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Bowen Gas Project SREIS

AUSTRALIA

Supplementary Air Quality Technical Report

March 2014
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URS

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ABBREVIATIONS

Abbreviation	Description
%	percent
°C	degrees Celsius
°E	degrees east
°S	degrees south
APM	airborne particulate matter
Arrow	Arrow Energy Pty Ltd
BOM	Bureau of Meteorology
CGPF	central gas processing facility
CO	carbon monoxide
CO_2	carbon dioxide
CSG	coal seam gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model
DERM	Department of Environment and Resource Management
EHP	Department of Environment and Heritage Protection
EIS	Environmental Impact Statement
ekW	Electrical Kilowatts
EPA	Environmental Protection Agency
EP Act	*Environment Protection Act 1994*
EPAV	Environment Protection Authority Victoria
EPP (Air)	*Environmental Protection (Air) Policy 2008*
FCF	Field Compression Facility
FPM	fine particulate matter
GAMS	Gladstone Airshed Modelling System
GRS	Generic Reaction Set
g/s	grams per second
H_2O_2	hydrogen peroxide
H_2SO_3	sulfurous acid
H_2SO_4	sulfuric acid
Hz	hertz
IIEPG	Infield Integrated Electrical Power Generation
K	Kelvin
kg/a	kilograms per annum
km	kilometre
km^2	square kilometre
kVA	kilovolt amperes
LNG	Liquefied Natural Gas
m	metre
m/s	metres per second
m^3	cubic metre

Abbreviation	Description
mg/m^3	milligrams per cubic metre
$\mu g/m^3$	micrograms per cubic metre
MJ/m^2	megajoules per square metre
µm	micrometre
mm	millimetre
mtpa	million tonnes per annum
MW	megawatt
NEPC	National Environment Protection Council
NEPM (Ambient Air Quality)	National Environment Protection Measure (Ambient Air Quality)
NO_2	Nitrogen dioxide
NO	nitrogen monoxide
NO_x	nitrogen oxides
NPI	National Pollutant Inventory
O_2	oxygen
O_3	ozone
PAN	peroxyacetyl nitrate
PM_{10}	particulate Matter with aerodynamic diameter equal to or less than 10 µm
$PM_{2.5}$	particulate Matter with aerodynamic diameter equal to or less than 2.5 µm
ppm	parts per million
Qld	Queensland
RO_x	oxygenated organic and inorganic compounds
Rsmog	smog reactivity
SO_2	sulfur dioxide
TAPM	The Air Pollution Model
The Act	*Environment Protection Act 1994*
TJ/day	terajoules per day
ToR	Terms of Reference
TOC	Total Organic Compounds
TSP	total suspended particulates
URS	URS Australia Pty ltd
V	volts
VOCs	Volatile Organic Compounds

EXECUTIVE SUMMARY

Arrow Energy Pty Ltd proposes an expansion of its gas operations in the Bowen Basin through the Bowen Gas Project (the Project). An air quality assessment was submitted for inclusion in the Environmental Impact Statement (EIS) for the Project (Air Quality Technical Report (Appendix H) of the EIS). Since publication of the EIS for public comment, Arrow's field development plan and conceptual design for the Project has advanced. This progression is the result of ongoing exploration activities that have improved Arrow's understanding of the gas resource and the evolution of the Projects design, planning and operational processes. This has led to a number of design changes to the Project.

Arrow is required to prepare a supplementary report to the EIS (SREIS) to:

- Present information on any material changes to the project description;
- Address issues identified in the EIS as requiring further consideration and/or information; and
- Respond to comments raised in the submission of the EIS.

The objective of this SREIS air quality assessment is to evaluate air emissions from the Project as a result of the proposed Project design changes. This report describes the changes to the air quality assessment for the EIS resulting from refinements to the project description, the inclusion of updated and/or new datasets and supplementary information requested by stakeholders. The report provides an evaluation as to whether the estimated pollutant concentrations applied in the EIS are still relevant after the project description refinements and whether the mitigation measures applied for the EIS are still appropriate to address identified impacts.

The key difference between the EIS and SREIS is power generation. In the EIS, the Project generated electricity from combustion of gas. Grid power supply based on connection to existing electricity transmission infrastructure is the preferred (base case) SREIS power supply scenario. In specific cases, power for the remote wellheads (up to 10% of total number of wells) will be generated locally by gas fired engines. In the event that the infrastructure to provide power to the Project from the electricity grid is not fully developed at the start of the Project, power generation utilising CSG as a fuel source will be used as a temporary alternative (alternative power supply scenario). Electrical power supply from the grid will significantly reduce the number of Project related air emission sources, which would lead to much lower emissions of air pollutants from the Project.

Due to the new concept of multi-well pads that may require a drill rig located at a specific location for a considerably longer period of time, the SREIS also includes evaluation of emissions from diesel combustion to generate power for drilling operations, which were not assessed in the EIS. Further design optimisation has changed the projected flare emission sources. Ramp-up flaring is no longer part of the current concept, and flare emissions from well completions and workovers have been included in the SREIS. Further to this, gas combustion rates for upset conditions flaring have been revised in the SREIS.

The methodology applied to the assessment of regional scale air quality impacts is largely the same in the EIS and SREIS. Atmospheric dispersion modelling of regional scale air quality impacts was undertaken, and this included the modelling of existing and future sources for the purpose of estimating existing background air quality. Background concentrations were estimated to be below the respective air quality objectives for human health and wellbeing, but higher than presented in the EIS as a result of changes to data employed in the National Pollutant Inventory. However, annual average NO_2 background concentrations were predicted to be higher than the corresponding air quality objective for health and biodiversity of ecosystems for three limited areas surrounding coal mines with the highest emissions. These predicted concentrations should be interpreted with caution as regional models are not suitable for identifying local scale impacts. Regional impacts on the ground level concentrations of NO_2 and O_3 were assessed for two scenarios: an alternative (worst case) scenario based on temporary gas fired power generation in the first two years of the Project and the base case scenario of mixed power generation from the grid and gas fired power generation at remote wellheads (10% of total). Emissions from non-Project related sources were also incorporated into the modelling to provide an estimate of cumulative impacts. For the alternative worst case scenario, Project operations were predicted to increase ground level concentrations in the region, with a 2.4% increase in 1-hour average NO_2 concentrations and 2.8% increase in 1-hour average O_3 concentrations. No EPP (Air) objective for human health and wellbeing was predicted to be exceeded in the study area, which is consistent with the EIS. The predicted maximum ground-level concentrations of NO_2 and O_3 concentrations at the sensitive receptor locations were not estimated to exceed any of the EPP (Air) objectives. However as in the modelling of the background air quality, annual average NO_2 concentrations were predicted to be higher than the EPP (Air) objective for health and biodiversity of ecosystems for the same areas surrounding coal mines with the highest emissions. These high concentrations are largely a result of background sources, rather than Project related emissions.

The base case scenario was assessed qualitatively. The emissions from power generation using gas fired engines at remote wellheads were significantly lower compared to emissions modelled for the alternative worst case scenario. Therefore, impacts on regional pollutants (compared to background levels) are expected to be smaller than the increase predicted in the alternative worst case scenario and, therefore, the EPP (Air) objective for human health and wellbeing will be achieved. However, as in the alternative scenario, annual average NO_2 concentrations are likely to be higher than the EPP (Air) objective for health and biodiversity of ecosystems for the same areas surrounding coal mines with the highest emissions. This is largely a result of the increase in background contribution and not Project related emissions

In the local air quality assessment, the minimum separation distance between power generation sources and sensitive receptors were determined for the alternative power generation scenario. The distance for the SREIS power source configuration was estimated to be lower than the EIS configuration. For the largest SREIS power source, this distance should be approximately 1,160 m to achieve compliance with the NO_2 health-based objective. However, a separation distance for gas fired power generation sources at the production facilities will only be required in the event that the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project. For emissions from power generation for drilling and well completions, the minimum separation distance was estimated to be 225 m.

The refined project description indicates that the current development concept no longer requires ramp-up flaring; however flaring during well completions and workovers has been included. No relevant air quality objectives for NO_2, CO and particulate matter were predicted to be exceeded for flaring from well completions and workovers. While the proposed gas flaring rates associated with planned and unplanned upset conditions flaring increased in the

SREIS, predicted 1-hour NO_2 concentrations were estimated to be well below the EPP (Air) objective.

Further assessment of cumulative and localised impacts is still recommended at significant infrastructure development milestones or phases. These could include instances where clustering of sources occurs, infrastructure is developed in close proximity to existing or proposed sources or infrastructure is developed in close proximity to sensitive receptors.

In the EIS, mitigation measures were established to ensure the Project is environmentally acceptable. With the updates to separation distances between power sources and proximate sensitive receptors estimated in the SREIS, the recommended EIS mitigation measures remain valid.

1 INTRODUCTION

URS Australia Pty Ltd (URS) was engaged by Arrow Energy Pty Ltd (Arrow) to undertake an air quality assessment in the preparation of an Environmental Impact Statement (EIS) for the proposed development of the Bowen Gas Project (the Project).

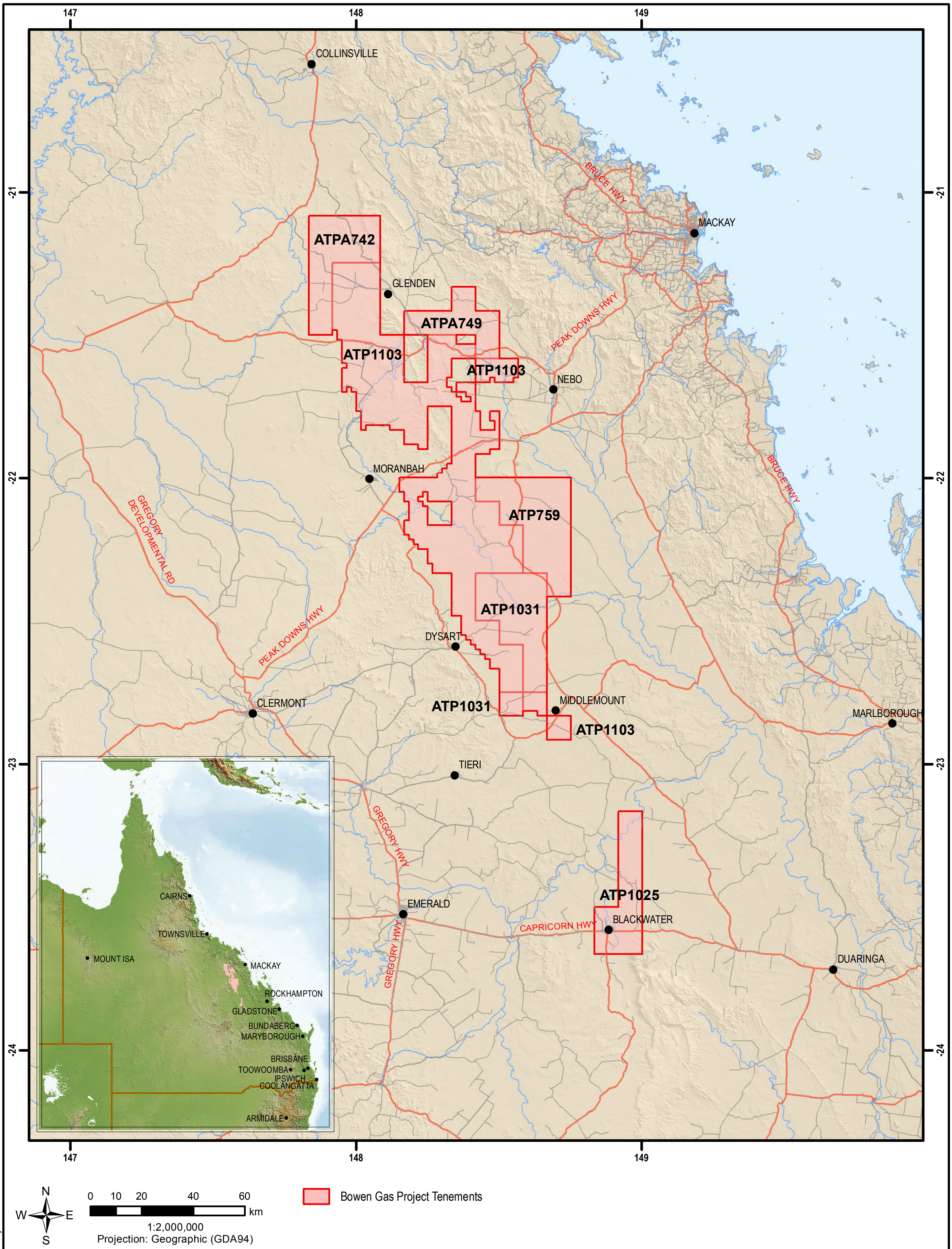
A conceptual description of the Project was developed by Arrow to inform the EIS. The project description formed the basis for all initial baseline environmental studies and guided the approach for how impact assessment studies were conducted for the EIS.

Since publication of the EIS for public comment, Arrow's field development plan and conceptual design for the Project has advanced. This progression is the result of ongoing exploration activities that have improved Arrow's understanding of the gas resource, and the evolution of Arrow's planning and operational processes. Refinements to the basis of design, including revised typical arrangements, configurations, construction methods and coal seam gas (CSG) infrastructure design are being undertaken by Arrow to prepare for the front-end engineering design (FEED) phase and incorporate new design elements to improve efficiencies and reduce the Project's disturbance footprint. Until Project-specific design details have been determined during FEED, this refined project description will remain largely conceptual (see Project Description chapter (Section 3) of the supplementary report to the EIS (SREIS)).

This report describes the changes to the air quality assessment for the EIS resulting from refinements to the project description, the inclusion of updated and new datasets and supplementary information requested by stakeholders. The report provides an evaluation of whether the estimated pollutant concentrations applied in the EIS are still relevant after the project description refinements and whether the mitigation measures applied for the EIS are still appropriate to address identified impacts.

Further discussion of environmental values, potential impacts and mitigation measures are outlined in the Air Quality chapter (Section 9) of the EIS.

Figure 1–1 shows the Project location and study area.



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BOWEN GAS PROJECT SREIS

PROJECT STUDY AREA

AIR QUALITY TECHNICAL REPORT

Figure: **1-1**

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2 PROJECT DESCRIPTION

2.1 Project Description Changes Relevant to Air Quality

Since preparation of the EIS, Arrow has improved its knowledge of the gas reserves and refined the field development plan and design of Project infrastructure. This section provides a description of the changes as a result of refinements to the project description.

2.1.1 Major Infrastructure Components

Changes to major infrastructure components include:

- Construction sequencing and yearly gas production have been revised;
- The location of development areas have been revised; this influences the indicative location of gas production facilities (central gas processing facilities (CGPFs) and field compression facilities (FCFs));
- The number of CGPFs has reduced from three to two. The CGPFs will have co-located water treatment facilities;
- The number of FCFs has increased from 10 to 33 (as a result of drainage area radius being reduced from 12 km to 6 km);
- The term ‘integrated processing facility’ is no longer being used; and
- The planned number of production wells has reduced from 6,625 to approximately 4,000 wells. Wells will be clustered together onto common well pads where possible, with a maximum of 12 wells per pad (6 production and 6 lateral wells).

2.1.2 Electrical Power Supply Options

2.1.2.1 Base Case

Grid power supply based on connection to existing electricity infrastructure is the preferred (base case) SREIS power supply scenario. However, it may not be feasible to connect some remote wells to the Arrow built electricity distribution field network. Therefore, gas fired wellheads would be used to generate power at these remote wells. Local well head power generation has been assumed conservatively for 10% of wells.

2.1.2.2 Alternative Case

Temporary power generation using CSG at the Project facilities (CGPFs and FCFs) for the first two years of Project life, with connection to the existing electricity network from the third year onwards, is considered as an alternative power supply scenario if grid connection is not completed on time. The temporary power installed at the FCFs over the first two years will provide power for the wells through an overhead distribution network and if required underground. In specific cases, power for some remote wellheads (up to 10% of total number of wells) will need to be generated locally at the wellhead by small gas fired engines.

2.1.3 *Power Requirements for Project Facilities*

Changes to Project facility power supply requirements include:

- CGPFs will have a 44 MW maximum power supply requirement, including power supplied to water treatment facilities, compared to 60 MW assessed in the EIS;
- The maximum power demand for FCFs has increased from 19 MW assessed in the EIS to 35 MW for the SREIS. However, in the first two years of Project life the maximum power demand for FCFs is estimated to be 30 MW; and
- The maximum power demand for wellheads has decreased from 60 kW assessed in the EIS to 20 kW for the SREIS.

2.1.4 *Changes to Power Generation Equipment*

Changes to power generation equipment include:

- For the temporary power generation option at the Project facilities, a fleet of typical gas engines, each with a capacity of 1.16 MW (temporary), is being considered. A fleet of 3 MW gas engines was assessed in the EIS;
- Multi-well pads share common surface infrastructure, including power supply. To estimate emissions from gas fired power generation at the remote multi-well pads, the same gas engines as those assessed in the EIS, were considered in the SREIS; and
- Diesel power generation for drilling operations has been included in the SREIS assessment, based on power availability of four generators with 1 MW engines.

2.1.5 *Project Flaring Options*

Changes to Project flaring options include:

- Under the current development scenario there is no expected requirement for ramp-up flaring at facilities;
- Flaring during well completions and workovers has been included in the SREIS assessment; and
- Upset condition / operational flaring rates have been updated, with the maximum worst-case rates increased.

3 LEGISLATIVE CONTEXT

3.1 National Environment Protection Measure

As discussed in the EIS, the *National Environment Protection Council Act 1994*[1] (NEPC Act) and subsequent amendments define the National Environment Protection Measure (NEPM) as instruments for setting environmental objectives in Australia.

The NEPM (Ambient Air Quality) was first released in 1998 and was amended in 2003. There have been no changes to the NEPM air quality guidelines used for the EIS assessment.

3.2 Queensland Environmental Protection Policies

In Queensland, air quality is managed under the *Environment Protection Act 1994* (EP Act), the Environmental Protection Regulation 2008[2] (EP Regulation) and the Environmental Protection (Air) Policy 2008 (EPP (Air)). The latest reprint of the EP Act includes legislation current as at 23 September 2013, and the latest reprint of the EP Regulation includes all amendments that commenced on or before 20 September 2013. The EPP (Air) was reprinted as at 9 November 2012 to incorporate legislative changes introduced on or before this date. However, there have been no changes to the EPP (Air) air quality guidelines used for the EIS assessment.

3.3 Summary of Project Ambient Air Quality Objectives

The adopted air quality assessment criteria / objectives for the Project are presented in Table 3-1.

