5

AIR QUALITY

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SUPPLEMENTARY REPORT TO THE EIS

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5 Air Quality

This chapter summarises the supplementary air quality impact assessment completed as a result of refinements to the field development plan and conceptual design of the Project. Updates to the legislative and policy context, study approach and methodology, emissions sources and likely impacts are described and discussed.

The chapter also describes the review of abatement, management and mitigation commitments made by Arrow to minimise air pollutant emissions from the Project. The supplementary air quality impact assessment is included in the Air Quality Technical Report (Appendix B) of this SREIS. The study supplements the air quality impact assessment presented in the Air Quality Technical Report (Appendix H) of the EIS, the main findings of which are summarised in the Air Quality chapter (Section 9) of the EIS.

The revised project description is provided in the Project Description chapter (Section 3) of the SREIS and the revisions with specific relevance to the assessment of air quality are discussed in this chapter. In addition to the study findings, the key submissions raised in the EIS consultation process are presented. The responses to all submissions are provided in the Submission Responses chapter (Section 21) of this SREIS.

5.1 Summary of Updates to the Air Quality Assessment

The Project refinements that are applicable to the supplementary air quality assessment relate to changes in major infrastructure components, power supply requirements for Project facilities and flaring.

Table 5-1 provides a summary of the changes relevant to the air quality assessment as a result of refinements to the project description and the inclusion of updated and/or new datasets.

Table 5-1 Summary of Key Changes to the EIS

Project Aspect	EIS	SREIS	Basis for Change
Estimated maximum annual gas production	189,070 TJ (2046)	283,240 TJ (2027)	Project description refinement.
Location of development areas	Conceptual locations	Revised conceptual locations.	Project description refinement.
Number of central gas processing facilities (CGPF)	Three	Two with co-located water treatment facilities.	Project description refinement.

Section 5 Air Quality

Project Aspect	EIS	SREIS	Basis for Change
Number of field compression facilities (FCF)	10	33	Project description refinement - drainage area radius has been reduced from approximately 12 km to approximately 6 km.
Integrated processing facilities	Four	Removed	Project description refinement.
Number of vertical production wells	6,625 (single well pads)	Up to 4,000 (up to 12 wells per pad, six vertical production and six lateral wells).	Project description refinement.
Power supply	<u>Base Case</u> Integrated power generation utilising CSG as a fuel source at Project facilities. <u>Alternative Case</u> Connection to existing electricity transmission and/or distribution infrastructure.	<u>Base Case</u> Grid power supply based on connection to existing electricity infrastructure with partial gas-fired power generation at remote wellheads (up to 10% of total number of wells). <u>Alternative Case (Temporary Power Supply)</u> In field power generation at the facilities using CSG for approximately the first two years. After two years, grid power supply with partial gas-fired power generation at remote wellheads if required (up to 10% of total number of wells).	Project description refinement. An assessment was made between the preferred 'Base Case' power option and 'Alternative Case' (temporary power supply). The temporary power supply option during approximately the first two years represents 'worst-case' scenario, which is impact assessed.
CGPF power requirement (largest)	60 MW maximum power requirement.	44 MW maximum power requirement, including power supplied to water treatment facilities.	Project description refinement.
FCF power requirement (largest)	19 MW	35 MW	Project description refinement.
Production wellhead power requirement	60 kW	20 kW	Project description refinement.
Emissions from diesel power generation for drilling and completions	Not included	Included (four diesel generators with 1,000 kVA engines).	Updated / new information.
Gas power generation engines capacity at production facilities	3 MW	1.16 MW (temporary)	Updated / new information.
Ramp up flaring	Assessed	Not required	Project description refinement.

Project Aspect	EIS	SREIS	Basis for Change
Flaring during well completions and workovers	Not included	Assessed	Project description refinement.
Upset condition / operational flaring rates	Based on maximum worst-case rate.	Based on updated maximum worst-case rate.	Project description refinement.

Grid power supply based on connection to existing electricity transmission 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 the wells.

Temporary power generation using CSG at the Project facilities (CGPFs and FCFs) for approximately 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. As in the base case, it has been assumed that 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. The temporary power installed at the FCFs over approximately the first two years will provide power for the wells through a predominantly overhead distribution network with an underground distribution alternative depending on requirements.

