekline Consult Ltd Community Survey Team, Alphonsus Isusu, introduced the team members.

The community were represented during the Focus Group Discussion by The Eze, Village heads, Chiefs, Women leaders, Youth leaders and community members/other stake holders.

Kola-nut was also offered as a core tradition of the people. Kola-nut signifies welcome, which is usually offered before asking visitors their mission. As tradition demands, the kola-nut was blessed by the Eze of the community, Moses UgochukwuEze, before it was broken and passed round for eating.

Attendance was taken by Opha Odafe James for Creekline Consult Limited (Community Survey Team)

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The led consultant of Creekline Consult Ltd, MrAlphonsus Isusu, gave the presentation in this segment. He started the presentation by saying that although Geometric Power Limited owned the OMA Power Project, the entire community had a stake in the project as well.He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to achieve the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

MrAlphonsus, the team lead for Creekline Consult told the community that, the essence of our coming is to interact with the community, know some of their challenges, how they co-exist as a community, their fears if any as it concerns the proposed project and take their message back to the project proponent (OMA) for consideration.

The Eze started by pointing out that there exist a borehole water projects in the community but said that it's no longer working. He also made mentioned of power supply as not stable in the community, saying that there is a lot of things that is not going well with the community. However, the Eze calls on the company (OMA Power Independent Company Limited) to assist the community. At this point, Mr Alphonsus Isusu, the team lead for Creekline Consult told the community to be patient as the essence of our visit is to interact with the community to know how they co-exist as a community, their fears if any as it

concerns the proposed project and at the end take their message back to the project proponent (OMA Power).

Thereafter, the session was further divided into three focus groups for discussion namely, Elders group, Women Group and Youth Group.

In response, the community expressed satisfaction on the survey study, saying that it is a good thing we came to interact with them.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The His Royal Highness (Eze Moses Ugochukwu) asked the team how when the project will commence and what the community stands to benefit. Elder Samuel Ekpo said that the community have been receiving study team like us but noted that at the end of the day, nothing comes to them. While Mrs Ngozi Odo (Woman Leader) said that she on her side want to be positive and that she is happy the company is coming to their area and want OMA Independent Power) to help the women in the area of vocational training and possibly a starter pack after the training. One of the youth, Mr Michael Eze want to know if OMA will award scholarship and provide employment opportunities.

In responding, the Creekline Consult team lead, Mr Alphonsus Isusu said that every project has its positive and negative impacts while believing that the project will bring about employment opportunities, and as a company, that OMA in carrying out their corporate social responsibilities in the communities my initiate empowerment program that will sure be benefit not only the women but also the youth. However, Mr Alphonsus Isusu said that all their comment and questions will be reported back to the company (OMA) to look into.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Eze and his cabinet and other members of the community present, and assured the community that OMA Power as a company all things being equal will carry out its corporate social responsibilities in the community. Eze on his part thank the Creekline Consult team for coming, urging the team to carry their message to the project proponent as it was said, assuring that the community is ready to work with the company (OMA Independent Power).

The meeting ended at exactly 3:37pm

**OBUZO-NGWA COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTES OF MEETING**

**VENUE: Eze's Palace, Obuzongwa in Ugwunagbo LGA of Abia State**

**DATE: August 18, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at exactly 9:46am with the opening prayer by His Royal Highness (Eze Daniel Ogbulu). The Eze welcome the team, saying he was given information on our coming, and said he is delighted to see the team. Thereafter, the led consultant of Creekline Consult Ltd Community survey team, Alphonsus Isusu, introduced the team members.

The community were represented during the Focus Group Discussion (FGD) by the Eze, Village heads, Council of Chiefs, Women leaders, Youth leaders and community members/other stake holders.

Kola-nut was also offered and blessed by the Eze of the community, Eze Daniel Ogbulu, before it was broken and passed round for eating.