Pollutant	Averaging Period	Criteria/Objectives ($\mu g/m^3$)	Jurisdiction	Allowable Exceedences
Carbon monoxide (CO)	8-hour	11,000	NEPM / EPP (Air) [a]	1 day per annum
Nitrogen dioxide (NO_2)	1-hour	250	NEPM / EPP (Air) [a]	1 day per annum
	Annual	62	NEPM / EPP (Air) [a]	
	Annual	33	EPP (Air) [b]	
Ozone (O_3)	1-hour	210	NEPM / EPP (Air) [a]	1 day per annum
	4-hour	160	NEPM / EPP (Air) [a]	1 day per annum
PM_{10}	24-hour	50	NEPM / EPP (Air) [a]	5 days per annum
$PM_{2.5}$	24-hour	25	NEPM / EPP (Air) [a]	
	Annual	8	NEPM / EPP (Air) [a]	

[a] EPP (Air) objective for human health and wellbeing

[b] EPP (Air) objective for ecological health and biodiversity (for forests and natural vegetation)

[1] *National Environmental Protection Council Act 1994*

[2] Queensland Government *Environmental Protection Regulation 2008,* Office of the Queensland Parliamentary Council

4 STUDY APPROACH AND METHODOLOGY

4.1 Overview

In the EIS, generation of electrical power from combustion of gas through a series of gas fired engines and related electrical generators for different types of gas compression, processing and wellhead facilities was considered as a major source of pollutant emissions to air. Therefore, the major change to the Project, with implications to the air quality assessment, is the move away from in-field power generation towards power supply from the electricity grid (base case power supply scenario). Electrical power supply from the grid will significantly reduce the number of Project related air emission sources, which would lead to much lower emissions of air pollutants from the Project.

In the event that the infrastructure to provide power to the Project from the electricity grid is not fully developed at the start of the Project, power generation utilising CSG as a fuel source will be used as a temporary alternative (alternative power supply scenario). This would occur at selected CGPFs and FCFs, with power distributed from FCFs to the wells.

In specific cases, when grid connection is achieved, it may not be feasible to connect some remote wells to the electricity grid. Therefore, local gas fired power generation would be used to supply power to the remote wells. Local well head generation has been assumed conservatively for 10% of wells.

Updates to flaring conditions, such as flaring type, duration, frequency, and gas consumption rates, lead to changes in pollutant emission rates and, consequently, to modelled impacts on local air quality.

Emissions from diesel power generation for well drilling and completion operations are a source of emissions during the construction phase of the Project. These emissions were not assessed in the EIS.

The location and number of production areas have been revised in the SREIS.

Based on the above refinements to the Project description, the following reassessments were required:

- Regional assessment:
  - Baseline modelling to incorporate the latest information on non-Project related emissions from industrial facilities in the region; and
  - Cumulative impact modelling to incorporate the latest information on non-Project related emissions from industrial facilities in the region and updates to Project related sources for two power generation scenarios:
    a) Alternative scenario (temporary gas fired power generation for the first two years, with grid connection to the network from the third year onwards with 10% of wells gas fired locally); and
    b) Base case scenario (grid connection with 10% of wells gas fired locally).

- Localised assessment:
  - Gas fired power generation (alternative power generation scenario) at a CGPF (the most significant source of emissions) to re-estimate the minimum separation (buffer) distance between Project sources and any proximate sensitive receptors;
  - Flaring; and
  - Diesel power generation for drilling and completion operations.

Atmospheric dispersion models are subject to uncertainties caused by estimated model inputs and choices in tuneable model parameters, which affect their performance (Air Quality Technical Report (Appendix H, Section 4.4.4) of the EIS). The impact of these uncertainties is accentuated when the maximum model value is used to represent the ground level maximum. Ground level concentrations at any particular receptor may be skewed and the highest concentration may be significantly higher than the second highest. Peak concentrations, therefore, are particularly sensitive to model error. Therefore, to reduce the impact of model uncertainty, the second highest modelled concentration has been used to represent the maximum predicted ground level concentrations in this assessment.

Oxides of nitrogen (NO_x), as nitrogen dioxide (NO_2), were identified as the main pollutants of concern in the EIS. Other pollutants, such as ozone (O_3), volatile organic compounds (VOC), particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), and odour were found not to exceed the statutory air quality objectives. However, the refinements to Project operations include Project activities that were not previously impact assessed, such as diesel power generation for drilling and completion operations and new flaring option (flaring during well completions and workovers). Therefore, to assess the impacts from the revised Project activities and re-assess the impacts presented in the EIS based on the refined project description, the SREIS assessment was focused on the following key air pollutants:

- Oxides of nitrogen (NO_x), as nitrogen dioxide (NO_2);
- Ozone (O_3);
- Particulate matter (PM_{10});
- Particulate matter ($PM_{2.5}$);
- SO_2;
- CO; and
- VOCs.

Consistent with the definition of VOCs adopted for the National Pollutant Inventory (DEWHA, 2009)[3], VOCs assessed in this report are defined as any chemical compound based on carbon chains or rings with a vapour pressure greater than 0.01 kPa at 293.15 K that participate in atmospheric photochemical reactions. Methane is specifically excluded from this definition of VOCs.

4.2 Emissions to Air

This section provides the updated maximum expected emission rates and physical stack parameters for the main potential sources.

[3] http://www.npi.gov.au/resource/npi-definition-volatile-organic-compounds

4.2.1 Power Generation

4.2.1.1 *Facility Power Generation*

The current development scenario (base case) is to have a permanent power supply via electricity from the grid to supply Project facilities, with up to 10% of wells powered locally by gas fired engines. An alternative worst case power supply scenario of the Project assumes gas fired power generation in the first two years, with grid connection and with 10% of wells powered locally by gas fired engines from the third year onwards. Power generation using gas fired engines provides the main source of air emissions from a facility for both scenarios.

Emissions for each production facility were estimated based on the maximum power supply requirements per facility as provided by Arrow. The working assumption adopted from this project description is that the expected ranges of power could be generated by reciprocating gas engines with lean burn technology.

A typical configuration for power generation adopted for this assessment is based on 1.16 MW gas engines (unit model C1160, N5C produced by CUMMINS). This is the same reciprocating gas engine proposed as 'configuration 1' in Section 5.2.1 of the Surat SREIS (Arrow, 2013); it has the higher emission rates than the other engine considered by Arrow. The maximum facility requirements expressed as total megawatt (MW) and a number of 1.16 MW gas engines are presented in Table 4-1.

Table 4-1 Maximum Power Generation Gas Engine Requirements per Facility Assumed for the Alternative Power Supply Scenario

Facility	Peak gas flow (TJ/d)	Total power demand (MW)	No. of 1.16 MW units
CGPF1/ WTF1 (co-located with CGPF1)	430	44	40
CGPF2/ WTF 2 (co-located with CGPF2)	344	36	33
FCF01	109	30	28
FCF02	114	30	28
FCF04	41	15	15
FCF08	45	15	15
FCF12	22	10	10
FCF19	45	15	15
FCF20	68	20	19
FCF22	43	15	15
FCF27	57	15	15
FCF28	43	15	15
FCF29	45	15	15
FCF31	68	20	19
FCF36	88	25	24
FCF38	38	10	10
FCF39	57	15	15
FCF40	38	10	10

Note: Central gas processing facility (CGPF), water treatment facility (WTF) and field compression facility (FCF).

The physical stack parameters for a 1.16 MW gas engine are presented in Table 4-2.

Table 4-2 Typical 1.16 MW Engine Stack and Emission Specifications

Source	Height of release (m)	Stack diameter (m)	Exit velocity (m/s)	Actual exhaust volume flow rate (m^3/s)	Exit temperature (K)
1.16 MW gas engine	5.21	0.3	55	3.88	742

Pollutant emission estimates for the 1.16 MW gas engines (Table 4-3) are based on equipment manufacturer specifications for 75% fuel consumption load plus additional 10%. Note that emissions for 75% loading are higher than for 100% loading, so this approach is conservative.

Table 4-3 Emissions Estimates for 1.16 MW Gas Engine

Source	Emission Rate (g/s)				
	CO	NO_x	VOC	PM_{10}	$PM_{2.5}$*
1.16 MW gas engine	0.72	0.55	1.45	0.0147	0.0147

* It is assumed that the particulate matter fractions of PM_{10}, and $PM_{2.5}$ are equal in the gas stream (PM profile ID 120 Gaseous Material Combustion http://www.arb.ca.gov/ei/speciate/pmsizevv10001xx20120920.zip)

The Project Description chapter (Section 3) of the SREIS indicates that the peak power requirement for a multi-well pad with up to 12 wells (6 production and 6 lateral wells) is approximately 120 kW, as only the vertical production wells require power. The physical stack parameters and emission rates for a 60 kW engine assessed in the EIS Air Quality Technical Report (Appendix H, Section 5.2.1.5) of the EIS were adopted for the SREIS assessment.

4.2.1.2 *Power Generation for Drilling and Completion Operations*

Diesel power generation for drilling and completion operations is a potential source of emissions to air. These emissions were not assessed in the EIS as the drilling period on a single pad was in the order of weeks, whereas the drilling period at a 12 hole pad can be in the order of over a year. At the time of SREIS preparation, the final rig designs for the Project were not available. The following information is based on Arrow's latest rig proposals. In general, the drilling rigs systems are expected to be run off the central diesel generator sets located at the well pad and will satisfy the following conditions:

- Power availability of 4 (four generator sets) x CAT C32 600 Volts (V), 50 Hertz (Hz),1500 revolutions per minute (RPM) Engines (737 bkW) driving, Rated 1000 kVA @ 1500 RPM;
- Operational time: 24 hours per day;
- Typical load: 50% for 23 hours a day and 100% for up to 1 hour per day over short durations of several minutes at a time;
- Expected drilling time per well:
  - Vertical well: 7 days; and
  - Lateral well: 60 days.

- Expected worst case drilling and completion time per well pad:
  - 12 well pad: 450 days;
  - 8 well pad: 300 days; and
  - 4 well pad: 150 days.

Physical stack parameters of diesel generator engines are presented in Table 4-4.

Table 4-4 Physical Stack Parameters for Drilling and Completions Power Generation Sources

Height of release (m)	Stack diameter (m)	Exit velocity (m/s)	Actual Exhaust volume flow rate (m^3/s)	Exit temperature (K)
2.5	0.25	31	1.52	782

Emissions from diesel power generation for drilling and completions were estimated based on equipment manufacturer specifications for a series of four generator sets[4]. To calculate the emission rates from diesel power generation, the typical engine load of 50% was assumed for 55 minutes and the extreme engine load of 100% was assumed for 5 minutes for each operational hour.

The calculated emission rates are presented in Table 4-5.

Table 4-5 Emission Rates for Diesel Power Generation (4 generator set)

Emission Rates for Diesel Power Generation					
Pollutant	CO	NO_x	VOC	PM_{10}	$PM_{2.5}$*
Emission Rate (g/s)	0.76	4.56	0.019	0.052	0.052

* It is assumed that the particulate matter fractions of PM_{10}, and $PM_{2.5}$ are equal in the gas stream (PM profile ID 116 Gaseous Material Combustion http://www.arb.ca.gov/ei/speciate/pmsizevv10001xx20120920.zip)

4.2.2 Flaring

4.2.2.1 Ramp-up Flaring

In an effort to reduce gas flaring and therefore air emissions, Arrow expect to minimise flaring associated with the upstream Project ramp-up. Based on the timing of the Surat Gas Project (with the first Arrow LNG Train) and the Arrow Bowen Pipeline Project, the Bowen Gas Project commissioning strategy looks to use gas from the Arrow Bowen Pipeline, backfilled from the Gladstone Gas Hub, for commissioning of wells, FCFs and CGPFs. This would negate the need to use gas from the Project wells for commissioning of the wells, FCFs and CGPFs, and minimises the possibility of excess gas being flared during commissioning of the upstream facilities. Hence under the current development scenario, no ramp-up flaring is expected to take place in any gas field or at any compression facility.

[4] http://s7d2.scene7.com/is/content/Caterpillar/EPD0170-B

4.2.2.2 *Flaring during Well Completions and Workovers*

Gas released during the course of regular well completion and well intervention (workovers) operations will be disposed of at the well site via a lit flare. Individual well characteristics and the type and duration of well intervention activities will significantly impact the duration and intensity of any gas flared. Arrow has advised that flare rates will be, on average, approximately 5,000 m^3/day, but could range from 0 to 225,000 m^3/day (8.39 TJ/day) in an extreme case scenario. An average well intervention is anticipated to take up to 2 days, with flaring typically only occurring for part of this time. As such, total average flaring per well completion or intervention is expected to be in the order of 400 m^3 of gas. For the purposes of this study and as a conservative approach, the extreme maximum rate of 225,000 m^3/day or 8.39 TJ/day was adopted.

4.2.2.3 *Pilot Flaring*

Flaring will not be used for disposal of process gas within the facilities under normal conditions. Each flare requires a pilot flame that will be continuously lit to ensure their readiness state should there be an event due to upset conditions.

Continuous pilot flaring will occur at FCFs and CGPFs with the same rate of 0.02 TJ/day/facility as assessed in the EIS. The pilot flame scenario has not been changed since the EIS and therefore this scenario has not been presented in this study.

4.2.2.4 *Upset Condition / Maintenance Flaring*

Flaring at CGPFs and FCFs may occur due to upset conditions (unplanned) or during maintenance (planned) throughout the operational phase of the Project. Worst-case unplanned and planned maintenance flaring frequency and rates at CGPFs were updated as follows:

- Approximately one occurrence in 2 years at a rate of 360 TJ/day for 21 hours;
- Approximately one occurrence in 5 years at a rate of 141 TJ/day for 22 hours;
- Approximately one occurrence in 3 years at a rate of 62 TJ/day for 18 hours; and
- Approximately 12 occurrences per year at a rate of 30 TJ/day for 41 hours.

Worst-case unplanned and planned maintenance flaring frequency and rates at FCFs were updated as follows:

- Approximately one occurrence in 5 years at a rate of 40 TJ/day for 13 hours; and
- Approximately 10 occurrences per year at a rate of 20 TJ/day for 26 hours.

A maximum rate of 360 TJ/day at a CGPF was adopted for this assessment.

4.2.2.5 *Summary of Emissions from Flaring*

The physical parameters of the flaring stacks are provided in Table 4-6. These are subject to detailed design; however, Arrow does not expect them to differ significantly from those presented.

Table 4-6 Flare Gas Consumption Rates and Physical Stack Parameters

Flaring Type	Gas Consumption Rate (TJ/day)	Height of Release (m)	Stack Diameter (m)	Exit Temperature (K)	Exit Velocity (m/s)
Well completions and workovers	8.39	0.1 *	0.15	1,273	147
Maintenance / upset conditions (maximum rate per Facility)	360.29	50.0	0.60	1,273	250

* horizontal ground flare

Pollutant emissions from flaring are provided in Table 4-8, and are based on emission factors presented in Table 4-7. These factors were adopted from Table 8 – Emission Factors for Flaring of Emission Estimation Technique Manual for Oil and Gas Extraction and Production Version 2[5] published by the Department of Sustainability, Environment, Water, Population and Communities .

The emission factor for VOC presented in Table 4-7 was adjusted based on Bowen CSG composition (98.69% CH_4 and 0.04% VOC). The default emission factor for VOC ($1.5x10^{-2}$ kg/kg of gas) is based on assumed gas composition of 70% CH_4 and 30% of VOC by weight and destruction efficiency of 95%.

Table 4-7 Emission Factors (kg/kg of gas)

CO	NO_x	VOC	PM_{10}
8.70×10^{-3}	1.50×10^{-3}	2.00×10^{-5}	5.60×10^{-5}

Table 4-8 Flaring Emission Estimates

Flaring Type	Emission Estimates (g/s)			
	CO	NO_x	VOC	PM*
Well completions and workovers	16.45	2.84	0.04	0.11
Maintenance/upset conditions (maximum rate per facility)	706.32	121.78	1.62	4.55

* It is assumed that all particulate matter emissions are in the $PM_{2.5}$ size range for which the fractions of PM_{10}, $PM_{2.5}$ and PM_1 are all equal (PM profile ID 120 Gaseous Material Combustion http://www.arb.ca.gov/ei/speciate/pmsizevv10001xx20120920.zip)

4.2.3 Fugitive Emissions

Fugitive gas emissions are associated with sources such as gas processing facilities, water gathering lines, degassing of water at feed dams, production well surface facilities and related

[5] http://www.npi.gov.au/resource/emission-estimation-technique-manual-oil-and-gas-extraction-and-production-version-20

gas production infrastructure. Consistent with the NPI definition of VOCs , methane is specifically excluded from the VOC substance grouping. As described in the Greenhouse Gas Technical Report (Appendix C) of the SREIS, the main impact of methane is on a global scale, as a greenhouse gas and not on local or regional air quality. The same approach to assess fugitive emissions as presented in the EIS was adopted for the SREIS assessment. A conservative emission estimate of 10,000 kg/year of VOCs was assumed in the assessment.

4.2.4 Transport Emissions

Transport emissions were not assessed in the EIS as they were considered to be insignificant. It is not expected that the refined field development plan and Project infrastructure design would lead to an increase in transport emissions. Therefore, transport emissions have not been assessed in the SREIS.

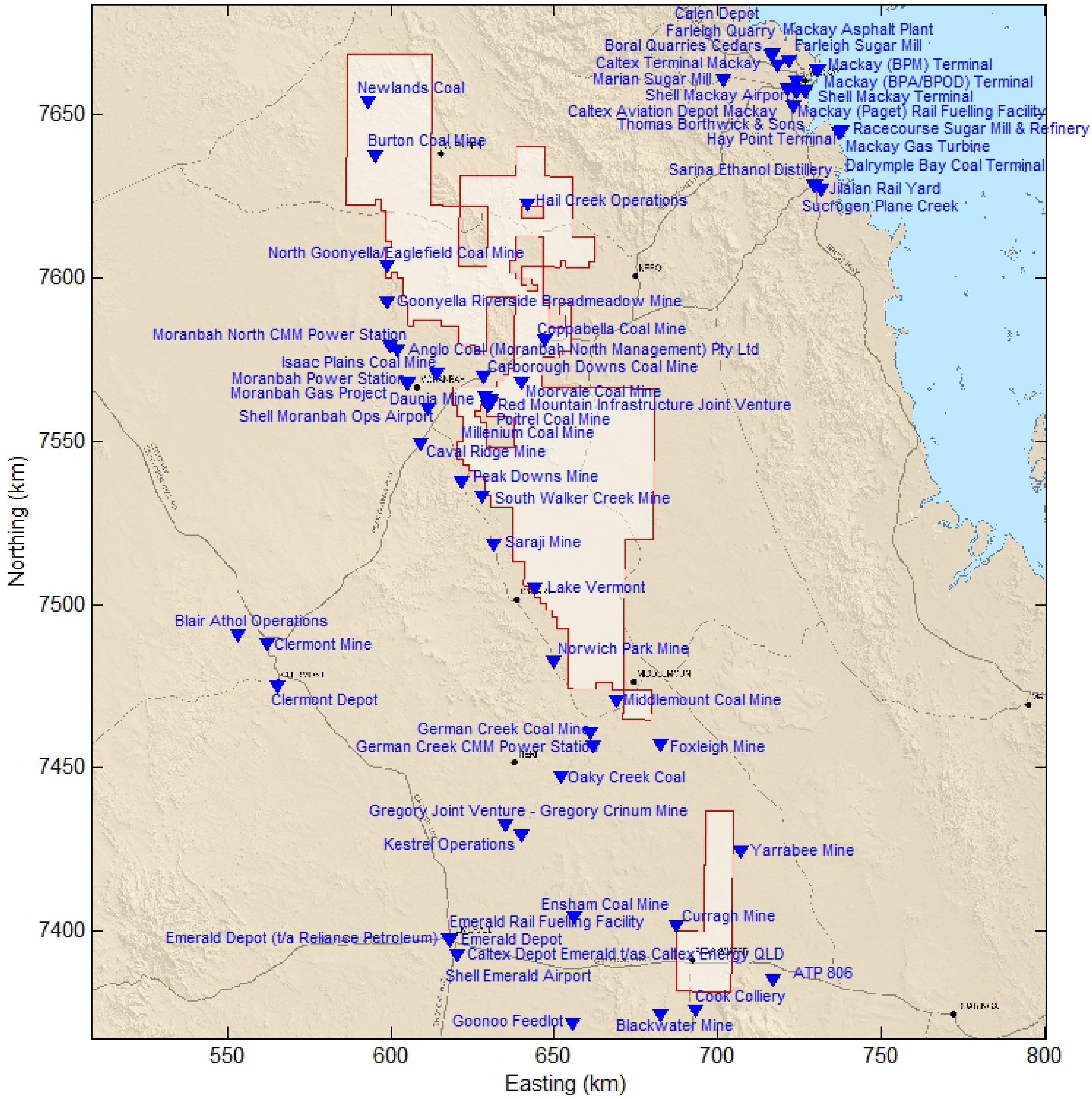
4.2.5 Biogenic Emissions

The approach taken in estimating biogenic emissions (non-Project) in the EIS was to relate them to land use categories and vegetation density using TAPM-generated data (refer to the Air Quality Technical Report (Appendix H, Section 5.2.2.2) of the EIS). The same methodology was used for the SREIS assessment.