5.2 Legislative Context

The following legislation, policies and guidelines were used to develop Project criteria for the protection of the air quality environment in the Project area.

5.2.1 National Environment Protection Measure

As discussed in the EIS, the *National Environment Protection Council Act 1994* (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.

5.2.2 Queensland Environmental Protection Policies

In Queensland, air quality is managed under the *Environment Protection Act 1994* (EP Act), the Environmental Protection Regulation 2008 (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.

5.2.3 Project Assessment Criteria

The air quality assessment criteria (Project criteria) are based on the NEPM (Ambient Air Quality) and the EPP (Air) objectives for human health and wellbeing and for ecological health and biodiversity. The Project criteria are presented in Table 5-2.

Table 5-2 Project Air Quality Criteria

Pollutant	Averaging Period	Criteria/Objectives (µg/m³)	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).

5.3 Assessment Methodology

Based on the refinements to the project description described in Table 5-1, the following assessment updates were required in the SREIS:

- 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 case scenario (temporary gas fired power generation for approximately 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 to re-estimate the minimum required separation (buffer) distance between the largest power source and any proximate sensitive receptors;
  - Flaring; and
  - Diesel power generation for well drilling and completion operations.

Note that 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. Further modelling will be undertaken during detailed design for preparation of the environmental authority (EA) application, whereupon constraints will be further refined with the design.

5.3.1 Study Area

The Project study area (airshed) has not changed since the EIS. Detailed definitions of the study areas for the regional and local air quality assessments can be found in the Air Quality Technical Report (Appendix H, Section 4) of the EIS.

5.3.2 Pollutants

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) and sulfur dioxide (SO_2) 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 scenarios (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:

- NO_x as NO_2;
- O_3;
- PM_{10};
- $PM_{2.5}$;
- SO_2;
- CO; and
- VOCs.

Consistent with the definition of VOCs adopted for the National Pollutant Inventory (NPI) (DEWHA, 2009), VOCs assessed in this study 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.

5.3.3 Emission Sources

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

5.3.3.1 Power Generation

Facility Power Generation

Power generation using gas fired engines provides the main source of air emissions from a facility. The working assumption adopted from the project description is that the expected ranges of power could be generated by reciprocating gas engines with lean burn technology.

As a conservative approach, emissions for each production facility were estimated based on the maximum power requirements per facility as provided by Arrow.

The maximum facility requirements expressed as total megawatt (MW) and a number of 1.16 MW gas engines are presented in the Air Quality Technical Report (Appendix B, Section 4) of the SREIS.

The physical stack parameters and pollutant emissions estimates for a 1.16 MW gas engine are shown in Table 5-3.

Table 5-3 Typical 1.16 MW Engine Stack and Emission Specifications

Stack Parameter	Value	Units
Height of release	5.21	m
Stack diameter	0.3	m
Exit velocity	55	m/s
Actual exhaust volume flow rate	3.88	m^3/s
Exit temperature	742	K
CO emission rate	0.72	g/s
NO_x emission rate	0.55	g/s
VOC emission rate	1.45	g/s
PM_{10} emission rate	0.0147	g/s
$PM_{2.5}$ emission rate	0.0147	g/s

To assess the impact from power generation at wellheads, the physical stack parameters and emission rates for a 60 kW engine used in the Air Quality Technical Report (Appendix H, Section 5.2.1.5) of the EIS were adopted for the SREIS assessment.

Power Generation for Drilling and Completions

Diesel power generation for well drilling and completion operations were not assessed in the EIS as the drilling period on a single well pad was in the order of weeks and the drilling period for a multi-well pad with 12 wells can be over a year.

Based on Arrow's latest rig proposals, the drilling rig systems are expected to be run off the central diesel generator sets located at the well pad and will operate for the following durations:

- 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.

Emissions from diesel power generation for drilling and completions were estimated based on equipment manufacturer specifications for a series of four generator sets. A summary of generator stack parameters and emissions is shown in Table 5-4.