Attendance was taken by Opha Odafe James for Creekline Consult Limited (Community Survey Team)

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The lead consultant of Creekline Consult Ltd, Mr Alphonsus Isusu, gave the presentation in this segment. He started the presentation by saying that though Geometric Power Limited are co-owners of the OMA Power Project, the whole community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

Thereafter, the meeting was further divided into three focus groups for discussion namely - the Elderly group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

Eze Daniel Ogbulu express fear/concern on the possibilities of explosion in as much the plant will be supplied with gas through pipeline and how the company (OMA Power) may want to forestall this. Chief Sunday Ugwu want to know in specific terms how the proposed power plant will benefit the community. While Mrs Grace Appolos want OMA to empower the women. MrKelechi Daniel was concerned about the possibilities of the project attracting vices to the communities.

In responding, MrAlphonsus from Creekline Consult allays the community fears by saying that OMA Independent Power will use the best available technology to forestall any possibilities of gas explosion. And in responding toMr Sunday Ugwu question,

MrAlphonsusIsusu said that it all depends on what the community pressing need(s) are but assuring them that OMA as a company will carry out their corporate social responsibilities to its stakeholder's communities, all things being equal.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Eze especially and every members of the community present, advising them to be reasonable in their demands and most importantly work harmoniously with the company as it's only peace that bring about development.

The meeting ended at exactly 12:29pm

**OBIGA COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTES OF MEETING**

**VENUE: Civic Center, Obiga in Ukwa West LGA of Abia State**

**DATE: August 18, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting commenced at 1:40pm with the opening prayer by the traditional Prime Minister (Chief Cyril Azuonwu). The Chief Cyril Azuonwu welcome the team, and said that the community member present is happy to receive the team. Thereafter, the lead consultant of Creekline Consult Ltd team lead, Alphonsus Isusu, introduced the study team members.

The community were represented during the focus group discussion (FGD) by Traditional Prime Minister, Isiala (Community head), Village heads, Council of Chiefs, Women leaders, Youth leaders and community members/other stake holders.

Thereafter, kola-nut was presented and blessed by the Traditional Prime Minister and given to the Isiala (Community Head) for final blessing before it was broken and passed round for eating.

Attendance was taken by Opha Odafe James for Creekline Consult Limited (Community Survey Team)

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The Creekline Consult Ltd team lead, Alphonsus Isusu, gave the presentation in this segment. He made the presentation by saying that although Geometric Power Limited is co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa

West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The meeting was further shared into three focus groups for discussion namely - the Elder group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The Traditional Prime Minister (Chief Cyril Azuonwu) expressed his joy for the proposed power plant project, however want the company to repair their malfunction water project. Chief Mark Ahunanya (the Isiala) want to know how many slot of employment opportunities and scholarship will be given to Obiga community. Mrs Oluchi Chinedu asked how the women will benefit. The youth, as represented by Mr Ndudim Isaac asked what are the plans put in place by OMA Power to be able to include them in the project implementation.

The Creekline Consult team lead said that, although resources may be limited to meet up with all the host communities' request, OMA Power as a company will look into their needs and see what they can do as it is not in our power to assure the community of anything. In response to Chief Mark question, on what slot will be given to the community in terms of employment and scholarship, Mr Alphonsus advice the community to be patient as it's not in the consultant position to answer such question, however, that such question is better answered by the project when that time comes. Mr Alphonsus Isusu rather assures the community that whatever discussion we have will be taken to the project proponent. On how the women will benefit, Alphonsus Isusu responded that when the project kicks off, the local economy will be boosted; that women can open local eatery around the company premises where workers could eat etc. In responding to Ndudim Isaac, the team lead said that he is very sure that OMA Independent Power will not sideline any group among the host communities, as that was the essence of interacting with both elders, women and youth group to know some of their needs.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Traditional Prime Minister as well as other members of the community for the interaction and importantly for receiving the team well. On the part of the community, the Prime Minister thanked the team and said that the community is willing and ready to work with the company (OMA Ind. Power).

The meeting ended at exactly 3:15pm

**ORGWU (OGWE) COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTE OF MEETING**

**VENUE: CDC Chairman, Orgwu (Ogwe) in Ukwa West LGA of Abia State**

**DATE: August 19, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at around 9:30pm with the opening prayer by the CDC Chairman (Chief Jude Emeka) of the Orgwu village. The CDC Chairman expresses his joy at seeing the team, saying that he had pre-information on our coming…and said he's happy with his people to see the team.