4.2.6 Existing and Future Projects in the Region

For the baseline and cumulative impact modelling on a regional scale, a review of non-Project related industrial facilities in the region was undertaken; 68 industrial sources were identified based upon the latest (2011/2012) National Pollutant Inventory (NPI) and available information on future approved projects. Note that 2010/2011 NPI data were used in the EIS. Figure 4-1 indicates the location of the identified sources from the latest NPI Inventory. Data associated with non-Project related sources are presented in Appendix A of this report.

Figure 4-1 Non-Project Related Industrial Air Emission Sources in the Study Area



4.3 Dispersion Modelling Methodology

4.3.1 Overview

The assessment of potential impacts on air quality was carried out using the atmospheric dispersion modelling methodology developed for the EIS.

The modelling methodology involved the following steps:

- Review of the background (baseline) pollutant datasets to ensure that the most recent data were used to represent the existing contaminant levels in the Project area;
- Review of the non-Project related industrial emission sources in the region;

- Baseline dispersion modelling at regional scale to estimate background concentrations of NO_2 and O_3 using an airshed photochemical model (TAPM-GRS);
- Cumulative impact dispersion modelling at regional scale using TAPM-GRS; and
- Local scale dispersion modelling using a steady-state Gaussian Plume model.

No new monitoring data sets representing air pollutant levels in the area were identified; therefore, the conservative monitoring datasets presented in the EIS were used in the assessment. These data sets are from areas that are more urbanised and industrially intensive than the Project area.

Emissions from the 68 identified non-Project related sources were incorporated into baseline and cumulative impact modelling at a regional scale. As in the EIS, ground level concentrations of NO_2 were extracted from baseline modelling to represent the background air quality in the localised assessment.

In the EIS, the Ausplume model was used to assess localised impacts. However, in January 2014 the Aermod[6] model was adopted by the Environment Protection Authority Victoria (EPAV) as the replacement for Ausplume for regulatory air impact assessments. This is significant as EPAV developed and maintained the Ausplume air dispersion model. Therefore, Aermod was adopted for the SREIS assessment. The model is described in the following section.

4.3.2 Aermod Dispersion Model

The Aermod model developed by the American Meteorological Society and United States Environmental Protection Agency (US EPA) as a regulatory dispersion model for near-field applications (less than 50 km), was adopted by the US EPA and promulgated as their preferred regulatory model in 2005.

In Australia, Aermod was adopted by EPAV in January 2014 as the replacement for Ausplume for regulatory air impact assessments.

Aermod is widely used in a number of countries for regulatory and assessment purposes. The model is a steady-state Gaussian atmospheric dispersion model, which uses hourly sequential meteorological data to calculate ground level pollutant concentrations within a specified grid or at discrete receptor locations. The modelling system incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

Aermod has been extensively validated with model evaluation results showing good performance of the model[7],[8] or over-prediction tendency[9].

The model version 12345 released in December 2012 and incorporated into Lakes AERMOD View version 8.2 was used in the assessment.

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[6] http://www.epa.vic.gov.au/~/media/Publications/1550.pdf
[7] http://www.ncbi.nlm.nih.gov/pubmed/23926853
[8] http://www.ncbi.nlm.nih.gov/pubmed/21751580
[9] http://www.epa.gov/scram001/7thconf/aermod/evalrep.pdf

4.3.3 Modelling Approach and Scenarios

4.3.3.1 *Regional Scale*

To evaluate the Project's regional impact on air quality, the EIS considered two scenarios for photochemically reactive compounds (NO_2 and O_3) assuming the Project is powered locally by gas. Emissions from Project operations at year 2023, two years after the Project reaches its full production capacity, were considered in Scenario 1. In Scenario 2, total emissions from fully operational Project facilities were considered as a worst case scenario (refer to the Air Quality Technical Report (Appendix H, Section 7) of the EIS). The model also included natural (biogenic) sources, such as vegetation, and a comprehensive list of 64 existing and approved future industrial sources. The EIS dispersion modelling for both scenarios predicted no exceedences of the EPP (Air) guidelines within the study area.

Since the completion of the EIS for the Project, there have been a number of significant changes to the Project power options as well as to the type, number and location of Project sources and non-Project related sources. This would potentially affect the predicted impacts reported in the EIS. To address this in the SREIS, revised baseline and cumulative impact modelling were undertaken to incorporate the latest information on non-Project related sources (68 current and future approved projects) and updated information on Project related sources.

Two modelling scenarios were considered in the SREIS regional modelling of Project impacts:

- Scenario 1: Alternative temporary power generation using CSG as a fuel source at CGPF and FCF locations assuming Project operation at maximum installed capacity for the first two years; and
- Scenario 2: Base case grid power supply based on connection to existing electricity transmission infrastructure and gas fired power generation at a conservative 10% of wellheads assuming Project operations at maximum capacity.

Scenario 1 was assessed quantitatively and Scenario 2 was assessed qualitatively.

As discussed in the EIS, only VOCs, NO_x, particulate matter and SO_2 emissions were considered in the TAPM-GRS modelling. Pollutants, such as VOCs and NO_x, contribute to the generation of NO_2 and O_3. Since the TAPM-GRS model includes gas and aqueous-phase reactions of SO_2 and particles, these pollutants were also included in the modelling. As in the EIS, a conservative estimate of Project fugitive VOC emissions (10,000 kg/year) was used in the modelling. These emissions were modelled as an area source. However, in the SREIS these emissions were distributed over a much smaller area than in the EIS, as during the first two years of Project life only northern and central production areas will be developed.

Atmospheric dispersion modelling is subject to a number of limitations which are described in the Air Quality Technical Report (Appendix H, Section 4.4.4) of the EIS. Further to the general limitations described in the EIS, it should be noted that the TAPM-GRS model is intended for the estimation of regional scale pollutant concentrations which result from long-range chemical transformations. TAPM-GRS is not an appropriate model for assessing local impacts because of the low spatial resolution of both input parameters such as terrain and concentration outputs which are produced.

4.3.3.2 Local Scale

In the EIS, the dispersion of emissions from gas fired power generation and flaring at local scale was modelled with the Ausplume model. The Aermod model was used in this assessment instead of Ausplume, because Aermod was recently (in January 2014) adopted by the EPAV, as the replacement for Ausplume for regulatory air impact assessments. For consistency with the EIS results, the input model settings, where possible, were kept similar to those used in the Ausplume modelling. This includes a flat terrain assumption for the selected representative regions in the Project area.

The EIS assessment used meteorological data for four locations in the Bowen Basin, representing the northern, north-eastern, central and southern parts of the Project area. EPAV indicates that meteorological files constructed using meteorological data generated by prognostic models such as TAPM are acceptable in situations where there are no measured mandatory data within a 5 km radius of the application site. Therefore, site-specific Aermod meteorological files were extracted from the TAPM prognostic meteorological model to represent the meteorological regions and terrain influences within the Project area. For consistency with the EIS, only one year of meteorological data was considered in the assessment.

In the EIS, ground level concentrations of NO_2 resulting from gas fired power generation were predicted at model receptors set out at different distances from the emission sources for the four regions. The highest concentrations at each distance were selected for the analysis. The results from the region with the highest predicted ground level concentrations were then applied to the whole Project area to assess the potential local impacts and source separation distances. The same approach was adopted for the SREIS assessment to estimate separation distances from power generation sources.

For consistency with the conservative assumptions of the EIS, an ambient NO_x / NO_2 ratio of 0.3 was used and an ambient air quality concentration of NO_2 was extracted from baseline modelling to account for the background concentration of NO_2. For more information on the EIS local scale modelling methodology refer to the Air Quality Technical Report (Appendix H, Section 7.2) of the EIS.

Several modelling scenarios at local scale were considered in the SREIS:

- Alternative temporary gas fired power generation (see Scenario 1 in Section 4.3.3.1 of this report) was modelled to estimate separation (buffer) distance between power sources and any proximate sensitive receptors based on the emissions from the source with the highest emission rates (CGPF);
- Emissions from diesel power generation for drilling operations were assessed to estimate separation (buffer) distance as in the previous scenario for typical engine loads; and
- Emissions from flaring were assessed for a CGPF with the highest emission rates and for flaring during well completions and workovers.

4.3.4 Model Validation

Modelling of complex physical systems is based on the use of numerical techniques to solve a set of governing equations. In general, the more complicated the system that is modelled, the more parameterisations (or approximations) are required in order to solve these equations;

particularly in relation to the representation of sub-grid scale processes. Thus, there are inherently a number of ‘tuneable’ parameters that are required as input into the models. Model developers often suggest default values for these parameters; these may be based on observational data, laboratory experiments or professional experience.

Model validation is a critical component to both model development and application. It is seen as the process by which any differences between model and observation are investigated and where possible minimised. Rarely, however, does a suitable data set exist with which to conduct a detailed, statistically meaningful model validation study. No data sets from the study area were available to validate the air dispersion models used in this study. However, both dispersion models used in this study, TAPM-GRS and Aermod, have been extensively validated and approved for regulatory purposes in Australia by policy-makers. TAPM is Australia’s leading air quality model, used under licence by more than 190 national and international users in 25 countries[10]. Aermod has had regulatory status in the United States since 2005. Many European countries as well as Canada extensively use Aermod for regulatory purposes. In Australia, the EPAV air pollution regulatory model AUSPLUME V6 was replaced by AERMOD on 1 January 2014.

[10] http://www.csiro.au/products/TAPM

5 ASSESSMENT OF POTENTIAL IMPACTS

5.1 Regional Scale

5.1.1 Overview

As in the EIS, TAPM-GRS was used in this study to estimate the existing (background) concentrations of O_3 and NO_x and assess the potential of the Project to cause air quality impacts in relation to ozone.

The pollutants considered in TAPM-GRS modelling are:

- NO_x;
- VOCs (calculated as a reactivity coefficient multiplied by the VOC concentration (Rsmog);
- O_3;
- Particulate matter; and
- SO_2.

Note that TAPM-GRS also includes gas and aqueous-phase reactions of particulate matter and SO_2, therefore, these pollutants were also included in the model.

The emission sources to affect the photochemical transformations in the Project area are:

- Biogenic; and
- Industrial.

The same initial (boundary) concentrations of the pollutants of interest as in the EIS (refer to the Air Quality Technical Report (Appendix H, Section 7.1.2) of the EIS) were adopted for the SREIS assessment.

5.1.2 Modelling of Background Concentrations

5.1.2.1 Model Inputs

TAPM-GRS was configured with the following parameters and datasets:

- Initial (boundary) concentrations as per the Air Quality Technical Report (Appendix H, Table 7–1) of the EIS;
- The pollution grid equivalent to the innermost TAPM meteorological domain (refer to the Air Quality Technical Report (Appendix H, Section 4.4.2) of the EIS). The extent of the grid defines the airshed considered in this study;
- Industrial emission point sources based upon the 2011/2012 NPI. These include a total of 68 existing industrial facilities and future approved projects. For details see Appendix A of this report; and
- Biogenic emissions as described in the Air Quality Technical Report (Appendix H, Section 5.2.2) of the EIS and Section 4.2.5 of this report.

5.1.2.2 Estimated Background Concentrations

The existing (background) concentrations were modelled at each grid point of the modelling domain. A comparison of the second highest and area average concentrations with the EPP (Air) health and well-being based objectives is presented in Table 5-1.

Table 5-1 Predicted Existing (Background) Concentrations

Pollutant	Air EPP Objective (µg/m^3)	Averaging period	Highest concentration (µg/m^3)	Highest concentration averaged across the model grid
NO_2	250	1 hour	171.3*	29.1*
	62	Annual	38.1	2.4
O_3	210	1 hour	168.7*	117.2*
	160	4 hour	134.5*	103.9*

* Second highest modelled concentration to reduce the impact of model uncertainty

Contour plots of the second highest ground-level concentrations of NO_2 and O_3 are presented in Figure 5-1, Figure 5-2, Figure 5-3, Figure 5-4, and Figure 5-5. In general, the predicted background concentrations are higher than those predicted in the EIS. It can be attributed to the fact that higher emissions from more sources were modelled in the SREIS (Table 5-2).

Table 5-2 Comparison of Emissions Modelled in EIS and SREIS (non-project related sources)

Pollutant	Emissions modelled in EIS (t/annum)	Emissions modelled in SREIS (t/annum)
NO_x *	38,116	45,787
VOC	2,842	3,052

* 95% of NO_x was assumed to be NO.

Pollutants, such as VOCs and NO_x, contribute to the generation of NO_2 and O_3. Since the TAPM-GRS model includes gas and aqueous-phase reactions of SO_2 and particles, these pollutants were also included in the modelling. However, they have no significant effect on the photochemical reactions but are required for aqueous phase reactions. Therefore, these emissions are not included in Table 5-3.

The predicted concentrations are below the relevant air quality objectives for human health and wellbeing. The second highest 1-hour average background concentration of NO_2 (171.3 µg/m^3) was predicted for a limited area surrounding Burton Coal Mine, which is a large coking coal mine. The average concentrations of NO_2 are well below this value.

Figure 5-3 is an isopleth plot of annual average NO_2 concentrations from existing sources in the airshed. It shows small areas (red shading) where the background concentration is higher than the air quality objective for the health and biodiversity of ecosystems (33 µg/m^3) for annual average NO_2.

It should be noted that this air quality objective should be applied at locations of off-lease ecological sensitivity within the modelling domain. Therefore, elevated concentrations do not correspond to exceedences of the objective if there are no sensitive ecological receptors.

Furthermore, TAPM-GRS is a low spatial resolution, regional scale photo-chemical model which has been applied in the EIS and SREIS to assess the impact of emissions on air quality within the airshed. Detailed source characteristics needed for local scale impact assessment are not included in the model. It is not, therefore, an appropriate tool for the assessment of localised impacts at sensitive receptors; these impacts are assessed in Section 5.2.

Figure 5-1 Predicted Background Second Highest NO_2 (1-Hour Average) Concentrations ($\mu g/m^3$)

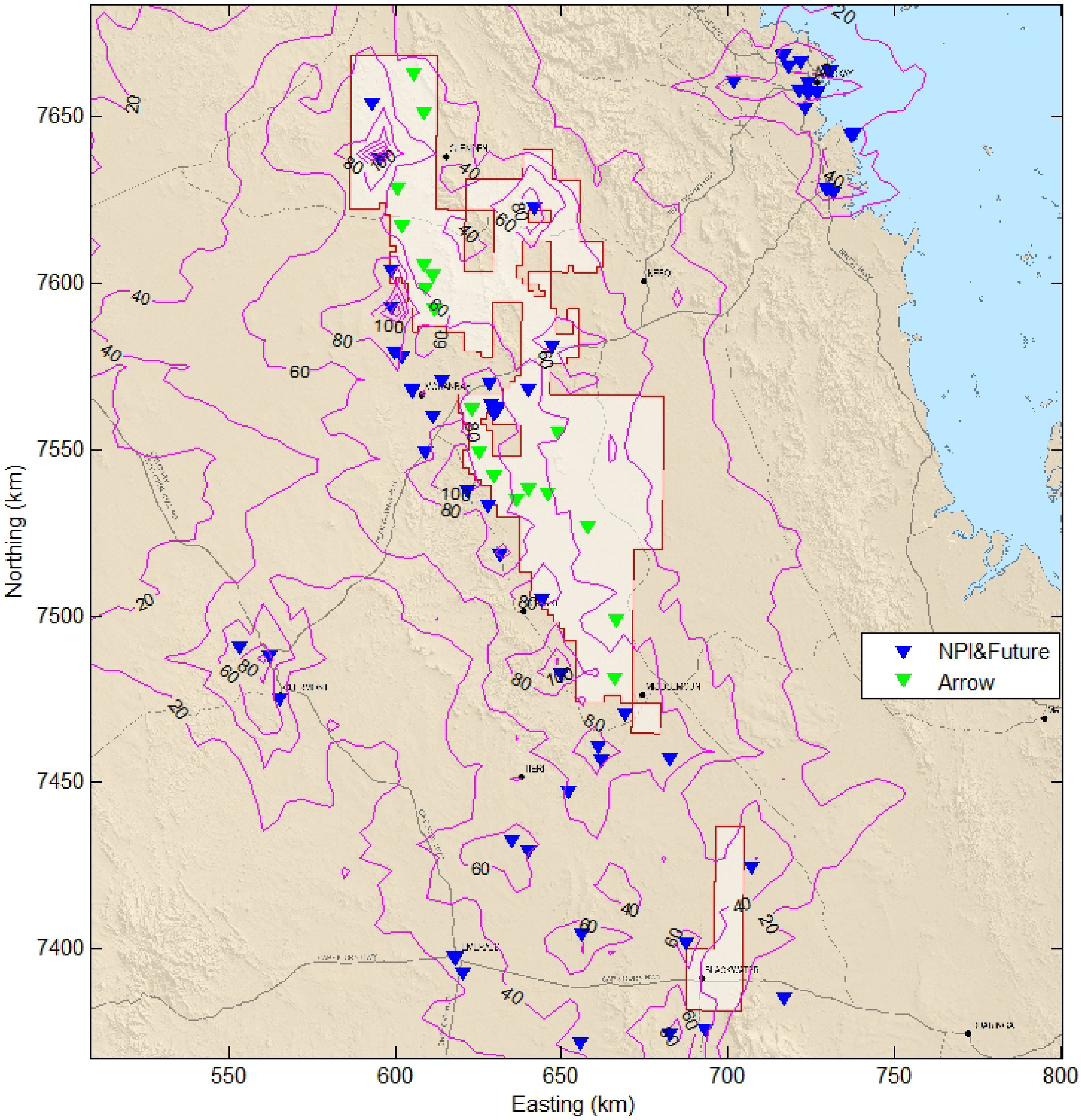


Figure 5-2 Predicted Background Annual Average NO_2 Concentrations (µg/m³)