Table 5-4 Drilling Emissions Summary

Stack Parameter	Value	Units
Height of release	2.5	m
Stack diameter	0.25	m
Exit velocity	31	m/s
Actual exhaust volume flow rate	1.52	m^3/s
Exit temperature	782	K
CO emission rate	0.76	g/s
NOx emission rate	4.56	g/s
VOC emission rate	0.019	g/s
PM_{10} emission rate	0.052	g/s
$PM_{2.5}$ emission rate	0.052	g/s

5.3.3.2 Flaring

Ramp-up Flaring

The EIS assessed ramp-up flaring in each gas field. Arrow now expects to minimise flaring associated with the Project ramp-up through commissioning all upstream facilities using gas from the Arrow Bowen Pipeline. Hence under the current development scenario, no ramp-up flaring is expected to take place.

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. The flare rates are expected to be, on average, approximately 5,000 m^3/d, but could range from 0 to 225,000 m^3/d (8.39 TJ/d) 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/d or 8.39 TJ/d was adopted.

Pilot Flaring

Currently, continuous pilot flaring is planned at FCFs and CGPFs with the same rate of 0.02 TJ/d/facility as assessed in the EIS. Pilot flame scenario has not been changed since the EIS and therefore this scenario has not been presented in this study.

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

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/d for 13 hours; and
- Approximately 10 occurrences per year at a rate of 20 TJ/d for 26 hours.

The rate of 360 TJ/d at a CGPF was adopted for this assessment.

Flaring Emissions Summary

The physical parameters of the flaring stacks are provided in Table 5-5. These are subject to detailed design; however, Arrow does not expect them to differ significantly from those presented.

Table 5-5 Flare Gas Consumption Rates and Physical Stack Parameters

Flaring Type	Gas Consumption Rate (TJ/d)	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 5-6, and are based on emission factors presented in the Air Quality Technical Report (Appendix B, Section 4) of this SREIS.

Table 5-6 Flaring Emissions Estimates

Flaring Type	Emission Estimates (g/s)				
	CO	NO_x	VOC	PM_{10}	$PM_{2.5}$
Well completions and workovers	16.45	2.84	0.04	0.11	0.11
Maintenance / upset conditions (maximum rate per facility)	706.32	121.78	1.62	4.55	4.55

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.

5.3.3.3 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 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 this 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/a of VOCs was assumed in the assessment.