Kola-nut was presented by the CDC Chairman while the Vice Chairman (Mr Okolo Nwala) blessed the kola-nut, and thereafter was broken and shared for eating.

The lead consultant of Creekline Consult Ltd team, Alphonsus Isusu, introduced the study team members while the CDC Chairman in turn introduced the community people as represented during the focus group discussion (FGD) by the CDC Chairman, Vice Chairman, Youth leader, Youth Vice President and other members of the community.

Attendance was taken by Opha Odafe James for Creekline Consult Limited

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The Creekline Consult Ltd team lead, Alphonsus Isusu, gave the presentation in this segment. He made the presentation by saying that although Geometric Power Limited is co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The meeting was further shared into three focus groups for discussion namely - the Elder group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The CDC Chairman (Chief Jude Emeka) asked when the project will kick off. The Youth Chairman (Mr Nwaogwugwu Chigozie) ask question that borders on the type of employment that will be given to the community member especially the youth and the women.

In responding to the questions by the CDC Chairman, Mr Alphonsus Isusu, the team lead said that the project might take sometimes to kick off as every necessary steps has to be taken before the project could commence, noting that our interaction with the community is one of the step and advice the community to be patient. Again, in response to the youth Chairman's question on what type of employment that will be given to the community members, the Creekline Consulting team lead said that employment could be categorized into permanent and casual (contract) and also depends on individual qualification, however, that the project proponent will decide on the criterion they will use to employ when that time comes as that can't be determined by Creekline Consult. Mr Alphonsus further make the community to understand that we (the study team) are like a messenger, assuring them that their message will be carried back to the project proponent (OMA Independent Power).

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Orgwu village member present and solicit their co-operation always as the proposed power plant project has stages. On the part of the community, the CDC Chairman (Chief Jude Emeka) thanked the team and said that OMA Power should carry the community along always.

The meeting ended at exactly 12:04pm

**OWO-ALA COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTE OF MEETING**

**VENUE: Community Town Hall, Owo-ala in Ukwa West LGA of Abia State**

**DATE: August 19, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at exactly 1:32 pm with the opening prayer by the Executive Chairman (Chief Adim Okpokiri) of Owo-ala community. Kola-nut was presented, and blessed by the Chief Adim Okpokiri and broken for eating.

Thereafter, the Creekline Consult team lead, Alphonsus Isusu introduced the study team while the Executive Chairman and the welcomed the study team and also made the introduction of the community members gathered for the meeting as represented during the Focus Group Discussion (FGD) by the Executive Chairman, Vice Chairman, Treasurer, Secretary, Women Chairlady, Youth leaders and other members of the community.

Attendance was taken by Opha Odafe James for Creekline Consult Limited.

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The Creekline Consult Ltd team lead, Mr. Alphonsus Isusu, gave the presentation in this segment. He made the presentation by saying that although Geometric Power Limited is co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The meeting was further shared into three focus groups for discussion namely - the Elder group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The Executive Chairman (Chief Adim Okpokiri) want to know in specific term how the community will benefit from the project as many promises has been made to the community in the past and never been fulfilled. The Women Chairlady wants to know if their children will be given scholarship and employment.

In responding, Mr Alphonsus Isusu advice the community member to be positive in their think, assuring the community that the team will convey their message back to the project proponent. The team lead also reminds them that in the course of focus group discussion, that most of their expectation will be listed out and the company (OMA Independent Power) will look into it. On if the children will be offered scholarship and employment, Mr Alphonsus Isusu told the community that those will be determined by the project proponent.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Owo-ala community member present and urge them to pray for the success of the proposed project as such project do attract development. On the part of the community, the Executive Chairman (Chief Adim Okpokiri) thanked the team and said that the community is ready to work with the company.