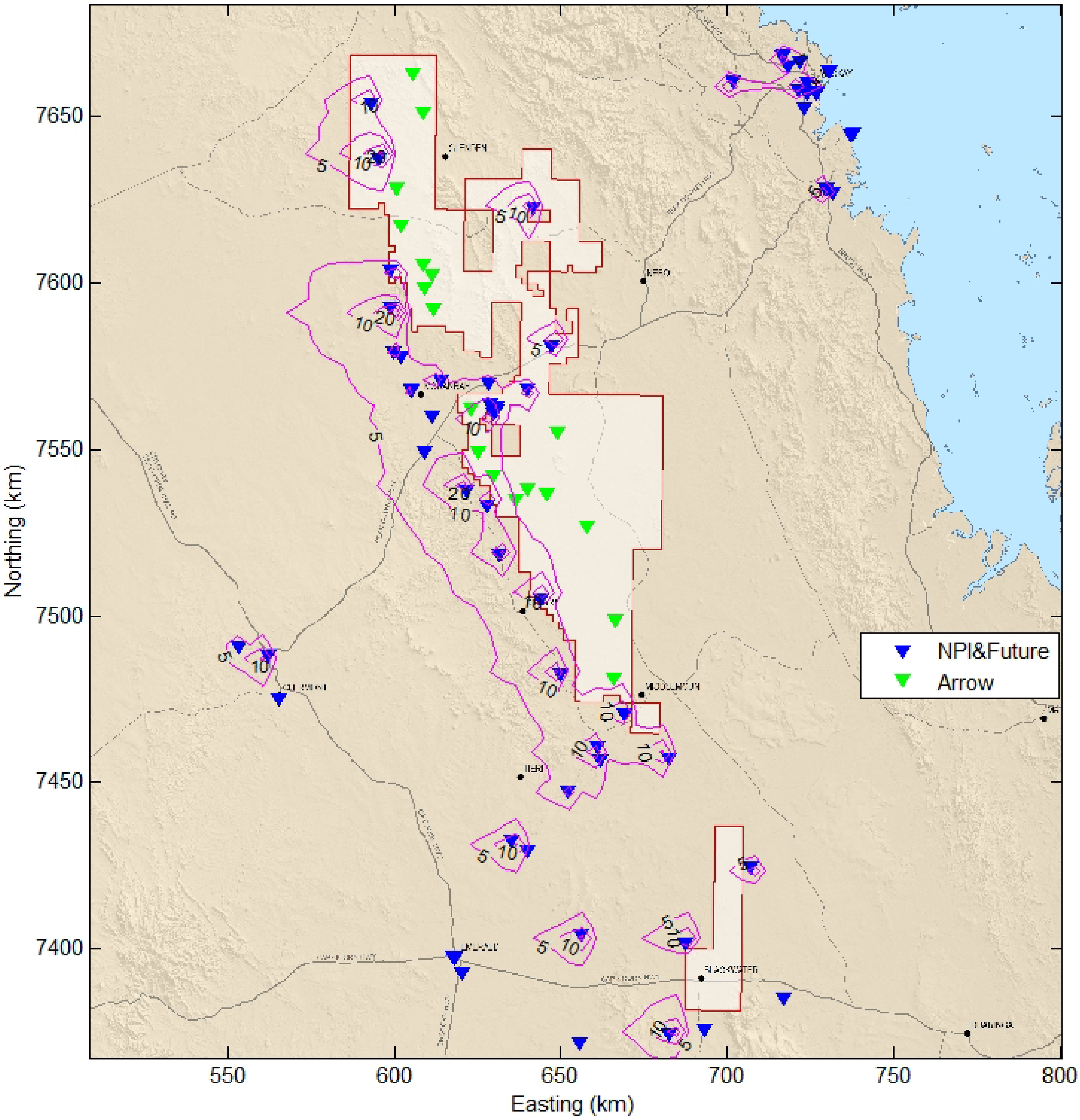


Figure 5-3 Predicted Background Maximum NO_2 Annual Average Concentrations (µg/m³)

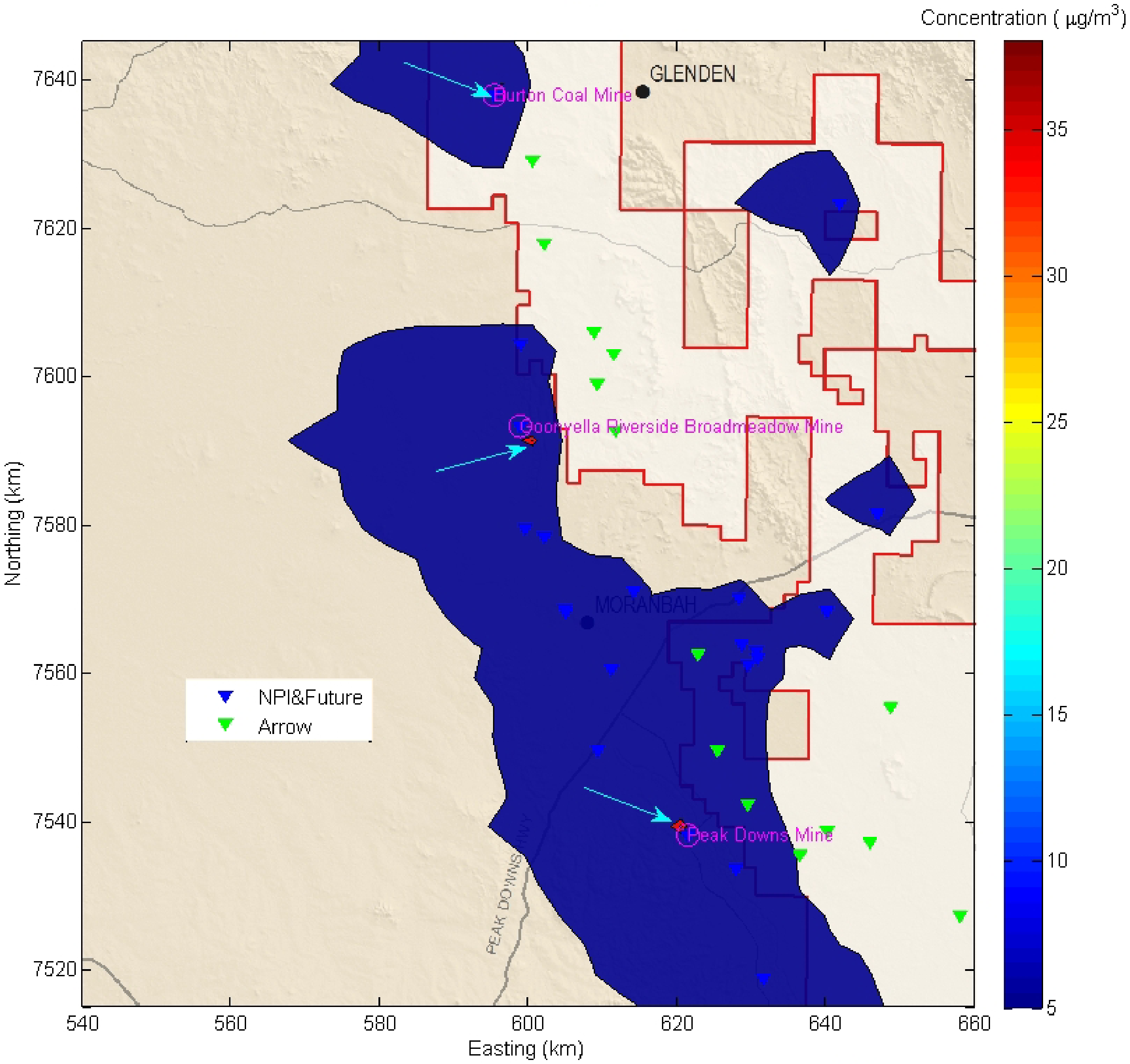


Figure 5-4 **Predicted Background Second Highest O_3 (1-Hour Average) Concentrations ($\mu g/m^3$)**

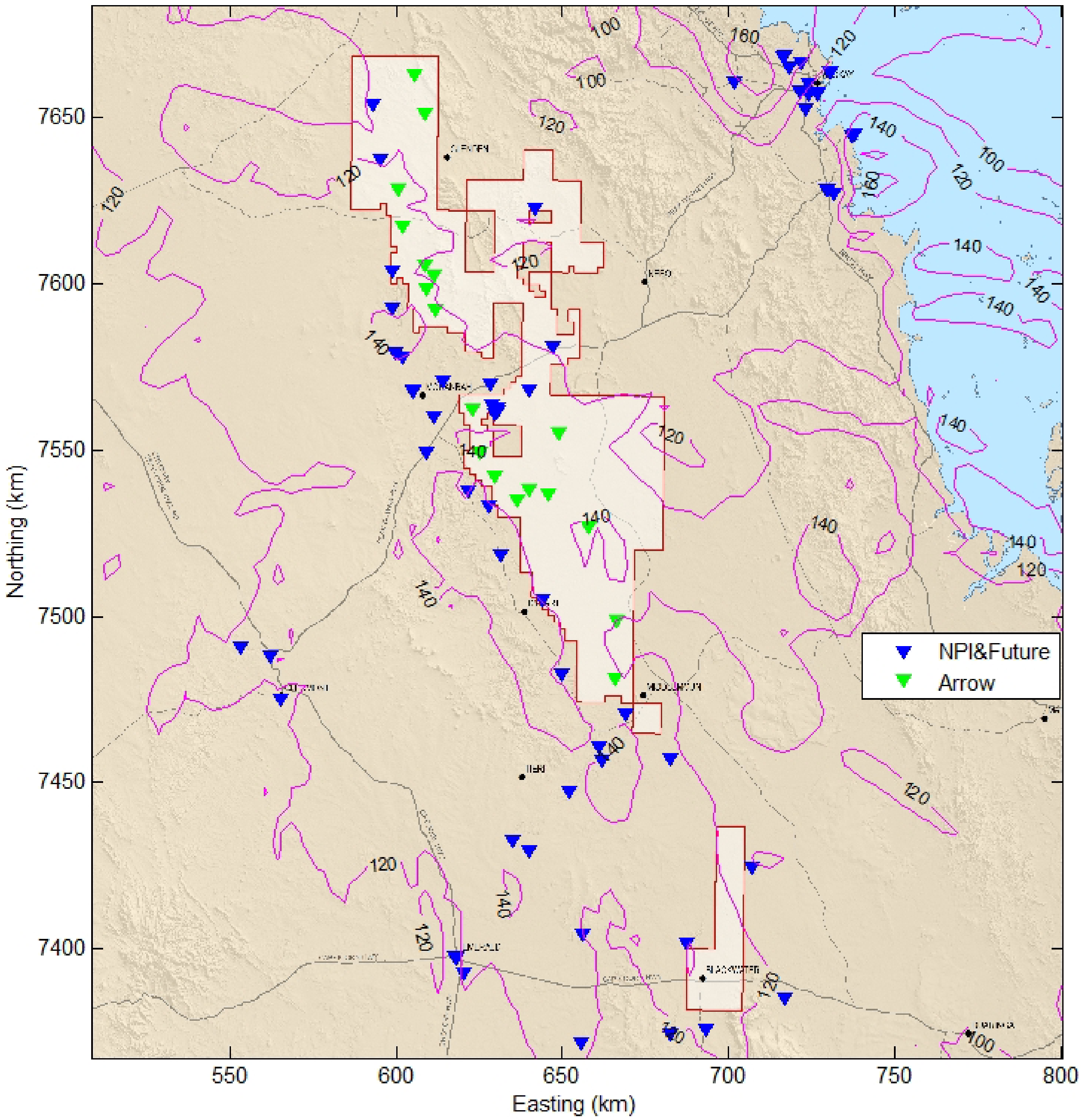
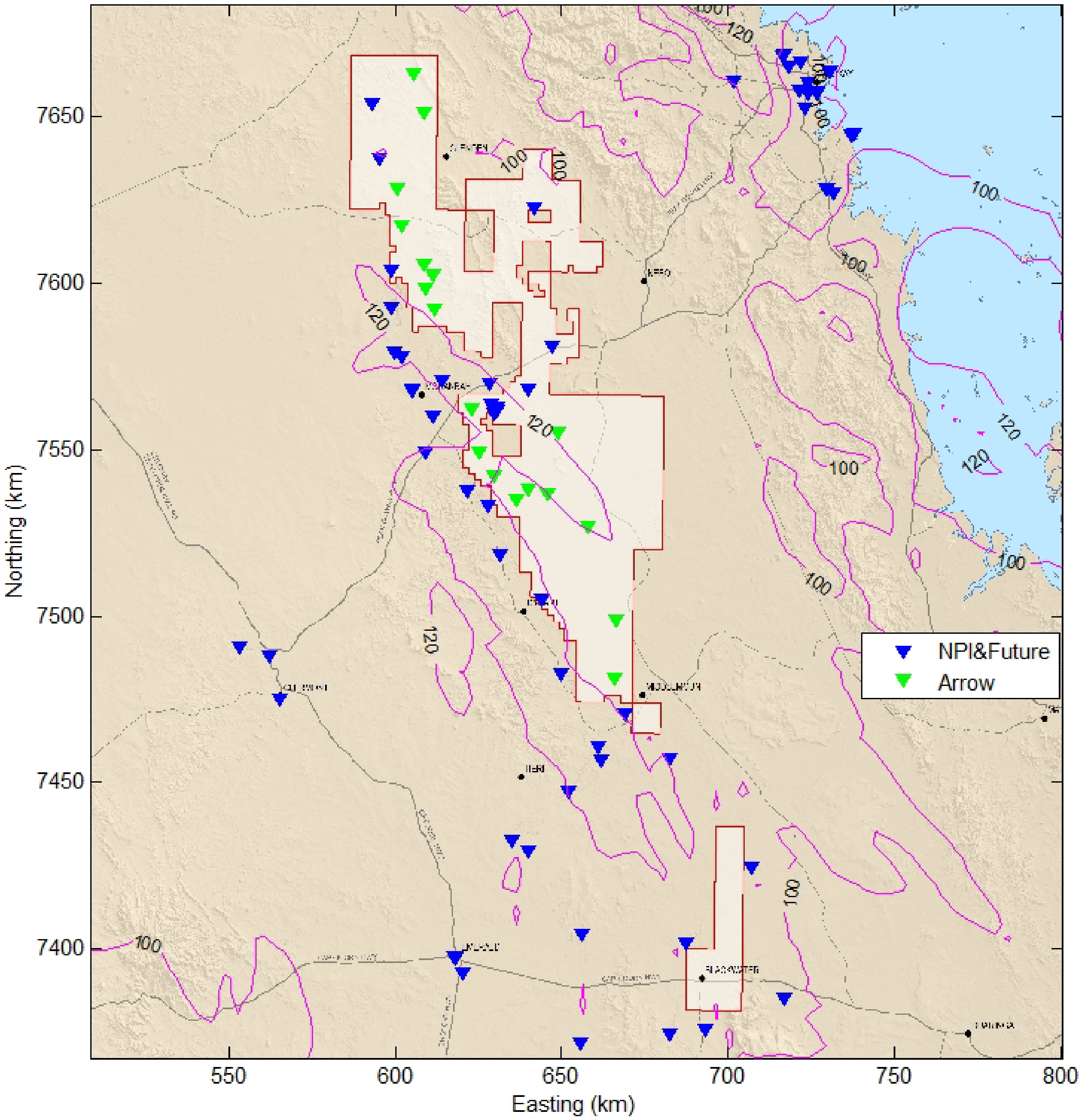


Figure 5-5 Predicted Background Second Highest O_3 (4-Hour Average) Concentrations ($\mu g/m^3$)



5.1.3 Modelling of Regional Impacts

This section evaluates the regional air quality impact due to Project and non-Project related emission sources.

5.1.3.1 Model Inputs

TAPM-GRS was configured with the following parameters and datasets:

- Initial (boundary) concentrations as per the Air Quality Technical Report (Appendix H, Table 7–1) of the EIS;
- The pollution grid equivalent to the innermost TAPM meteorological domain (see the Air Quality Technical Report (Appendix H, Section 4.4.2) of the EIS). The extent of the grid defines the airshed considered in this study;
- Industrial emission point sources based upon the 2011/2012 NPI. These include a total of 68 existing industrial facilities and future approved projects. For details see Appendix A of this report;
- Biogenic emissions as described in the Air Quality Technical Report (Appendix H, Section 5.2.2) of the EIS); and
- Project emissions represented as point (power generation) and area (fugitive emissions) sources as described in Section 5.1.3.2 of this report.

As the final locations of the gas processing facilities and power generation units co-located with them are yet to be confirmed, representative locations for these facilities within production areas were selected for the modelling purposes. Note that these locations are different to those selected in the EIS, as the location and number of production areas have been revised in the SREIS.

5.1.3.2 Summary of Project Emissions

Scenario 1 – Alternative Case: Temporary Power Generation in 2019

Scenario 1 considers emissions from alternative temporary power generation using CSG as a fuel source at CGPF and FCF locations, and fugitive leaks from gas production and processing. At year 2019, Project operations are assumed to reach their maximum production capacity. It is expected that 18 production facilities (16 FCFs and 2 CGPFs) will be operational across the production areas. This scenario also assumes 934 wellheads to be operating at full capacity continuously for the year and two water treatment facilities (WTFs), all powered by gas fired engines installed at the production facilities. Therefore, local gas fired power generation is represented in the model by point sources located at CGPFs and FCFs with capacity to produce power for other Project facilities. Given that the base case power supply scenario is grid supply, this scenario represents ‘worst-case’ emissions from Project operations. The summary of emission release specifications for this scenario is presented in Table 5-2.

In the EIS, emissions from 7 production facilities represented as point sources in the model were considered in Scenario 1 (Project facilities commissioned in 2019) and 17 production facilities in Scenario 2 (all Project facilities), respectively. Emissions from wellhead engines were modelled as distributed point sources within corresponding production areas, with 1,699 wellhead engines considered in Scenario 1 and 1,980 wellhead engines considered in Scenario 2.

Table 5-3 Summary of Total Emission Rates for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)

Facility	Peak gas flow (TJ/d)	Total power demand (MW)	No. of 1.16 MW units	Emission Rate (g/s)		
				NO_x	VOC	PM_{10}
CGPF1/ WTF1 (co-located with CGPF1)	430	44	40	22.00	58.08	0.59
CGPF2/ WTF 2 (co-located with CGPF2)	344	36	33	18.15	47.92	0.49
FCF01	109	30	28	15.40	40.66	0.42
FCF02	114	30	28	15.40	40.66	0.42
FCF04	41	15	15	8.25	21.78	0.23
FCF08	45	15	15	8.25	21.78	0.23
FCF12	22	10	10	6.05	15.97	0.17
FCF19	45	15	15	8.25	21.78	0.23
FCF20	68	20	19	10.45	27.59	0.28
FCF22	43	15	15	8.25	21.78	0.22
FCF27	57	15	15	8.25	21.78	0.22
FCF28	43	15	15	8.25	21.78	0.22
FCF29	45	15	15	8.25	21.78	0.22
FCF31	68	20	19	10.45	27.59	0.28
FCF36	88	25	24	13.2	34.85	0.35
FCF38	38	10	10	6.05	15.98	0.16
FCF39	57	15	15	8.25	21.78	0.22
FCF40	38	10	10	6.05	15.97	0.16

Scenario 2 – Base Case: Grid Power Supply and Gas Fired Power Generation at 10% of Wellheads

Scenario 2 assumes grid power supply based on connection to existing electricity transmission infrastructure and gas fired power generation at selected wellheads (400 or a conservative 10% of the vertical production wells to account for wells that are not feasible to be connected to the distributed electricity network) and fugitive leaks from gas production and processing. Project operations at maximum installed capacity are assumed in this scenario. The summary of emission release specifications for this scenario is presented in Table 5-4.