5.3.3.4 Transport Emissions

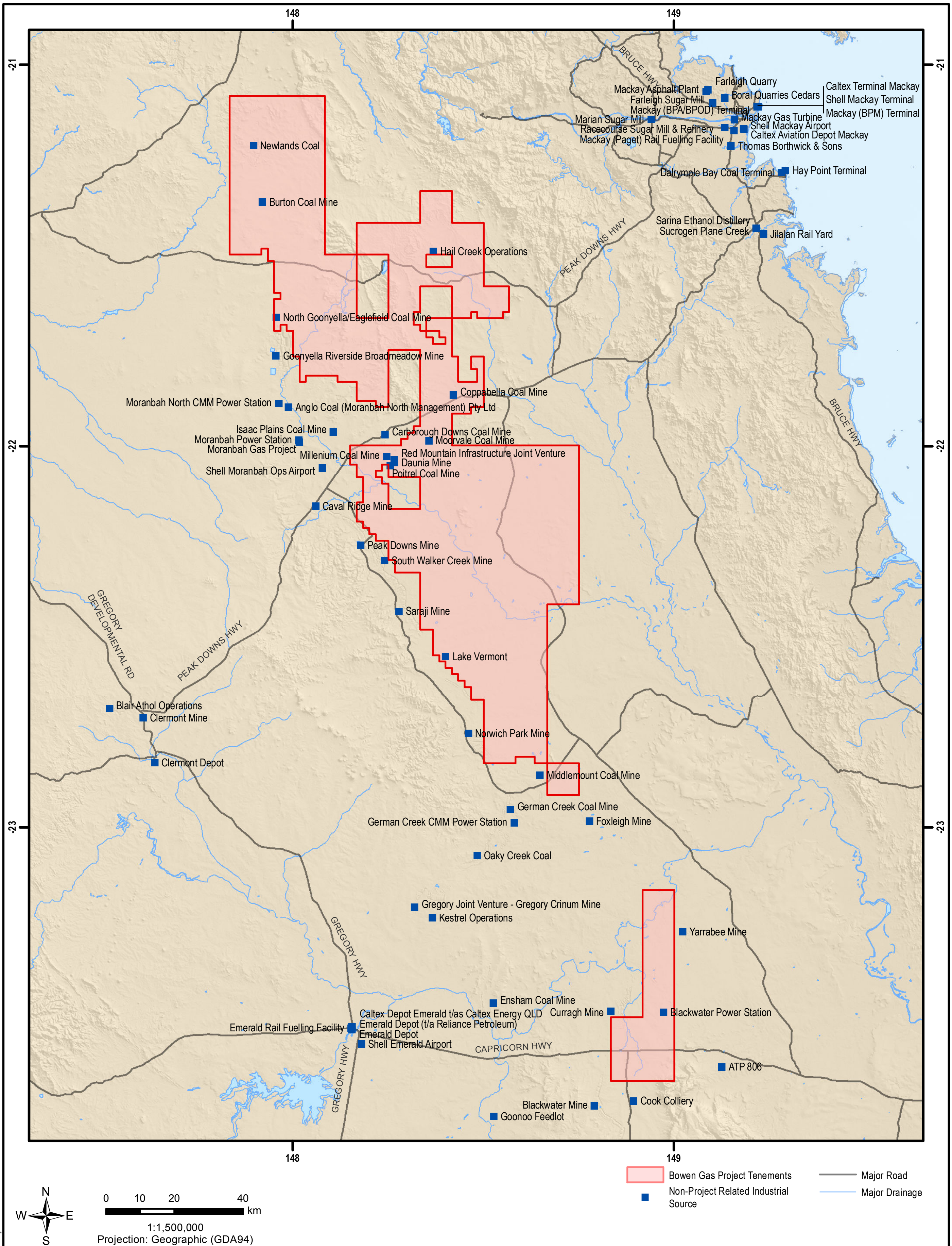
Transport emissions were not assessed in the EIS as they were considered to be insignificant. It is not expected that the refined field development plan and Project infrastructure design would lead to an increase in transport emissions. Therefore, transport emissions have not been assessed in the SREIS.

5.3.3.5 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 The Air Pollution Model (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.

5.3.3.6 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) NPI and available information on future approved projects. Note that 2010/2011 NPI data were used in the EIS. Figure 5-1 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 the Air Quality Technical Report (Appendix B) of the SREIS.



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NON-PROJECT RELATED INDUSTRIAL SOURCES IN THE STUDY AREA

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Figure: **5-1**

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5.3.4 Dispersion Modelling

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, since publication of the EIS, the Aermod model was adopted by the Environment Protection Authority Victoria (EPAV) as the replacement for Ausplume for regulatory air impact assessments (EPAV, 2013). Therefore, Aermod was adopted for the SREIS assessment. For consistency with the EIS results, the input model settings, where possible, were kept similar to those used in the Ausplume modelling.

5.3.4.1 Regional Scale Impacts

The method for the assessment of regional scale impacts of photochemically reactive compounds (NO_2 and O_3) has been updated as a result of changes to the Project power options and the type, number and location of Project and non-Project related sources.

A comparison between the atmospheric dispersion modelling scenarios considered in the EIS and SREIS is shown in Table 5-7.

Table 5-7 Regional Scale Dispersion Modelling Scenario

Scenario	EIS	SREIS
Baseline	64 existing and future non-Project sources based on emissions data from the 2010/11 NPI and available information on future projects.	68 existing and future non-Project sources based on emissions data from the 2011/2012 NPI and available information on future projects.
Cumulative impact (1)	Project powered locally by gas. Emissions from Project operations in year 2023, two years after the Project reaches its full production capacity.	Project powered locally by gas (alternative temporary power generation scenario). Emissions from Project operations at maximum installed capacity for the first two years (worst

Scenario	EIS	SREIS
		case).
Cumulative impact (2)	Total emissions from all proposed production facilities operating at maximum capacity (worst case).	Base case grid power supply based on connection to electricity infrastructure and gas fired power generation at 10% of wellheads. This scenario was assessed qualitatively.

In the EIS, emissions under Scenarios 1 and 2 were assessed through dispersion modelling. In the SREIS, emissions from Scenario 1 were assessed through dispersion modelling, and emissions from Scenario 2 were assessed qualitatively as they are significantly lower than Scenario 1 emissions.