The meeting ended at exactly 3:30pm

**COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTE OF MEETING**

**VENUE: Community Town Hall, Umuaka in Ukwa West LGA of Abia State**

**DATE: August 20, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at exactly 12:30 pm with the opening prayer by the Traditional Prime Minister (Chief Anosike Nkem) of Umuaka community. Kola-nut was presented, and blessed by the traditional Prime Minister and broken for eating.

After that, the Creekline Consult team lead, Alphonsus Isusu introduced the study team while the Traditional Prime Minister welcomed the study team and also made the introduction of the community members present for the meeting as represented during the Focus Group Discussion (FGD) by Vice Chairman, PRO, Secretary, Women leader, Youth leader and other members of the community.

Attendance was taken by Opha Odafe James for Creekline Consult Limited.

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The Creekline Consult Ltd team lead, Alphonsus Isusu, gave the presentation in this segment. He made the presentation by saying that although Geometric Power Limited is co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The meeting was further shared into three focus groups for discussion namely - the Elder group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The Traditional Prime Minister asked how the community will benefit from the proposed project. The Youth Leader said that in as much the company sends the team for interaction with the community, that he believes the company started on a good note and pleaded that the company should always remember the community when they start operation.

Mr Alphonsus while responding to the Traditional Prime Minister's question said that from the expectations/needs of the community, the company (OMA Independent Power) will look into it, and probably see how they can help the community. On the youth leader's comment, Mr Alphonsus, the Creekline Consult team lead thank him and said he believe OMA Power will not forget her host communities all things being equal.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Traditional Prime Minister as well as other members of the community for the interaction and importantly for receiving the team well. On the part of the community, the Prime Minister thanked the team and said that the community is willing and ready to work with the company (OMA Ind. Power).

The meeting ended at exactly 2:10pm

**IHIE-IYI COMMUNITY**

**FOCUS GROUP DISCUSSION (FGD) MINUTE OF MEETING**

**VENUE: Eze Palace, Ihie-Iyi in Ugwunagbo LGA of Abia State**

**DATE: August 30, 2015**

**I. Opening Remarks/Attendance/Introduction**

The meeting started at exactly 12:30 pm with the opening prayer by the His Royal Highness of Iyie-Iyi community. Kola-nut was presented, and blessed by the Eze and broken for eating.

Thereafter, the Creekline Consult team lead, Alphonsus Isusu introduced the study team while the Eze asked the community members to introduce themselves one after. The community member present during the Focus Group Discussion (FGD) are Village Head, Youth leaders, Women leaders, Chairman, and other members of the community.

Attendance was taken by Opha Odafe James for Creekline Consult Limited.

**II. Creekline Consult Limited Presentation (Community Survey Team) Presentation**

The Creekline Consult Ltd team lead, Alphonsus Isusu, gave the presentation in this segment. He made the presentation by saying that although Geometric Power Limited is co-owners of the OMA Power Project, the entire community had a stake in the project as well.

He gave background information about the OMA Power Project. He said both GP and GE were undertaking the project; that phase one (1) of the project would erect/develop a 500MW gas fired open cycle power plant which would be located at Orgwu-Ogwe in Ukwa West LGA. He said the reason for the power project was to realize the most efficient use of energy resources.

In addition, he told attendees that the project would result in various positive and negative interactions within the host communities and the environment.

The meeting was further shared into three focus groups for discussion namely - the Elder group, Women group and Youth group.

**III. Comments/Questions from Stakeholders and answers given by Creekline:**

The Eze commended the company (OMA) for sending the study team of Creekline Consult to the community for interaction, noting that through the interaction the company will be able to know more about the community and their needs and possibly see how the company may be of help to the community. The Women leader also commend the company but noted that the women should not be sidelined in whatever benefits that will come to the community from the company (OMA Independent Power).

The Creekline Consult team lead, Alphonsus Isusu thanked the Eze and the Woman leader on their commendation and said their message will be taken back to the project proponent.

**IV. Vote of Thanks/Closing**

Mr. Alphonsus thanked the Eze and his Council of Chief, Village Heads, and other members of the community for receiving the team well. On the part of the community, the Eze thanked the team and said that the community is willing and ready to work with the company (OMA Ind. Power).

The meeting ended at exactly 2:14pm