Table 5-4 Summary of Total Emission Rates for Scenario 2 – Base Case (Grid Power Supply and Gas Fired Power Generation at 10% of Wellheads)

Well Pad Configuration *	Number of Production Wells	Number of Well Pads	No. of 60 kW units per pad	Total No. of 60 kW units	Total power (kW)	Emission Rate (g/s)		
						NO_x	VOC	PM_{10}
4 wells	284	142	1	142	8,520	29.07	1.28	0.13
8 wells	86	22	2	44	2,640	9.01	0.40	0.04
12 wells	30	5	2	10	600	2.05	0.09	0.01

* A 4 well pad configuration consists of 2 production wells and 2 lateral wells, an 8 pad configuration 4 production wells and 4 lateral wells and a 12 well pad 6 production wells and 6 lateral wells.

5.1.3.3 Interpretation of Results

Project regional impacts on the ground level concentrations of NO_2 and O_3 were modelled for Scenario 1 at each grid point of the modelling domain and assessed qualitatively for Scenario 2.

Scenario 1 – Alternative Case: Temporary Power Generation in 2019

A comparison of the maximum and average predicted pollutant concentrations for Scenario 1 are presented in Table 5-5 alongside the EPP (Air) health and well-being based objectives. Contour plots of the predicted ground-level concentrations of NO_2 and O_3 for Scenario 1 are presented in Figure 5-6, Figure 5-7, Figure 5-8, Figure 5-9, and Figure 5-10. The extent of Figure 5-8 has been reduced to show the maximum NO_2 annual average areas which are small.

Table 5-5 Predicted Concentrations for Regional Scale Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)

Pollutant	Air EPP Objective (µg/m^3)	Averaging period	Highest concentration (µg/m^3)	Highest concentration averaged across the model grid (µg/m^3)
NO_2	250	1 hour	167.6*	29.8*
	62	Annual	38.3	2.5
O_3	210	1 hour	170.2*	120.5*
	160	4 hour	139.3*	106.4*

* Second highest modelled concentration to reduce the impact of model uncertainty

In general, Project operations were predicted to increase ground level concentrations of NO_2 and O_3 in the region, with a 2.4% increase in the second highest 1-hour average NO_2 concentrations and 2.8% increase in 1-hour average O_3 concentrations (based on data averaged across the modelling domain). The highest 1-hour average NO_2 concentrations of 167.6 µg/m^3 and 140.3 µg/m^3 were predicted for the limited areas surrounding mines. The average concentrations of NO_2 and O_3 for all averaging periods modelled in this study are well below the maximum predicted values.

No EPP (Air) objective for human health and wellbeing was predicted to be exceeded in the study area. However, as in the modelling of the background concentrations (Section 5.1.2 of this report), annual average NO_2 concentrations were predicted to be higher than the air quality objective for health and biodiversity of ecosystems (33 $\mu g/m^3$) for some areas close to existing coal mines (see Figure 5-8). However, the impact of Project emissions on the ground level concentrations in these areas is very small or negligible.

The predicted maximum ground-level concentrations of NO_2 and O_3 at the sensitive receptor locations are shown in Appendix B of this report. No EPP (Air) objective was predicted to be exceeded at the sensitive receptor locations. However, it should be noted that the locations of the gas processing facilities have not yet been finlaised and are currently indicative. Further to this, the identification of sensitive receptors has at this stage been done as a desktop exercise and is assumed to be conservative.

Scenario 2 – Base Case: Grid Power Supply and Gas Fired Power Generation at 10% of Wellheads

Scenario 2 considers emissions from power generation using gas fired engines at remote wellheads (10% of total number of wells), while other Project facilities are powered by electricity from the local grid. No Project-related emissions are associated with the use of electricity from the outside sources. Table 5-4 presents a summary of emissions considered in Scenario 2. The emissions considered in Scenario 2 are significantly lower compared to emissions modelled in Scenario 1 (Table 5-3). Therefore, the effect on concentrations of photochemical compounds (compared to background levels) will be much smaller than modelled in Scenario 1.

Figure 5-6 Second Highest NO_2 (1-Hour Average) Concentrations ($\mu g/m^3$) Predicted for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)

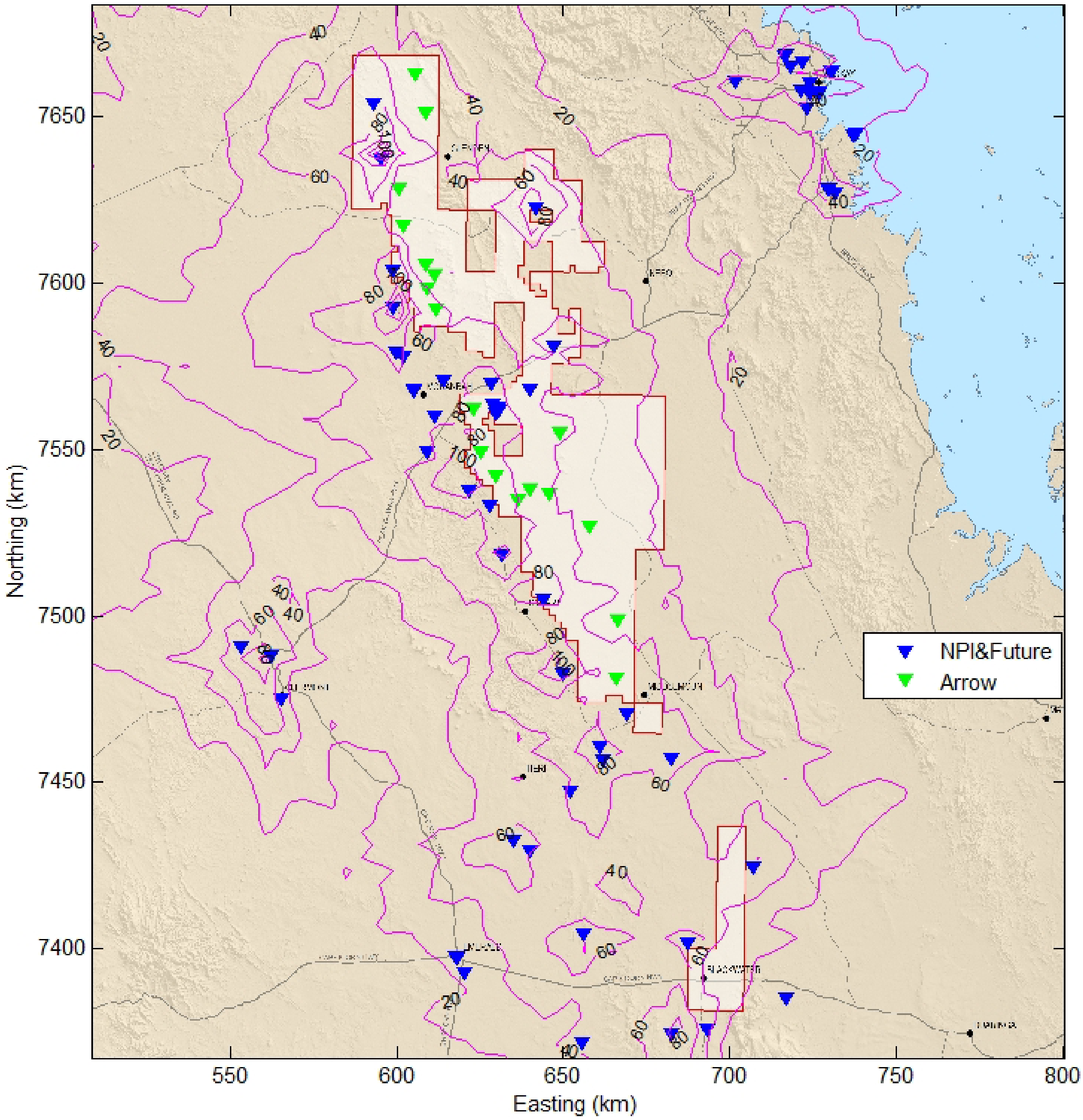


Figure 5-7 **Annual Average NO_2 Concentrations ($\mu g/m^3$) Predicted for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)**

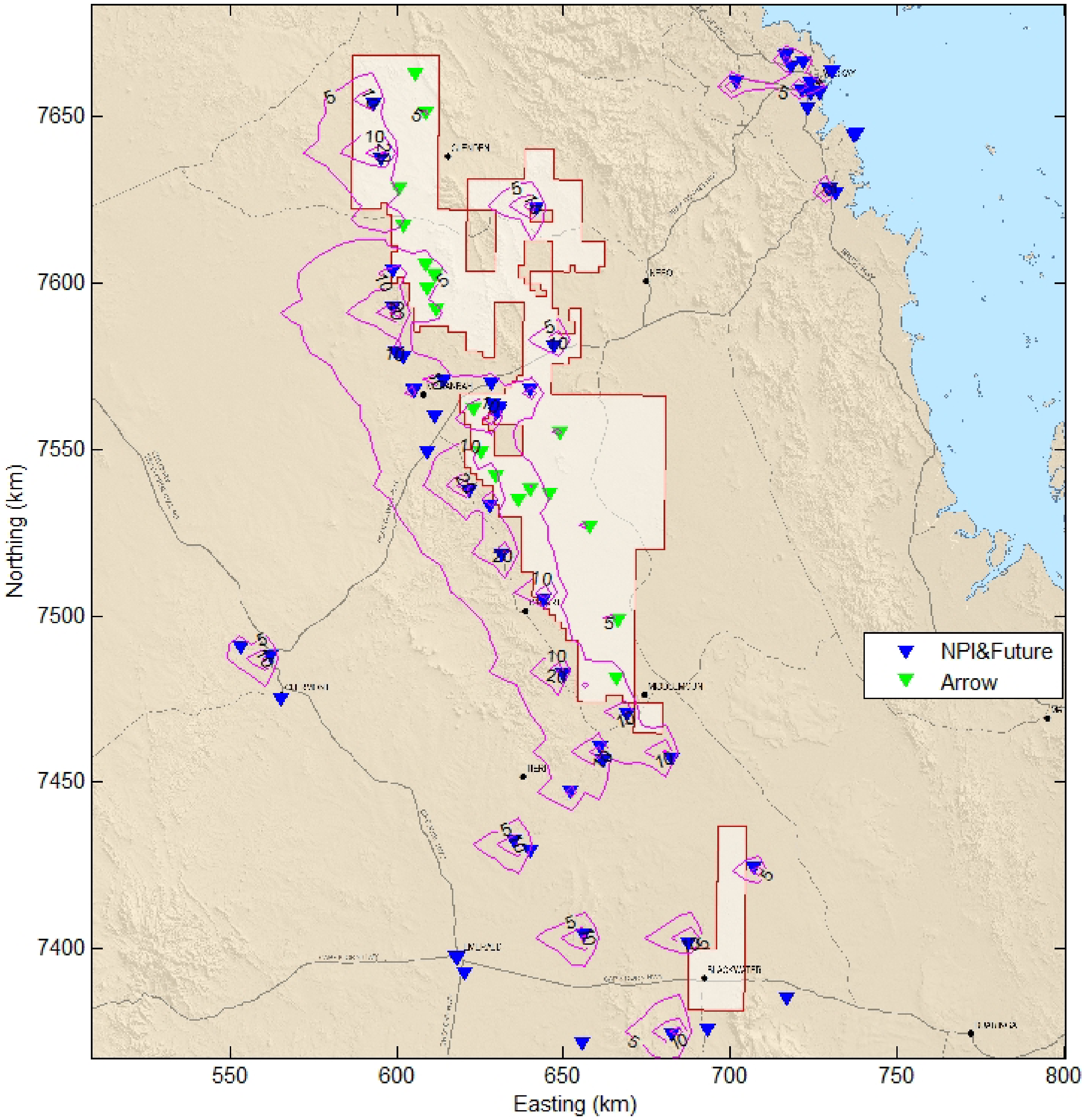


Figure 5-8 Maximum NO_2 Annual Average Concentrations (µg/m^3) Predicted for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation) (plot extent reduced)

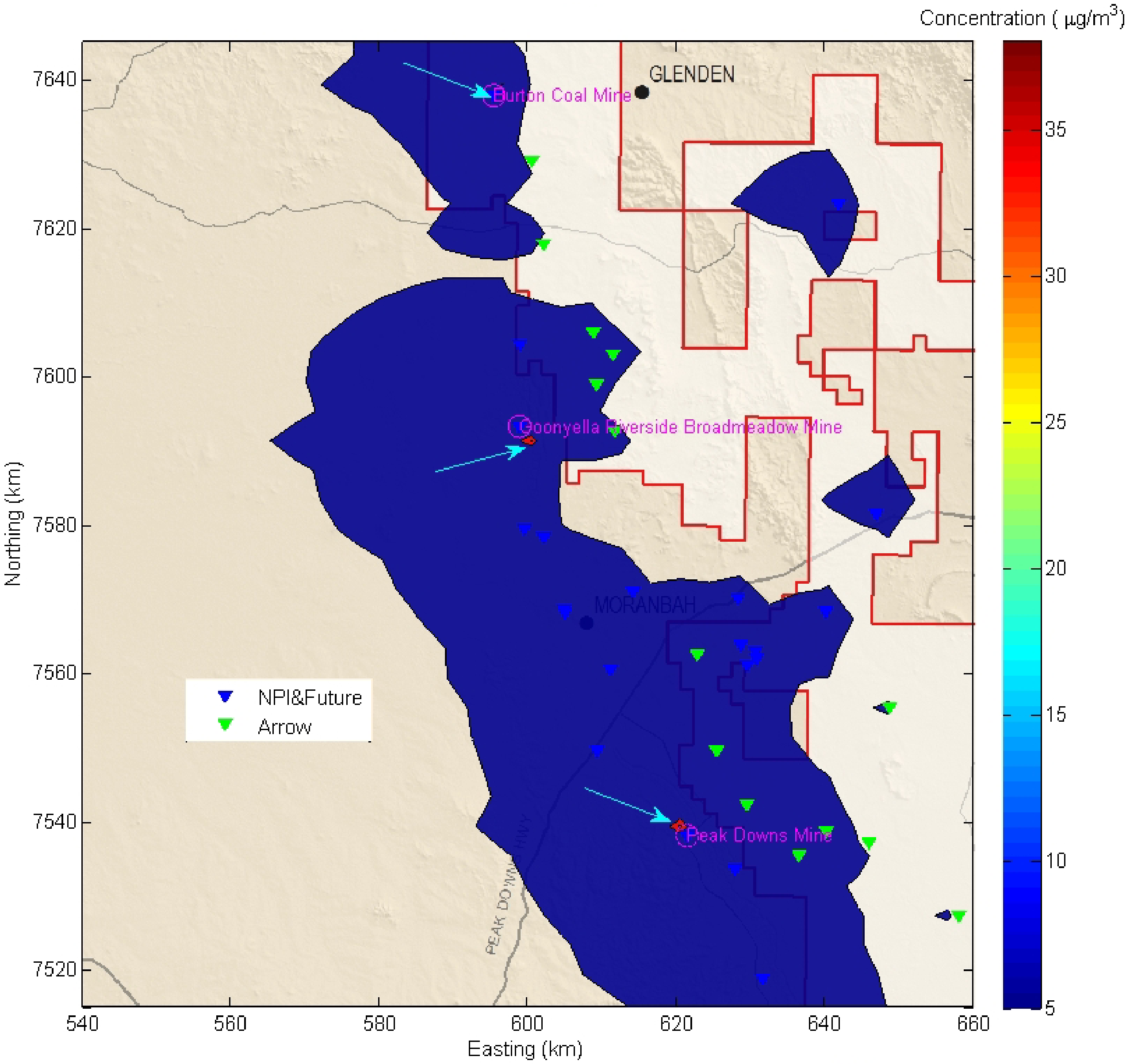


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Figure 5-9 Second Highest O_3 (1-Hour Average) Concentrations (µg/m[3]) Predicted for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)