5.3.4.2 Local Scale Impacts

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 northern, north-eastern, central and southern regions of the Project area. 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 the proposed possible temporary power generation sources located at CGPFs and FCFs. Table 5-8 shows the sources and scenarios considered in the local scale assessment.

Table 5-8 Local Scale Dispersion Modelling Scenarios

Scenario	EIS	SREIS
Gas fired power generation	Emissions from power generation at maximum facility and typical well head power requirements were assessed. The minimum separation (buffer) distance between power sources and any proximate sensitive receptors to achieve compliance with the NO_2 health-based objective were estimated for each facility.	Alternative temporary gas fired power generation scenario. Modelled as a preliminary estimated separation (buffer) distance between power generation facilities, not including wellheads, and any proximate sensitive receptors based on the emissions from the power generation facility at the largest CGPF.
Diesel power generation for drilling	Not assessed.	Emissions were assessed to estimate separation (buffer) distance as in the previous scenario for typical engine loads.
Flaring	Gas field ramp-up and upset conditions during operations were assessed.	Flaring during well completions and workovers as well as upset conditions flaring for a CGPF with the highest emission rates were assessed.

5.4 Impact Assessment

This section provides a summary of all emission rates used in the modelling assessment and the predicted results. Unless otherwise stated, background concentrations are included in all results presented.

The potential direct and indirect impacts of the Project on environmental values have been assessed using one of three impact assessment methods: significance assessment, risk assessment and compliance assessment. For the assessment of air quality, compliance assessment has been used. For further details see the Impact Assessment Method chapter (Section 6) of the EIS.

5.4.1 Regional Impacts on Air Quality

5.4.1.1 Background Concentrations

The existing (background) concentrations were modelled at each grid point of the modelling domain and are compared against the EPP (Air) health and well-being based objectives in Table 5-9.

Table 5-9 Predicted Existing (Background) Concentrations

Pollutant	Air EPP Objective (µg/m³)	Averaging Period	Highest Concentration (µg/m³)	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.

The predicted concentrations are below the relevant air quality objectives for human health and well-being. The second highest 1-hour average background concentration of NO_2 (171.3 µg/m^3) was predicted for a limited area within the modelling domain. The averaged concentrations of NO_2 across the modelling domain are well below this value. Background annual average concentrations of NO_2 higher than the air quality objective for the health and biodiversity of ecosystems (33 µg/m^3) were predicted for the three limited areas within the domain. 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.

SREIS predicted background concentrations are higher than those predicted in the EIS because more sources with higher emissions were included in the updated inventory.

5.4.1.2 Project Related Emissions

Project regional impacts on the ground level concentrations of NO_2 and O_3 were modelled for Scenario 1 (alternative case: temporary power generation in 2019) at each grid point of the modelling domain.