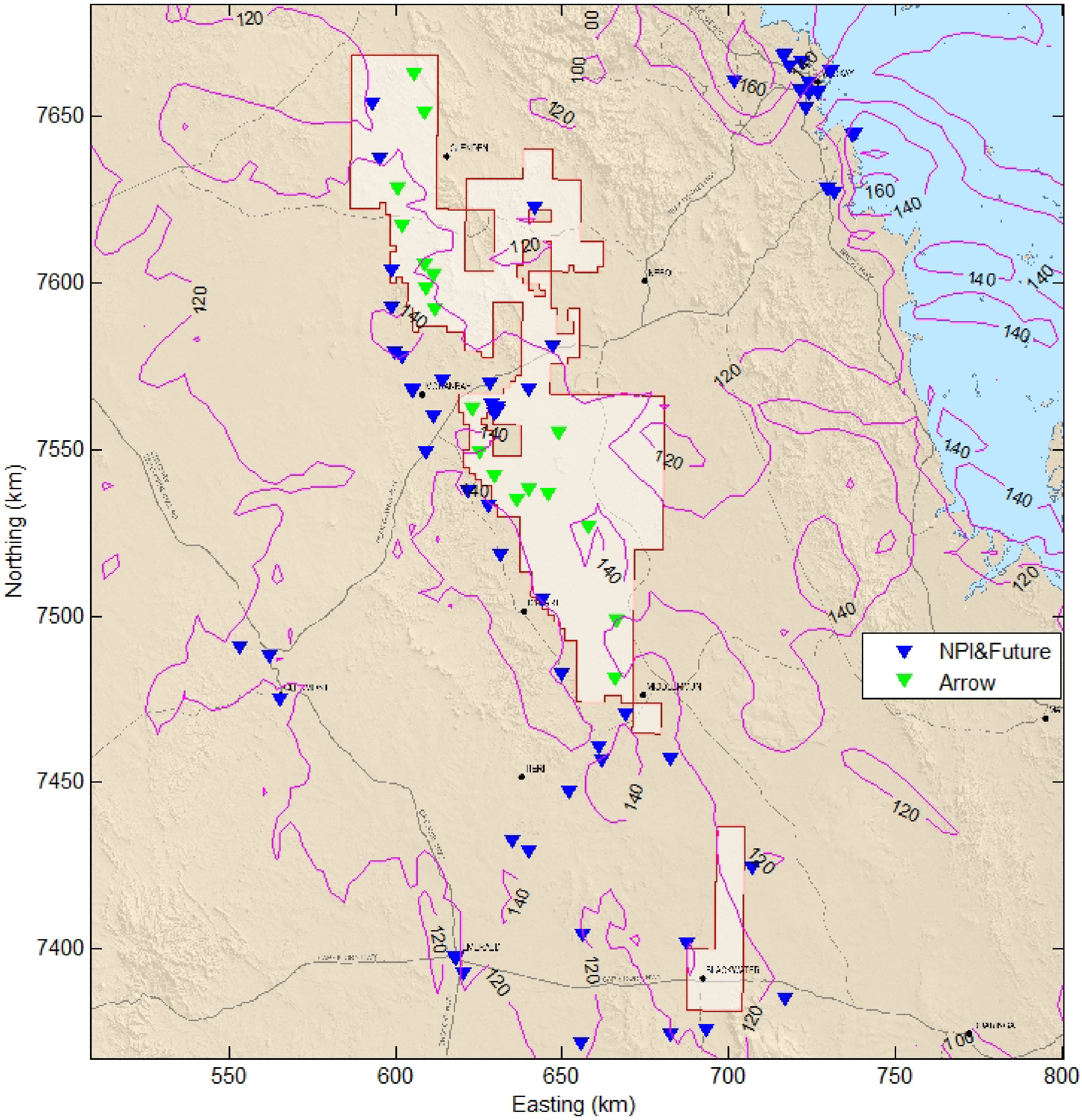
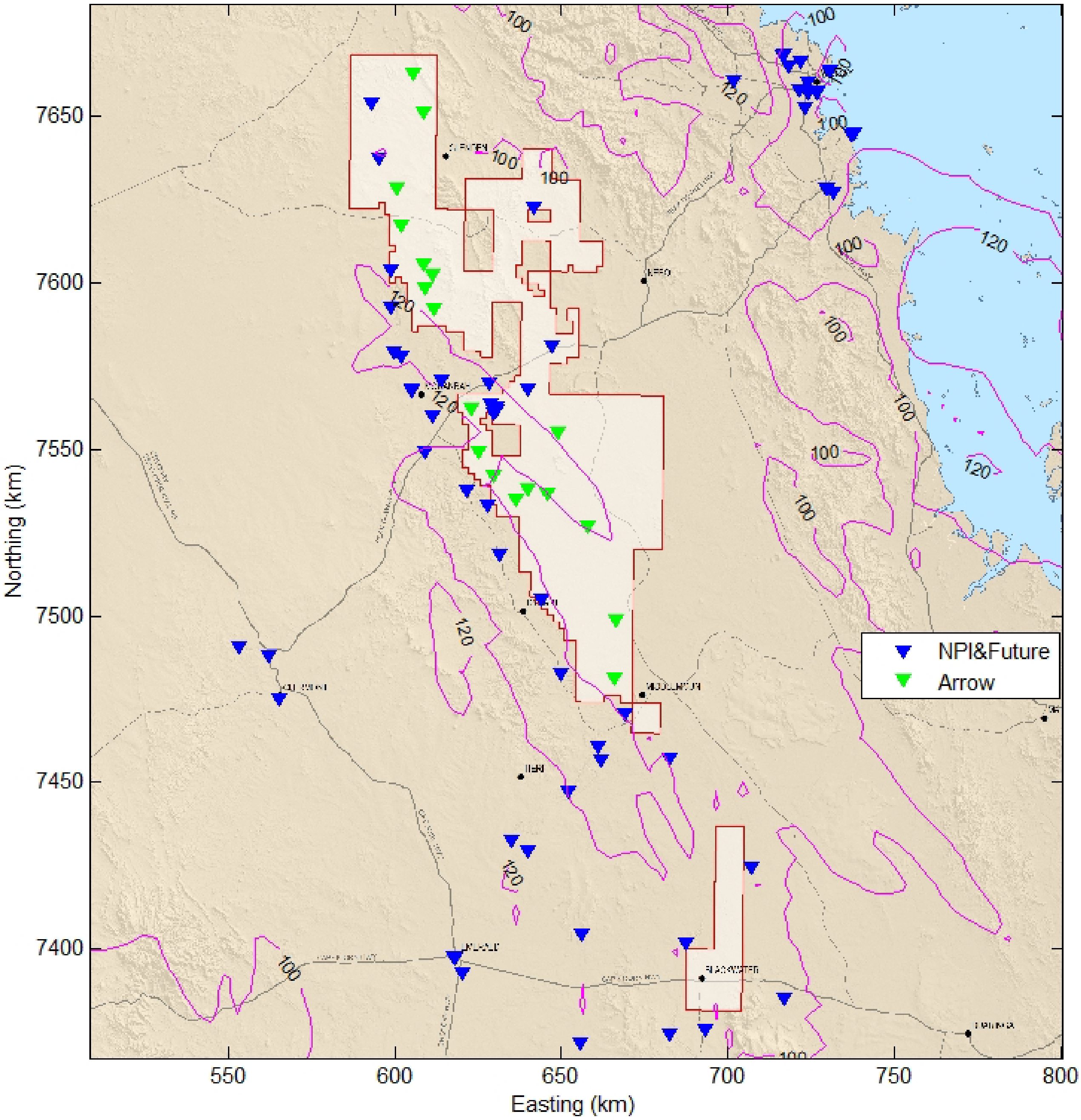


Figure 5-10 Second Highest O_3 (4-Hour Average) Concentrations (µg/m^3) Predicted for Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)



5.2 Localised Impacts

5.2.1 Overview

The Project has the potential to adversely impact local air quality through emissions released from the following sources:

- Local power generation (both gas and diesel based); and
- Flaring.

To reassess the potential impacts on local air quality for the updated project description, an atmospheric dispersion modelling exercise was undertaken using Aermod. As in the EIS, dispersion modelling was conducted for several meteorological subregions (refer to the Air Quality Technical Report (Appendix H, Section 8.1) of the EIS), which enabled the modelling exercise to capture the varying meteorological conditions throughout the Project area.

The pollutants considered in the assessment of near-field impacts were:

- NO_2;
- Particulate matter;
- CO; and
- VOCs.

To estimate ground levels of NO_2 concentrations from Ausplume modelled NOx concentrations, an ambient ratio (0.3) was adopted from the Gladstone Airshed Modelling System. Given the distances considered in this near-field impact assessment (<2 km from the source), a 30% conversion of NO_x to NO_2 was considered appropriate and is consistent with the EIS.

The meteorological parameters required for Aermod were extracted from TAPM.

For all of the scenarios modelled in Aermod, a 12 km x 12 km grid was defined, with a resolution of 100 m. Each stack and flare source was modelled at the centre of the grid.

5.2.2 Background Pollutant Concentrations

Background NO_2 concentrations were extracted from the regional scale atmospheric dispersion modelling results (Section 5.1.2) to represent each of the four selected meteorological subregions. The background values for the second highest 1-hour average and annual average NO_2 concentrations are presented in Table 5-6.

Table 5-6 Background NO_2 Concentrations

Meteorological Subregion*	Second highest 1-hour average background NO_2 concentration (µg/m^3)	Annual average background NO_2 concentration (µg/m^3)
1 (NE)	45.4	1.8
2 (S)	33.4	1.8
3 (N)	99.0	4.9
4 (C)	38.1	1.4
EPP (Air) Objective	**250**	**62**

* NE – northeast; S – south; N – north; C - central

The highest predicted value 99.0 µg/m^3 was used to represent background 1-hour average NO_2 for all subregions, thus providing a conservative assessment. To represent background annual average NO_2 concentration 4.9 µg/m^3 was used for all subregions. These values are conservative because they were selected from a location between existing coal mines, thus representing clustering of Project sources with the existing sources in the area.

Background pollutant concentrations for other pollutants were adopted from the EIS (for details see the Air Quality Technical Report (Appendix H, Section 3.5) of the EIS) and are presented in Table 5-7.

Table 5-7 Background Particulate Matter and CO concentrations

Pollutant	Background Concentration (µg/m^3)	Averaging period	EPP (Air) Objective (µg/m^3)
PM_{10}	28	24-hour	**50**
$PM_{2.5}$	8	24-hour	**25**
	6	Annual	**8**
CO	646	8-hour	**11,000**

5.2.3 *Temporary Gas Fired Power Generation (Alternative Case)*

The updated project description states that temporary gas fired power generation may be required in the first two years of Project life, if the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project (alternative power generation scenario). During this period only north, northeast and central production areas will be developed. Therefore, three corresponding meteorological subregions were selected to represent these areas.

As in the EIS, NO_2 was considered as a pollutant with the highest potential to cause an adverse impact on local air quality from power generation. The potential impacts of other pollutants are expected to be very minor in comparison with NO_2, with predicted values much lower than their respective guidelines.

A CGPF with the highest emission rates was selected to represent emissions from gas fired power generation. Table 5-8 shows a comparison of CGPF emissions modelled in the EIS and SREIS, which are based on different engine configurations. In the EIS, emissions from 3 MW engines were modelled, while SREIS considers emissions from 1.16 MW engines. The engines also have different physical flow and stack parameters. The facility engine and emission parameters for a 1.16 MW engine are presented in Section 4.3 of this report, and for a 3 MW engine are presented in the Air Quality Technical Report (Appendix H, Table 8-5) of the EIS.

Although the net emissions in the SREIS are lower than those in the EIS (except for VOCs), different flow and physical stack parameters, such as exit temperature, velocity and stack height, can result in different plume rise, and thus different ground level concentrations. The results can also be significantly influenced by different background concentrations. In order to determine how the power generation configuration adopted for the SREIS would affect local air quality, Aermod modelling was conducted for NO_x emissions.

Based on the EIS modelling results, the potential impact of VOC emissions is expected to be negligible. Therefore, modelling results for VOCs are not presented in this study.

Table 5-8 Comparison of Emissions Modelled in EIS and SREIS for CGPF Gas Fired Power Generation

Power Generation Source	Local Power Generation Emission Rates		
	NO_x(g/s)	PM_{10}(g/s)	VOC(g/s)
SREIS configuration based on 40 engines (1.16 MW)	22.00	0.59	13.94*
EIS configuration based on 21 engines (3 MW)	31.50	0.74	9.45

*The Total Organic Compound (TOC) emission rate (58.08 g/s) was scaled to estimate the VOCs emission rate based on the default speciation profile for internal combustion engines operating on natural gas of 76% (derived from the SPECIATE 4.3 9-28-2011-FINAL database from http://www.epa.gov/ttn/chief/software/speciate/index.html accessed 7/2/2014.

5.2.3.1 *Aermod Results for CGPF Located Gas Fired Power Generation (Alternative Case)*

Modelling results for NO_2 are presented in Figure 5-11 as a number of line plots, which illustrate the maximum 1-hour NO_2 concentrations as a function of distance from the proposed power generation source at a CGPF for each modelled meteorological subregion (north, northeast, and central). Each plot presents four lines, three of which relate to the second highest predicted concentration (plus background) for each subregion. The fourth line represents the 1-hour NO_2 objective. The background concentration used to estimate the separation distances is very conservative and represents possible clustering of Project sources with the existing non-Project related sources.

As in the EIS, the second highest concentrations of NO_2 were predicted to exceed the 1-hour NO_2 objective for all modelled meteorological subregions. Therefore, the minimum separation distance between the power generation stack source and any sensitive receptor to achieve compliance with the NO_2 health-based Project objective was determined for each subregion. The estimated distances are presented in Table 5-9.

Figure 5-11 Second Highest Predicted 1-Hour Average NO_2 Concentrations as Function of Distance from Proposed CGPF Source (Alternative Case – Temporary Power Generation)

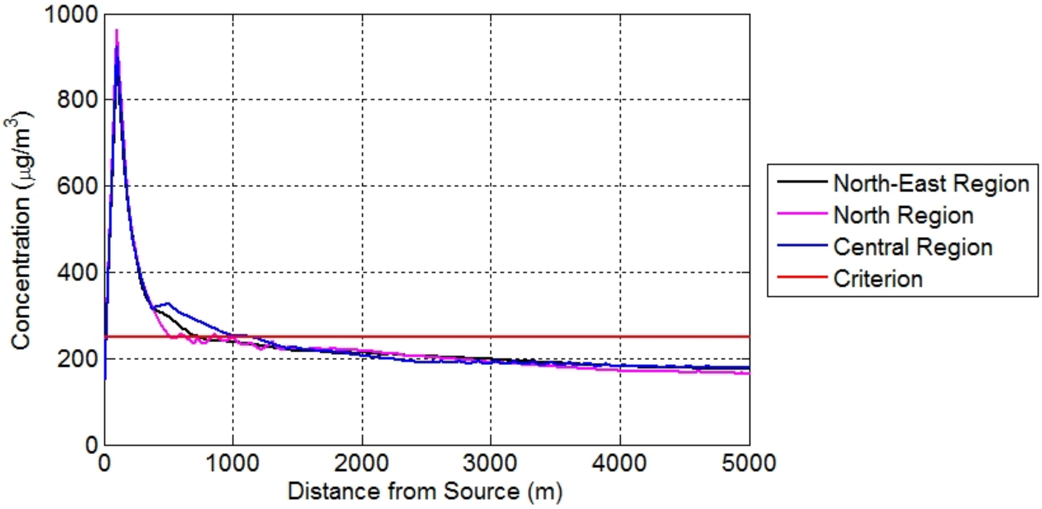


Table 5-9 Minimum Separation Distance from Gas Fired Power Generation Source to Sensitive Receptors Required to Achieve Compliance with 1-Hour NO_2 Project Objective

Meteorological subregion*	Minimum separation distance (m) From largest CGPF
1 (NE)	735
2 (N)	1,000
3 (C)	1,160

* NE – northeast; N – north; C - central

The estimated separation distance from a power generation source, co-located with a CGPF, ranges from 735 m to 1,160 m depending upon the meteorology data modelled. In the EIS, the minimum separation distance was predicted to range from 1,100 m to 1,400 m. However, a separation distance for gas fired power generation sources will only be required in the event that the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project.

5.2.4 Diesel Power Generation for Drilling and Completions

Diesel power generation for drilling and completions operations was not assessed in the EIS because the drilling period on a single pad was in the order of weeks, whereas the drilling period at a 12 hole pad can be in the order of over a year. Aermod was used to predict the impacts from diesel power generation sources, with physical stack parameters and mass emission rates presented in Table 4-4 and Table 4-5, respectively. The project description indicates that typical engine load is 50% for 23 hours a day and 100% for only one hour per day over short durations of several minutes at a time. To calculate the hourly emission rate, the typical engine load of 50% was assumed for 55 minutes and the extreme engine load of 100% was assumed for 5 minutes, which is equal to 22 hours of typical load and 2 hours of extreme load per day.

Table 5-10 shows the predicted ground level concentrations of modelled pollutants for diesel power generation for drilling operations in the modelling domain.

Table 5-10 Predicted Concentrations for Power Generation for Drilling and Completions

Meteoro-logical subregion	Pollutant	Averaging period	EPP(Air) Objective ($\mu g/m^3$)	Back-ground concen-tration ($\mu g/m^3$)	Predicted ground level concen-tration ($\mu g/m^3$)	Background plus predicted ground level concentration ($\mu g/m^3$)
1 (NE)*	NO_2 **	1-hour	250	99	**310**	**409**
		Annual	62	5	14	19
	CO	8-hour	11,000	646	36	782
	PM_{10}	24-hour	50	28	5	33
	$PM_{2.5}$	24-hour	25	8	5	13
	$PM_{2.5}$	Annual	8	6	1	7
2 (S)*	NO_2 **	1-hour	250	99	**324**	**423**
		Annual	62	5	22	27
	CO	8-hour	11,000	646	170	816
	PM_{10}	24-hour	50	28	6	34
	$PM_{2.5}$	24-hour	25	8	6	14
	$PM_{2.5}$	Annual	8	6	1	7
3 (N)*	NO_2 **	1-hour	250	99	**319**	**418**
		Annual	62	5	17	22
	CO	8-hour	11,000	646	134	780
	PM_{10}	24-hour	50	28	5	33
	$PM_{2.5}$	24-hour	25	8	5	13
	$PM_{2.5}$	Annual	8	6	1	7
4 (C)*	NO_2 *	1-hour	250	99	**314**	**413**
		Annual	62	5	11	16
	CO	8-hour	11,000	646	119	765
	PM_{10}	24-hour	50	28	6	34
	$PM_{2.5}$	24-hour	25	8	6	14
	$PM_{2.5}$	Annual	8	6	1	7

* NE – northeast; S – south; N – north; C - central

** 30% NO_x to NO_2

Table 5-10 shows that annual average NO_2, 8-hour average CO, 24-hour average PM_{10} and $PM_{2.5}$ and annual average $PM_{2.5}$ concentrations were predicted to be below the Project objectives. However, 1-hour average NO_2 concentrations higher than the Project objectives were predicted for all modelled subregions.

Modelling results for second highest 1-hour average NO_2 concentrations are presented in Figure 5-12 as a function of distance from the power generation source for each modelled meteorological subregion. To mitigate the NO_2 impacts and to achieve compliance with the

NO_2 health-based objective, the minimum separation distance between the power generation source and nearest sensitive receptor was determined for each subregion. The results of this analysis are presented in Table 5-11. The estimated minimum separation distance from the power generation source ranges from 198 m to 225 m depending upon the meteorology data modelled. Therefore, it can be concluded that the separation distance should be approximately 225 m to achieve compliance with the NO_2 health-based objective.

Figure 5-12 Second Highest Predicted 1-Hour Average NO_2 Concentrations as Function of Distance from Drilling Power Generation Source

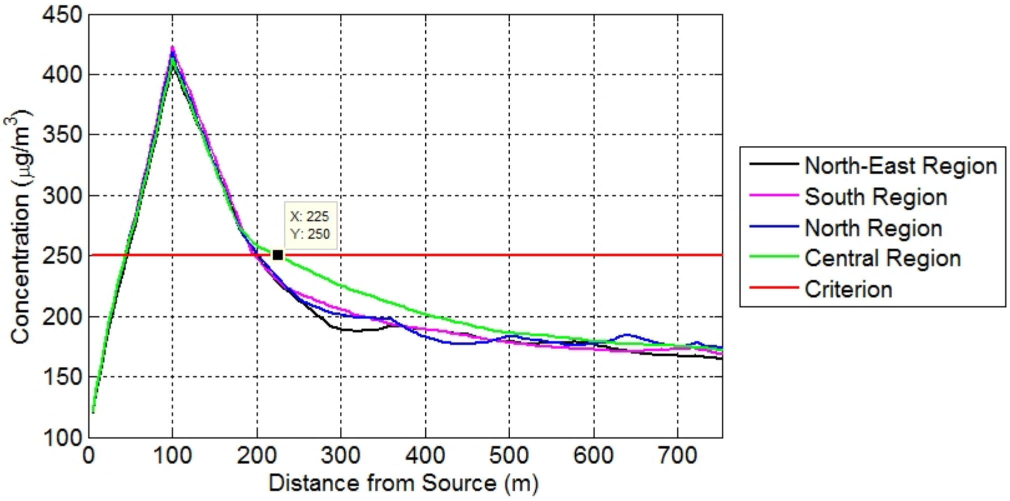


Table 5-11 Minimum Separation Distance from Drilling Power Generation Source to Proximate Sensitive Receptors Required to Achieve Compliance with 1-Hour NO_2 Project Objective (50% load)

Meteorological subregion	Minimum separation distance from source (m)
1 (NE)	200
2 (S)	198
3 (N)	200
4 (C)	225

** NE – northeast; S – south; N – north; C - central

5.2.5 Flaring

There are two main differences between the EIS and SREIS with regards to flaring. The refined project description indicates that there is no longer expected to be a need for ramp-up flaring. Flaring during well completions and workovers is a new flaring scenario included in the SREIS.

In general, both pilot flame and upset conditions flaring scenarios have not been changed since the EIS. However, worst-case gas consumption rates for upset conditions flaring have increased from 150 TJ/day assessed in the EIS to 360 TJ/day proposed for the SREIS. The new maximum flaring rate represents upset flaring conditions, which might take place only once in 2 years with approximately 21 hours duration (see Section 4.2.2.4 of this report).

A summary of flare gas consumption rates and physical stack parameters adopted for the SREIS are presented in Table 4-6. A summary of emissions from flaring is presented in Table 4-8. As a conservative approach, the maximum rate of 360 TJ/day at a CGPF was adopted for the SREIS to assess emissions from upset conditions flaring. Additionally, Aermod modelling was conducted to assess emissions from flaring during well completions and workovers. For the purposes of the dispersion modelling, flaring was assumed to be continuous throughout the modelled period (one year), thus providing a conservative assessment, which captured the potential range of meteorological conditions.

While flaring gas will release a number of pollutants, the impact assessment completed for the EIS showed that the emissions of NO_2 have the highest probability of leading to exceedences of the guidelines. The potential impacts of VOCs, particulate matter, SO_2, CO, or odour are very minor in comparison, with predicted values well below their respective guidelines. However for completeness, modelling results for CO and particulate matter (PM_{10} and $PM_{2.5}$) were included in the analysis of impacts from well completions and workover flaring, as this was not assessed in the EIS. The impacts associated with emissions of VOCs, SO_2 and odour were considered to be insignificant and no modelling was undertaken.

For each meteorological subregion within the Project area, Aermod was used to assess emissions associated with flaring. As described above, worst case flaring conditions might have a relatively short duration. However, for the purposes of the dispersion modelling, flaring was assumed to be continuous throughout the modelled period (one year), thus providing a conservative assessment, which captured the potential range of meteorological conditions.

5.2.5.1 Aermod Results for Upset Conditions Flaring

The second highest ground level NO_2 concentrations predicted for upset conditions flaring for each meteorological subregion are presented in Table 5-12.

Table 5-12 NO_2 Concentrations (including background) Predicted for Upset Conditions Flaring

Meteorological Subregion	Second Highest 1-hour Average NO_2 ground level concentration ($\mu g/m^3$)
1 (NE)	103
2 (S)	104
3 (N)	104
4 (C)	106
EPP (Air) objective ($\mu g/m^3$)	**250**

** NE – northeast; S – south; N – north; C - central

While the proposed gas consumption rates associated with planned and unplanned upset conditions flaring have increased for the SREIS compared to the EIS. However, the predicted concentrations of NO_2 presented in Table 5-12 are still well below the Project objective of 250 $\mu g/m^3$. These results are for the whole modelling domain of each meteorological sub-region, rather than at specific sensitive receptors.

5.2.5.2 *Aermod Results for Well Completions and Workovers Flaring*

The pollutants assessed within Aermod for well completions and workovers flaring were CO, NO_x (30% NO_2), PM_{10} and $PM_{2.5}$. Modelling results for these pollutants (except VOCs) are presented in Table 5-13 for each meteorological subregion. The potential impacts of VOCs are expected to be very minor in comparison to other pollutants, and therefore are not presented.

Table 5-13 Predicted Concentrations (including background) of NO_2, CO and Particulate Matter for Well Completions and Workovers Flaring

Meteoro-logical Subregion	2nd Highest 1-hour Average NO_2 ground level concentration ($\mu g/m^3$)	2nd Highest 8-hour Average CO ground level concentration ($\mu g/m^3$)	2nd Highest 24-hour Average PM_{10} ground level concentration ($\mu g/m^3$)	2nd Highest 24-hour Average $PM_{2.5}$ ground level concentration ($\mu g/m^3$)	Annual Average $PM_{2.5}$ ground level concentration ($\mu g/m^3$)
1 (NE)	101	667	28	8	6
2 (S)	100	666	28	8	6
3 (N)	101	670	28	8	6
4 (C)	100	664	28	8	6
EPP (Air) objective ($\mu g/m^3$)	**250**	**11,000**	**50**	**25**	**8**

** NE – northeast; S – south; N – north; C - central

It is evident from Table 5-13 that all relevant Project objectives are not predicted to be exceeded at any meteorological subregion, with respect to flaring emissions from well completions and workovers.

5.3 Summary of Assumptions

A number of conservative assumptions were made in this assessment:

- **Gas fired power generation (alternative case)**: Pollutant emission estimates for gas fired power generation are based on equipment manufacturer specifications for 75% fuel consumption load plus an additional contingency of 10%. Emissions for 75% loading are higher than for 100% loading.
- **Power generation for drilling and completions:** Typical engine load is 50% for 23 hours a day and 100% for only one hour per day over short durations of several minutes at a time. Modelling results were presented for an average engine load equivalent to 50% for 22 hours a day and 100% for two hours a day, which represents a conservative approach.
- **Upset condition / maintenance flaring**: The flaring rate of 360 TJ/d adopted for the assessment represents rare and rather atypical flaring conditions, which might take place only once in 2 years with approximately 21 hours duration.

- **Flaring during well completions and workovers**: Average or typical gas combustion rate per well completion / intervention is expected to be in the order of 5,000 m^3/d only for several hours. For the purposes of this study, the extreme worst-case rate of 225,000 m^3/d was adopted.
- **Project fugitive emissions in regional scale modelling**: A conservative fugitive emission estimate of 10,000 kg/year of VOCs was used in the assessment. These emissions were distributed over a much smaller area than in the EIS, as during the first two years of Project life only northern and central production areas will be developed.
- **Background concentrations**: Conservative monitoring datasets for the pollutants (other than NO_2) from areas that are more urbanised and industrially intensive than the Project were used in the assessment. To represent background NO_2 concentrations in the local scale modelling for all meteorological subregions the highest predicted values were used. These values are conservative because they were selected from a location between Newlands Coal and Burton Coal mines, thus representing clustering of Project sources with the existing sources in the area.

6 MITIGATION MEASURES

The impacts of the Project activities will be managed through the Environmental Management Plan (refer to the Draft Environmental Management Plan (Appendix Z) of the EIS).

During detailed design and preparation of EA application, further detailed modelling will be undertaken and suitable constraints will be applied to the site selection of the CGPF and FCF located power generation facilities and drilling and completion operations, based on the modelled minimum separation distance to sensitive receptors.

For gas fired power generation (alternative case) at the largest CGPF, modelling indicated that a distance of 1,160 m is required between the stack and sensitive receptor to achieve the hourly NO_2 Project air quality objective. However, a separation distance for gas fired power generation sources at the production facilities will only be required in the event that the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project.

For drilling and completions, a minimum separation distance is required between source and receptor to mitigate adverse health impacts from short term NO_2 exposure. Modelling indicated that a distance of 225 m is required between the source and sensitive receptor, to achieve the hourly NO_2 objective for human health.

7 CONCLUSIONS

The original project description was developed to inform the EIS. Since publication of the EIS for public comment in Q1 2013, Arrow's field development plan and project description have been refined. The major change relevant to the air quality assessment in the project description is a move away from on-site gas fired power generation, and the assessment of emissions from drilling and completion rigs due to their longer operational durations at one location with the introduction of multi-well pads. The air quality emissions inventory for the Project has been updated to reflect these refinements incorporating updated and new guidance documents and Project data sources. These updates and revised estimates of GHG air pollutant concentrations from the construction, operation and decommissioning of the Project have been reported. They are supplemented by new information about the Project and responses to stakeholder submissions. Atmospheric dispersion modelling of air quality impacts at regional and local scales has been undertaken.

The following conclusions can be drawn from the assessment.

7.1 Regional Scale

7.1.1 Modelling of Background Concentrations

- Background concentrations of NO_2 were estimated to be below the respective air quality objectives for human health and wellbeing but higher than presented in the EIS as a result of the update to the NPI data.
- At three limited areas surrounding coal mines, background concentrations were predicted to be higher than the air quality objective for health and biodiversity of ecosystems for annual average NO_2. However, regional models should not be used to predict local air quality impacts, so these results should be interpreted with caution.

7.1.2 Modelling of Cumulative Impacts

Scenario 1 – Alternative Case: Temporary Power Generation

- Project operations were predicted to increase ground level concentrations of NO_2 and O_3 in the region, with 2.4% increase in 1-hour average NO_2 concentrations and 2.8% increase in 1-hour average O_3 concentrations. The impact of Project emissions on the regional air quality was predicted to be small in comparison to background concentrations.
- No EPP (Air) objective for human health and wellbeing was predicted to be exceeded in the study area in Scenario 1, which is consistent with the EIS.
- No EPP (Air) objectives were predicted to be exceeded in the study area at the sensitive receptor locations, which is consistent with the EIS.
- At three limited areas surrounding coal mines, concentrations were predicted to be higher than the air quality objective for health and biodiversity of ecosystems for annual average NO_2. These elevated concentrations are largely a result of the background contribution and not Project related emissions.

Scenario 2 – Base Case: Grid Power Supply and Gas Fired Power Generation at 10% of Wellheads

- In Scenario 2, the regional impact of emissions from power generation using gas fired engines at up to 10% of wellheads was assessed qualitatively. The emissions from wellheads were significantly lower compared to emissions modelled in Scenario 1.
- No exceedences of the EPP (Air) objective for human health and wellbeing were predicted.
- No EPP (Air) objectives were estimated to be exceeded in the study area at the sensitive receptor locations.

7.2 Local Scale

Localised air quality impacts were assessed for temporary power generation and flaring as in the EIS with project description refinements applied. Emissions from power generation for drilling and completions were also assessed in the SREIS, as the time spent by a drill rig time at one location may be increased with the introduction of multi-well pads.

7.2.1 Gas Fired Power Generation (Alternative Case)

The minimum separation distance from the largest SREIS power source to receptors should be at least 1,160 m to achieve compliance with the NO_2 health-based objective. However, a separation distance for gas fired power generation sources at the production facilities will only be required in the event that the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project.

7.2.2 Diesel Power Generation for Drilling and Completions

- No exceedences of the objectives for annual average NO_2, 8-hour average CO, 24-hour average PM_{10} and $PM_{2.5}$ and annual average $PM_{2.5}$ concentrations were predicted.
- Minimum separation distance from power generators to receptor should be approximately 225 m to achieve compliance with the NO_2 health-based objective.

7.2.3 Flaring

Upset Conditions Flaring:

- No exceedences of the NO_2 health-based objective were predicted despite an increase in the proposed gas consumption rates.
- No exceedences of objectives for VOCs, PM_{10}, $PM_{2.5}$, SO_2, CO, or odour were estimated.

Well Completions and Workovers Flaring:

- No exceedences of the objectives for 1-hour average NO_2, 8-hour average CO, 24-hour average PM_{10} and $PM_{2.5}$ and annual average $PM_{2.5}$ concentrations were predicted.

7.3 Mitigation of Impacts

The recommended measures developed in the EIS remain valid in the SREIS.

For gas fired power generation at the largest CGPF, modelling indicated that a distance of 1,160 m is required between the stack and sensitive receptor to achieve the hourly NO_2 air quality objective. For diesel power generation for drilling and well completions operations, a separation distance of 225 m is required.

Further modelling will be undertaken during detailed design for preparation of the EA application, whereupon constraints will be further refined with the design.

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9 LIMITATIONS

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APPENDIX A INDUSTRIAL EMISSIONS SOURCES

The industrial emissions sources modelled within the regional air quality assessment are presented in Table A-1. The emissions are based on information obtained from the 2011/12 NPI. In addition to the NPI data, the approved Blackwater Power Station project was included within the modelling assessment. The industrial emission sources were modelled as point sources in TAPM-GRS, with the generic stack parameters presented below.

Main Activity	Easting (m)	Northing (m)	Emissions (g/s)					Stack Parameters			
			PM_{10}	NO_x	SO_2	VOCs	Rsmog	Height (m)	Diameter (m)	Velocity (m/s)	Temp (K)
Goonoo Feedlot	655717.7	7371749	0.03	0.21	0.00	0.02	0.0001	10	0.5	6	350
Moranbah Power Station	682630.8	7374516	231.93	0.85	0.01	1.66	0.03	10	0.5	6	350
German Creek Coal Mine	693148.6	7375826	5.24	35.07	0.02	2.98	0.003	10	0.5	6	350
Anglo Coal (Moranbah North Management) Pty Ltd	716852.7	7385359	0.02	9.77	0.01	1.26	0.007	10	0.5	6	350
Gregory Joint Venture - Gregory Crinum Mine	620421.8	7393068	0.00	11.37	0.01	1.37	0.01	10	0.5	6	350
Blackwater Mine	617938.9	7397328	0.00	138.51	0.37	2.86	0.03	10	0.5	6	350
Goonyella Riverside Broadmeadow Mine	617736.8	7397642	0.00	128.18	0.59	4.30	0.05	10	0.5	6	350
Hay Point Terminal	617935.1	7398027	0.00	3.40	2.14	0.11	0.0009	10	0.5	6	350
Norwich Park Mine	617916.8	7398056	0.00	49.18	0.16	1.41	0.03	10	0.5	6	350
Peak Downs Mine	687342.8	7401950	151.12	130.71	0.46	3.52	0.02	10	0.5	6	350
Caval Ridge Mine	598923.3	7604176	65.31	23.85	0.02	2.14	0.01	10	0.5	6	350
Shell Moranbah Ops Airport	641833.9	7623120	266.23	29.49	0.02	2.09	0.02	10	0.5	6	350
Poitrel Coal Mine	731673.6	7627181	0.00	49.07	0.03	4.03	0.01	10	0.5	6	350
Daunia Mine	729691.9	7628850	0.00	11.10	0.00	0.84	0.02	10	0.5	6	350
Red Mountain	729674.2	7628866	7.87	0.00	0.00	0.00	0.0001	10	0.5	6	350

Main Activity	Easting (m)	Northing (m)	Emissions (g/s)					Stack Parameters			
			PM_{10}	NO_x	SO_2	VOCs	Rsmog	Height (m)	Diameter (m)	Velocity (m/s)	Temp (K)
Infrastructure Joint Venture											
Millenium Coal Mine	595386.4	7637730	246.41	0.00	0.00	0.00	0.05	10	0.5	6	350
Moranbah Gas Project	736872.5	7644873	2.25	0.79	0.00	0.08	0.008	10	0.5	6	350
Moorvale Coal Mine	737948.5	7645504	13.50	6.20	0.06	0.51	0.009	10	0.5	6	350
Moranbah Power Station	723179.6	7652817	0.00	29.43	0.20	1.87	0.01	10	0.5	6	350
Carborough Downs Coal Mine	593113.9	7654178	106.45	43.61	0.85	2.38	0.01	10	0.5	6	350
Isaac Plains Coal Mine	724121.7	7657174	0.00	1.57	0.00	0.18	0.009	10	0.5	6	350
Anglo Coal (Moranbah North Management) Pty Ltd	726751.4	7657587	0.00	0.02	0.00	0.00	0.007	10	0.5	6	350
Moranbah North CMM Power Station	726652.3	7657886	0.00	0.00	0.00	3.20	0.004	10	0.5	6	350
Coppabella Coal Mine	721593.1	7658119	10.50	11.46	3.01	0.24	0.001	10	0.5	6	350
Goonyella Riverside Broadmeadow Mine	724219.2	7660324	0.00	0.00	0.00	0.02	0.05	10	0.5	6	350
North Goonyella/Eaglefield Coal Mine	701513.6	7660806	6.77	0.00	0.00	0.04	0.007	10	0.5	6	350
Hail Creek Operations	730702.1	7664051	0.00	0.00	0.00	0.00	0.02	10	0.5	6	350
Jilalan Rail Yard	730420.3	7664058	0.00	0.00	0.00	0.27	0.03	10	0.5	6	350
Sarina Ethanol Distillery	730748.7	7664079	0.00	0.22	0.00	0.02	0.02	10	0.5	6	350
Sucrogen Plane Creek	730651.6	7664086	0.00	77.66	0.15	3.80	0.02	10	0.5	6	350
Burton Coal Mine	718398.9	7665329	10.13	0.91	0.03	0.09	0.05	10	0.5	6	350
Dalrymple Bay Coal Terminal	721694.3	7666793	1.25	0.60	0.00	0.01	0.003	10	0.5	6	350
Hay Point Terminal	716634.4	7668771	0.95	0.00	0.00	0.03	0.001	10	0.5	6	350

Main Activity	Easting (m)	Northing (m)	Emissions (g/s)					Stack Parameters			
			PM_{10}	NO_x	SO_2	VOCs	Rsmog	Height (m)	Diameter (m)	Velocity (m/s)	Temp (K)
Thomas Borthwick & Sons	717121.2	7669161	1.12	0.00	0.00	0.08	0.0001	10	0.5	6	350
Newlands Coal	681527.4	7690701	0.00	0.00	0.00	0.00	0.002	10	0.5	6	350
Mackay (Paget) Rail Fuelling Facility	701,530	7,401,450	0.00	0.00	0.00	0.24	0.00002	12.5	0.6	32.41	648
Caltex Aviation Depot Mackay	655717.7	7371749	0.03	0.00	0.00	0.64	0.00003	10	0.5	6	350
Shell Mackay Airport	682630.8	7374516	231.93	37.51	0.06	2.62	0.03	10	0.5	6	350
Racecourse Sugar Mill & Refinery	693148.6	7375826	5.24	50.07	0.03	3.49	0.002	10	0.5	6	350
Mackay Gas Turbine	716852.7	7385359	0.02	22.44	0.03	1.40	0.0000004	10	0.5	6	350
Marian Sugar Mill	620421.8	7393068	0.00	2.49	0.00	0.21	0.003	10	0.5	6	350
Mackay (BPM) Terminal	617938.9	7397328	0.00	41.52	0.03	1.78	0.0003	10	0.5	6	350
Mackay (BPA/BPOD) Terminal	617736.8	7397642	0.00	13.37	0.00	1.24	0.031	10	0.5	6	350
Shell Mackay Terminal	617935.1	7398027	0.00	9.67	0.07	0.42	0.002	10	0.5	6	350
Caltex Terminal Mackay	617916.8	7398056	0.00	42.16	0.03	3.19	0.023	10	0.5	6	350
Farleigh Sugar Mill	687342.8	7401950	151.12	63.62	0.04	4.53	0.02	10	0.5	6	350
Boral Quarries Cedars	655932.7	7404730	336.17	33.24	0.02	2.89	0.02	10	0.5	6	350
Mackay Asphalt Plant	706927	7424777	178.94	0.00	0.00	0.08	0.01	10	0.5	6	350
Farleigh Quarry	639810.1	7429585	23.22	84.83	0.59	3.80	0.001	10	0.5	6	350
Calen Depot	635018	7432743	28.20	41.49	0.04	2.75	0.01	10	0.5	6	350
Blackwater Power Station	652012.5	7447628	32.37	5.56	0.00	0.46	0.01	10	0.5	6	350

APPENDIX B MODELLED SENSITIVE RECEPTORS

A list of the modelled sensitive receptor locations included within the regional air quality assessment is provided in Table B-1. The predicted concentrations presented for each pollutant averaging period are based on the worst case scenario (Scenario 1). However, it should be noted that the locations of the gas processing facilities have not yet been finalised and are currently indicative. Further to this, the identification of sensitive receptors has at this stage been done as a desktop exercise and is assumed to be conservative.