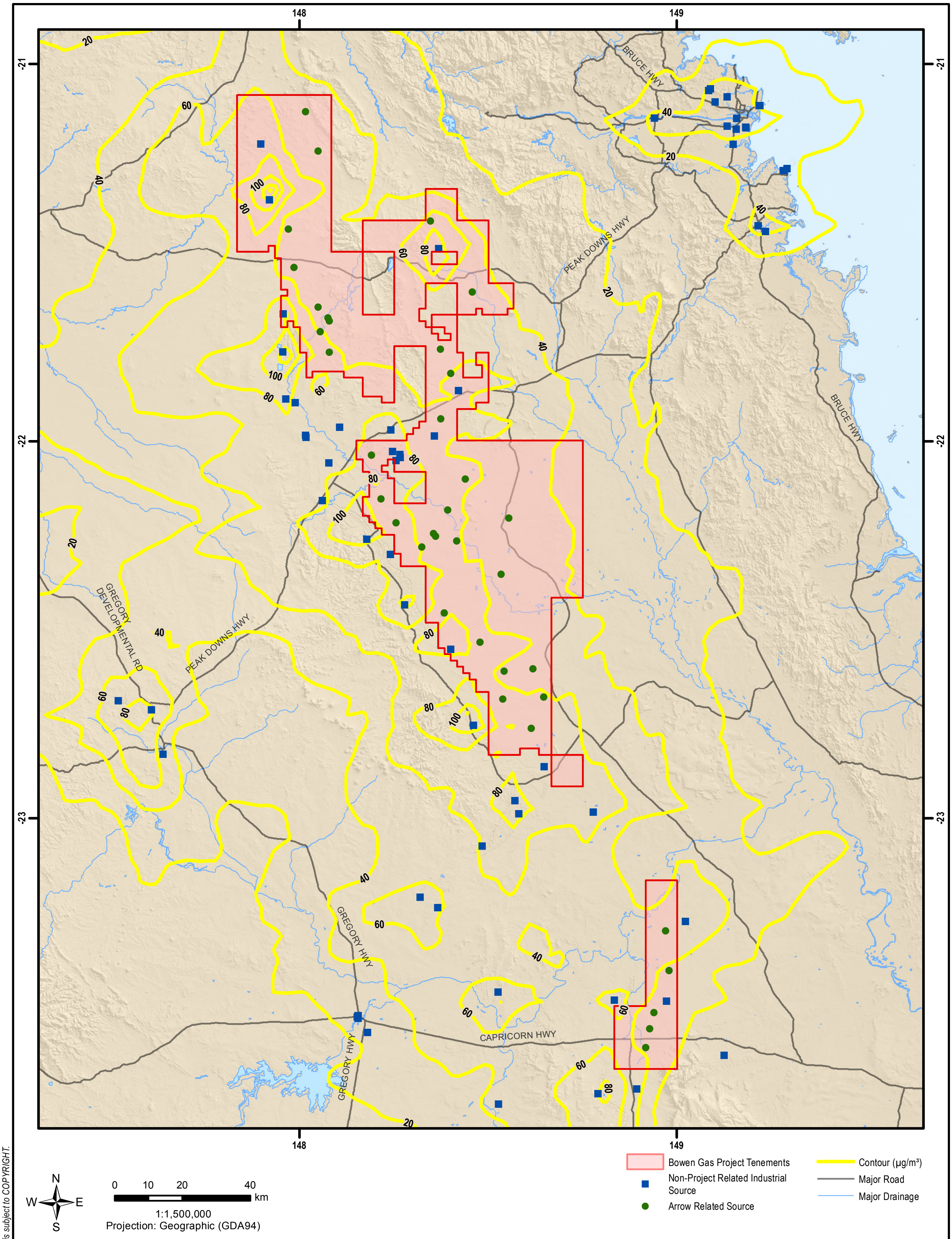
The emissions considered in Scenario 2 are significantly lower compared to emissions modelled in Scenario 1 (Air Quality Technical Report (Appendix B, Section 5.1.3) of the SREIS), with much lower potential effect on concentrations of photochemical compounds. Therefore, modelling results for Scenario 1 are reported in this section.

A comparison of the maximum and average predicted pollutant concentrations for Scenario 1 with the EPP (Air) health and well-being objectives is presented in Table 5-10. Contour plots of the predicted ground-level concentrations of NO_2 and O_3 for Scenario 1 are presented in Figure 5-2, Figure 5-3, Figure 5-4, Figure 5-5 and Figure 5-6. Figure 5-4 represents a zoomed-in version of Figure 5-3 highlighted to show spatially limited areas with the highest predicted NO_2 annual average concentrations.

Table 5-10 Predicted Concentrations for Regional Scale Scenario 1 – Alternative Case or "Worst-Case" (Temporary Power Generation)

Pollutant	Air EPP Objective (µg/m³)	Averaging Period	Highest Concentration (µg/m³)	Highest Concentration Averaged Across the Model Grid (µg/m³)
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.