Table B-1 Pollutant Concentrations for all Modelled Sensitive Receptors in the Regional Air Quality Assessment, Representing the Worst Case Predictions

Receptor UTM Co-ordinate (km)		Concentrations ($\mu g/m^3$) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
670.5917	7468.336	8.39	183.26	133.68	119.81
674.2337	7469.258	4.71	191.43	126.65	115.74
679.5837	7465.757	5.98	205.74	123.59	108.46
680.5931	7467.228	4.93	192.41	123.47	103.74
681.0793	7467.542	4.53	180.42	123.26	104.00
651.9887	7474.834	6.24	272.27	141.89	135.36
652.9929	7475.849	5.65	262.15	138.88	133.20
655.0914	7480.290	5.38	277.77	128.57	123.56
658.1968	7480.622	5.38	260.19	125.65	119.50
664.1684	7480.431	6.06	168.35	126.55	117.47
663.9639	7480.712	6.15	176.61	126.30	117.52
664.8299	7472.246	10.85	153.76	132.98	121.79
669.5158	7472.555	13.17	223.86	127.46	116.56
672.7753	7470.257	4.92	216.09	125.68	117.77
672.5229	7471.734	4.79	229.58	123.50	117.36
672.5335	7475.849	3.78	184.74	121.48	111.63
674.7278	7473.367	3.99	206.93	124.74	110.31
674.5923	7474.842	3.71	196.15	124.63	108.87
675.1953	7474.786	3.65	196.93	125.61	107.88
674.7065	7474.087	3.85	201.72	124.76	109.53
675.1209	7474.132	3.78	201.16	125.34	108.70
676.1835	7476.871	3.27	185.46	126.72	105.96
681.5946	7470.658	3.46	147.59	124.69	104.79
681.1457	7471.505	3.45	150.76	125.48	104.92
650.0841	7497.387	5.72	234.98	136.42	122.76
668.0229	7483.475	4.54	194.03	119.09	115.05
670.8069	7486.905	3.06	163.55	119.33	111.00
672.1802	7491.152	2.57	124.30	117.46	109.79
671.8243	7498.651	2.34	118.14	119.87	113.03
672.2626	7486.387	2.80	142.48	120.58	109.78
644.1177	7504.780	17.14	315.48	138.39	128.43
644.5002	7505.890	22.87	350.18	135.05	125.10
644.5906	7505.935	22.79	350.00	134.80	124.80
645.3875	7500.782	8.53	274.55	143.47	131.53

Receptor UTM Co-ordinate (km)		Concentrations (μg/m³) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
647.7331	7500.853	6.42	259.15	140.48	124.20
647.3161	7508.802	10.91	293.15	127.51	117.02
646.7051	7509.930	11.18	306.85	127.41	117.44
649.6192	7504.676	5.25	237.61	130.35	117.28
649.8503	7506.687	5.59	261.55	126.76	116.55
653.0965	7507.457	4.05	242.03	126.37	117.88
657.6974	7504.076	3.51	141.64	130.92	116.21
657.5327	7509.062	3.22	164.20	136.65	117.07
665.3240	7509.474	2.60	104.03	138.15	115.69
668.9235	7504.203	2.36	106.37	132.17	115.23
638.1328	7513.737	8.06	230.01	146.59	129.03
638.0531	7520.322	7.49	322.35	141.04	123.76
640.0428	7516.943	7.23	282.96	137.74	123.40
642.5371	7519.361	6.45	318.10	129.20	118.79
652.1348	7513.934	3.91	171.48	129.34	119.23
653.0433	7512.691	3.74	166.16	129.63	119.08
656.3346	7515.663	3.21	136.72	139.88	119.11
667.6191	7510.956	2.25	94.27	140.14	115.18
667.5262	7516.707	2.10	91.71	141.56	114.87
673.4288	7515.116	1.81	73.22	132.03	113.87
673.0622	7515.562	1.82	74.59	132.70	113.77
647.2257	7537.842	3.67	232.29	134.72	122.11
652.6820	7532.428	3.19	166.68	139.26	123.07
666.8461	7530.074	1.88	99.51	136.38	117.24
672.5388	7538.277	1.56	69.48	122.69	106.97
676.7785	7534.008	1.49	69.44	123.34	107.28
609.2335	7551.692	8.47	220.35	131.11	118.76
619.3093	7542.312	21.00	532.12	139.33	125.56
621.7028	7552.795	9.91	416.01	141.75	119.28
624.5000	7540.976	12.28	454.96	140.12	122.12
627.7010	7541.194	13.13	423.16	135.25	122.35
634.1296	7544.637	6.04	270.40	131.43	118.32
642.0696	7548.183	4.15	208.16	136.55	125.06
647.4409	7540.049	3.31	214.48	134.58	123.77
647.5764	7540.299	3.27	210.49	134.60	123.98
662.4710	7544.031	1.88	77.49	132.44	110.84
677.8730	7545.208	1.41	43.50	118.79	106.34
681.2944	7550.202	1.35	35.15	121.47	107.42
683.0025	7545.497	1.35	40.11	118.73	107.50
643.6369	7559.016	3.75	245.21	134.30	117.18
650.6393	7566.087	2.58	92.65	123.07	109.53
660.8187	7565.721	1.82	72.46	119.46	111.08
662.3355	7561.821	1.77	68.03	122.76	109.87

Receptor UTM Co-ordinate (km)		Concentrations (µg/m³) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
663.0262	7559.752	1.75	65.05	123.37	109.02
670.2490	7553.785	1.54	46.92	119.49	106.59
669.2528	7557.366	1.55	51.00	120.68	107.81
672.8789	7558.161	1.46	43.06	119.85	110.40
677.1451	7561.792	1.38	37.67	119.41	113.03
643.3367	7577.704	3.80	109.59	122.52	112.82
643.0498	7577.561	3.79	109.36	122.61	113.08
643.6714	7577.701	3.78	110.66	122.55	112.67
648.5274	7579.906	7.56	136.97	118.20	106.49
650.3524	7580.119	5.65	116.26	115.82	107.28
602.9589	7590.593	16.67	703.93	141.87	124.09
653.0977	7591.044	2.38	94.85	112.74	104.13
599.0137	7604.242	11.59	287.79	124.46	113.16
600.2383	7604.462	12.03	322.53	123.66	111.37
600.2675	7604.707	11.57	322.52	123.71	111.17
600.1670	7606.960	7.12	311.54	124.39	109.78
600.5341	7608.124	6.18	294.52	124.91	109.70
601.1365	7605.161	10.10	294.74	123.35	110.46
602.1988	7605.483	8.54	235.56	122.93	110.11
601.5252	7604.449	10.71	276.90	122.92	110.82
605.7680	7601.978	7.40	142.26	121.92	110.71
607.1067	7598.433	8.13	193.29	128.34	112.81
609.7150	7600.610	8.47	145.49	122.65	111.23
610.7989	7608.106	4.72	105.92	119.95	110.11
611.8526	7606.660	4.65	104.53	119.10	109.39
625.1835	7600.821	2.43	66.99	117.69	112.46
625.5895	7598.843	2.42	67.86	117.50	112.03
643.5843	7598.757	2.61	57.29	115.60	106.50
643.4590	7601.821	2.64	60.46	115.21	107.16
644.6963	7607.087	2.77	77.58	118.67	106.73
654.6934	7594.806	2.09	85.08	111.00	103.71
596.2524	7608.605	5.98	184.25	127.77	113.57
602.1427	7615.016	3.59	123.92	127.32	112.36
601.7972	7615.575	3.85	128.75	127.70	112.25
603.8809	7621.413	2.85	86.93	122.05	111.68
616.7713	7609.093	2.46	78.67	119.79	112.43
620.1591	7614.618	2.40	55.71	118.63	111.92
621.3531	7613.491	2.42	54.33	118.23	111.95
627.9840	7617.859	2.84	51.42	117.31	110.05
629.2925	7618.712	3.04	55.99	117.91	110.09
639.4904	7621.668	17.56	244.29	115.30	104.95
640.8270	7611.820	4.32	101.86	120.73	111.21
640.0993	7620.591	14.52	227.70	117.15	105.28

Receptor UTM Co-ordinate (km)		Concentrations (µg/m³) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
642.6623	7610.211	3.47	90.65	120.55	109.19
643.3748	7613.740	4.01	116.69	119.70	109.95
650.3771	7615.009	2.35	75.38	119.41	107.24
588.3519	7630.648	5.85	137.05	124.04	112.38
591.3074	7635.911	10.62	291.45	121.19	104.99
593.3699	7626.637	6.20	141.06	124.65	113.35
596.8030	7627.818	6.77	229.09	121.06	113.28
598.9881	7634.392	5.38	248.63	120.97	110.19
601.7109	7631.378	2.77	144.67	120.24	112.80
606.5065	7633.742	2.30	99.43	117.86	110.43
614.2601	7631.965	2.31	53.64	113.66	107.75
626.5913	7623.365	4.71	97.60	116.05	108.19
626.9498	7628.511	3.61	49.20	114.78	106.01
641.5978	7623.640	19.36	311.03	111.26	103.32
643.2971	7627.885	3.94	123.77	112.06	102.54
652.1455	7633.216	1.40	33.32	112.57	100.20
585.6343	7639.524	11.98	435.05	118.95	105.94
584.7532	7649.788	6.49	241.95	120.94	112.47
585.5438	7650.028	6.54	246.26	120.98	112.52
585.6137	7649.930	6.59	247.58	120.90	112.46
585.9518	7639.335	12.49	448.79	119.01	105.59
585.9820	7639.674	12.22	436.36	118.96	105.81
585.9518	7645.670	8.23	280.81	118.80	109.87
585.7423	7649.890	6.62	248.91	120.85	112.42
585.9566	7649.115	6.96	255.77	120.31	111.96
585.9772	7648.949	7.03	256.99	120.20	111.86
586.4042	7649.042	7.07	258.90	120.23	111.87
588.9030	7641.484	13.11	376.56	119.03	105.78
589.5237	7647.242	8.28	275.91	119.75	110.56
589.6697	7645.561	9.42	277.53	119.50	109.24
589.7444	7646.497	8.78	277.48	119.67	109.97
590.2920	7646.394	8.89	280.55	119.77	109.85
594.4930	7637.492	20.47	525.79	116.77	102.67
594.4660	7646.971	6.90	553.64	118.94	110.03
594.8438	7648.461	5.99	557.84	118.77	110.68
595.5963	7649.608	5.07	608.56	118.46	111.03
602.2194	7639.895	3.12	407.36	119.58	109.48
601.8304	7639.301	3.23	451.03	119.97	109.44
612.8747	7641.176	2.16	135.60	117.36	106.19
613.4303	7641.348	2.16	128.34	117.34	105.93
615.0464	7636.236	2.27	87.46	114.94	107.77
584.5610	7658.620	5.47	161.89	124.74	110.95
587.0939	7654.936	9.74	234.07	122.58	109.70

Receptor UTM Co-ordinate (km)		Concentrations (µg/m³) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
587.3000	7654.853	9.86	237.40	122.42	109.66
587.4374	7654.794	9.93	239.62	122.32	109.64
587.5061	7654.760	9.96	240.75	122.26	109.64
589.4149	7653.635	10.60	260.81	120.86	109.07
589.0017	7654.261	11.00	259.33	121.21	108.82
589.0567	7654.495	11.43	259.30	121.21	108.42
589.1685	7654.291	11.29	260.13	121.10	108.50
590.8980	7652.661	10.22	252.95	120.01	109.20
589.7203	7653.589	10.88	261.03	120.67	108.73
591.9509	7653.855	14.23	267.19	119.33	105.06
591.9832	7653.553	13.46	262.35	119.36	105.83
591.3262	7653.053	11.50	255.76	119.78	107.88
593.0995	7650.730	6.92	289.77	119.46	111.80
592.4866	7652.891	12.15	249.88	119.20	107.11
593.3436	7654.616	14.32	335.61	118.39	103.86
593.8403	7650.546	6.34	376.58	119.23	111.63
593.9236	7654.674	12.44	372.26	118.07	105.05
594.8178	7653.885	8.44	436.25	117.89	108.16
597.6197	7655.732	3.28	424.41	116.12	110.52
605.6971	7655.370	2.87	155.24	114.40	107.93
690.9828	7380.285	2.23	135.00	131.99	105.70
691.1768	7385.223	2.20	115.28	135.41	103.31
693.7030	7382.867	1.84	83.04	136.18	102.45
610.4103	7558.092	7.66	229.62	136.69	119.10
611.5207	7557.991	7.84	225.78	137.17	119.35
612.2299	7555.018	7.72	245.72	136.24	119.67
611.9085	7557.489	7.86	227.92	137.14	119.45
612.9923	7555.921	7.80	243.55	137.15	119.37
614.0416	7555.321	7.76	259.59	137.65	118.58
628.5165	7555.871	12.79	330.57	139.83	126.20
639.5912	7558.562	4.96	314.21	138.55	123.55
620.2231	7566.643	7.24	270.30	136.75	130.14
630.0201	7563.466	11.20	306.35	134.44	125.63
631.8052	7561.282	8.30	364.91	136.68	124.10
633.5823	7572.335	4.12	153.14	123.93	114.46
633.3990	7573.239	3.98	147.11	123.14	114.73
636.4805	7567.405	8.13	151.94	130.33	115.66
641.3736	7569.764	7.06	169.27	128.56	112.32
640.9220	7569.628	7.89	174.10	128.71	112.23
636.0900	7574.684	3.85	113.58	121.63	116.75
636.1777	7574.795	3.84	112.02	121.52	116.86
639.7346	7576.179	3.96	109.17	122.73	116.02
640.7042	7575.759	4.02	113.69	123.40	116.17

Receptor UTM Co-ordinate (km)		Concentrations (µg/m^3) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
641.3125	7576.657	3.91	109.42	123.00	114.86
641.4932	7576.708	3.88	109.56	123.00	114.71
641.7455	7577.515	3.87	105.62	122.51	113.77
620.8068	7581.561	3.29	107.73	121.34	113.86
621.0940	7582.477	3.21	108.29	119.55	112.71
630.3699	7581.069	3.27	116.22	121.48	114.14
638.7252	7508.432	12.28	228.63	147.01	132.34
609.6266	7561.109	7.31	202.61	137.55	119.03
609.9162	7561.999	7.25	188.49	137.79	118.90
610.2084	7560.315	7.54	209.91	137.50	119.11
610.8858	7562.504	7.36	174.93	137.92	118.65
611.5154	7562.751	7.44	167.13	137.94	118.48
640.9300	7503.903	9.82	220.51	145.82	134.95
604.6676	7659.731	2.77	157.50	114.02	106.73
596.5907	7667.803	2.37	343.80	114.69	108.09
601.7809	7636.483	2.78	254.86	120.17	109.80
599.4576	7623.803	4.20	134.07	124.22	111.57
587.1985	7646.016	8.52	274.27	119.10	109.90
593.7930	7639.717	24.93	622.28	114.63	100.96
640.6059	7638.250	1.90	55.27	107.84	101.16
596.4185	7667.178	2.45	348.83	115.21	108.21
596.7734	7668.121	2.35	332.43	114.38	107.98
688.7848	7400.682	9.64	185.11	140.73	109.64
692.8491	7391.522	1.99	73.94	136.47	104.53
696.7526	7419.063	2.58	65.79	125.68	116.73
700.3640	7390.186	1.59	32.81	134.03	116.67
646.6849	7581.311	9.25	144.71	117.42	106.54
640.7774	7577.037	3.96	105.71	122.69	114.76
594.9834	7638.632	26.94	664.67	113.55	100.07
703.2895	7391.349	1.51	25.50	129.93	116.21
703.3189	7391.511	1.51	25.49	129.79	116.09
692.1294	7388.586	2.05	86.24	136.87	101.99
694.0203	7382.478	1.81	79.52	136.15	102.26
697.0688	7388.438	1.68	46.02	135.78	109.23
699.8639	7421.349	3.67	75.15	116.57	111.59
699.9971	7412.200	2.53	61.54	124.09	114.45
700.4283	7412.131	2.50	56.78	123.60	114.34
703.5647	7410.357	2.09	46.90	118.10	111.62
701.4637	7428.294	3.51	57.15	115.17	105.41
705.0511	7404.460	1.70	42.43	121.08	111.71
704.5261	7420.339	4.48	83.22	112.18	103.92
704.8370	7434.974	2.37	65.69	110.61	104.83
704.9597	7434.121	2.53	66.48	111.42	105.27

Receptor UTM Co-ordinate (km)		Concentrations (µg/m³) for each modelled pollutant averaging period			
		NO_2 Annual	NO_2 1-hour	O_3 1-hour	O_3 4-hour
692.2008	7393.806	2.14	86.90	135.78	107.83
689.6649	7399.871	5.96	139.29	139.67	110.55
689.2208	7400.113	7.22	156.74	140.39	109.89
688.3856	7400.187	8.49	177.87	141.49	108.31
699.2893	7398.900	2.11	31.58	131.52	116.88
696.8862	7407.635	2.92	69.87	128.55	112.78
696.8764	7407.479	2.93	68.57	128.57	112.68
695.3383	7391.924	1.87	52.31	135.54	110.88
695.3983	7392.197	1.88	51.78	135.44	111.38
695.3696	7391.653	1.86	52.04	135.61	110.59
674.5694	7473.151	4.07	208.87	124.56	110.89
674.1041	7472.655	4.25	214.11	124.16	112.48
674.0081	7472.449	4.32	216.18	124.12	112.95
671.0219	7497.526	2.45	122.66	118.64	112.34
661.2856	7498.358	4.60	129.02	125.62	112.47
665.3945	7495.583	3.69	136.33	119.27	112.62
672.0286	7476.439	4.14	182.27	122.24	111.98
672.1446	7476.330	4.06	182.46	122.09	111.89
669.8047	7560.926	1.53	52.12	121.29	110.92
660.6832	7564.194	1.83	70.57	120.75	110.41
630.0016	7550.635	7.52	310.01	138.87	124.39
623.4774	7551.727	10.26	372.92	142.72	122.83
627.9198	7565.094	11.07	289.83	133.34	127.25
639.1076	7563.832	6.64	186.29	135.28	115.59
655.2653	7616.573	1.66	48.83	116.58	105.79
602.0074	7607.222	6.62	236.88	123.65	109.18
652.6055	7542.847	2.50	127.48	137.65	124.25
671.1586	7503.025	2.22	110.18	129.51	115.10
654.0963	7494.968	4.56	170.34	126.42	114.59
652.7312	7515.498	3.75	164.27	131.91	119.64
612.9641	7596.033	3.66	225.80	118.27	110.36
619.0069	7591.290	2.81	210.11	118.83	110.85
620.4065	7597.875	2.59	116.84	117.07	109.92
637.9558	7575.445	3.87	109.05	122.01	116.96
639.9060	7575.570	4.02	113.15	123.11	116.59
628.8493	7567.354	6.93	232.95	131.84	126.39
633.9226	7568.630	5.82	180.30	128.90	117.70

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