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SECOND HIGHEST NO_2 (1-HR AVG) CONCENTRATIONS (µg/m³) PREDICTED FOR SCENARIO 1 - ALTERNATIVE CASE OR "WORST-CASE" (TEMPORARY POWER GENERATION)

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Figure: **5-2**

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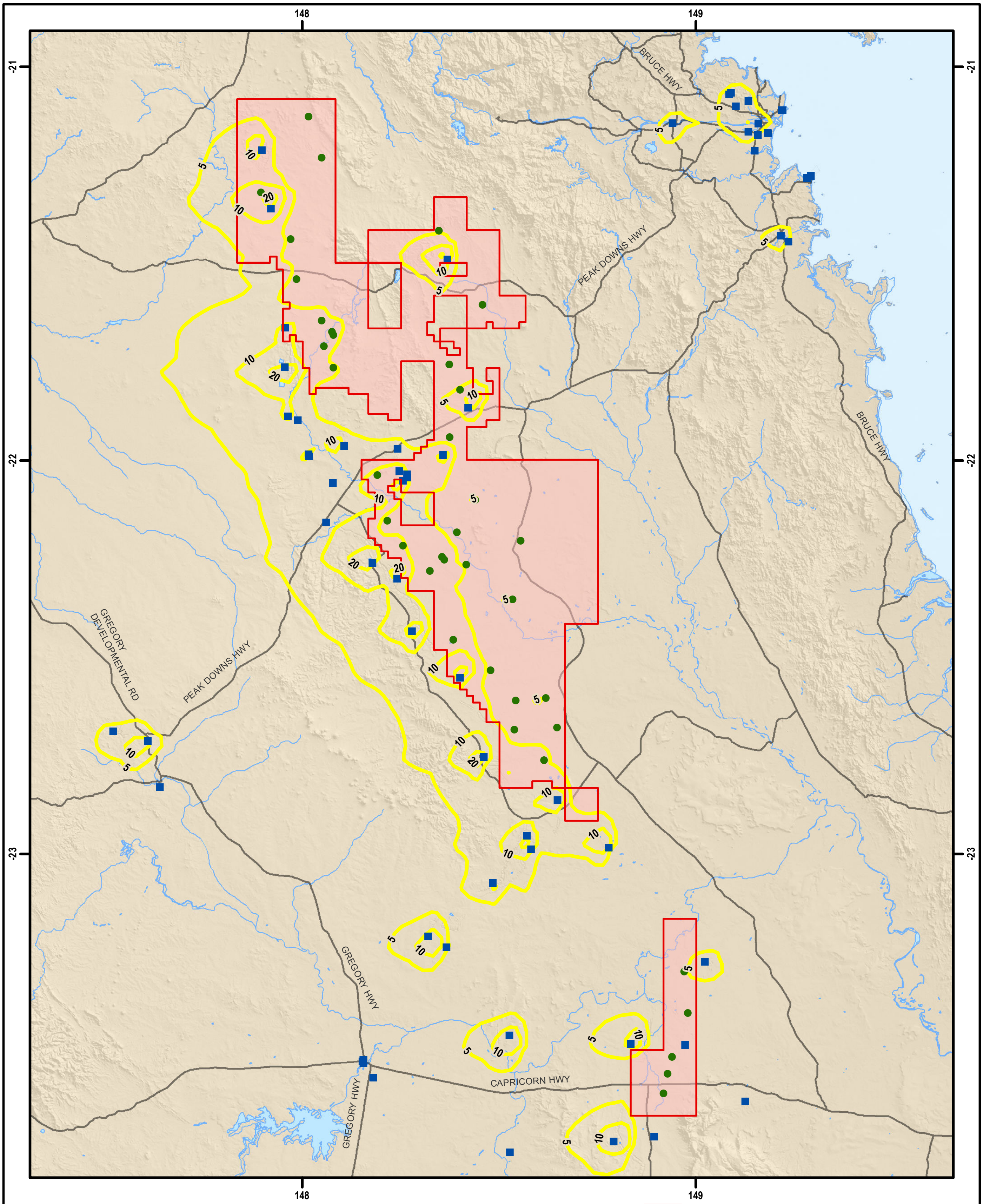

Bowen Gas Project Tenements
Non-Project Related Industrial Source
Arrow Related Source
Contour (μg/m³)
Major Road
Major Drainage

0 10 20 40 km
1:1,500,000
Projection: Geographic (GDA94)

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BOWEN GAS PROJECT SREIS

ANNUAL AVERAGE NO_2 CONCENTRATIONS (μg/m³) PREDICTED FOR SCENARIO 1 - ALTERNATIVE CASE OR "WORST-CASE" (TEMPORARY POWER GENERATION)

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Figure: **5-3**

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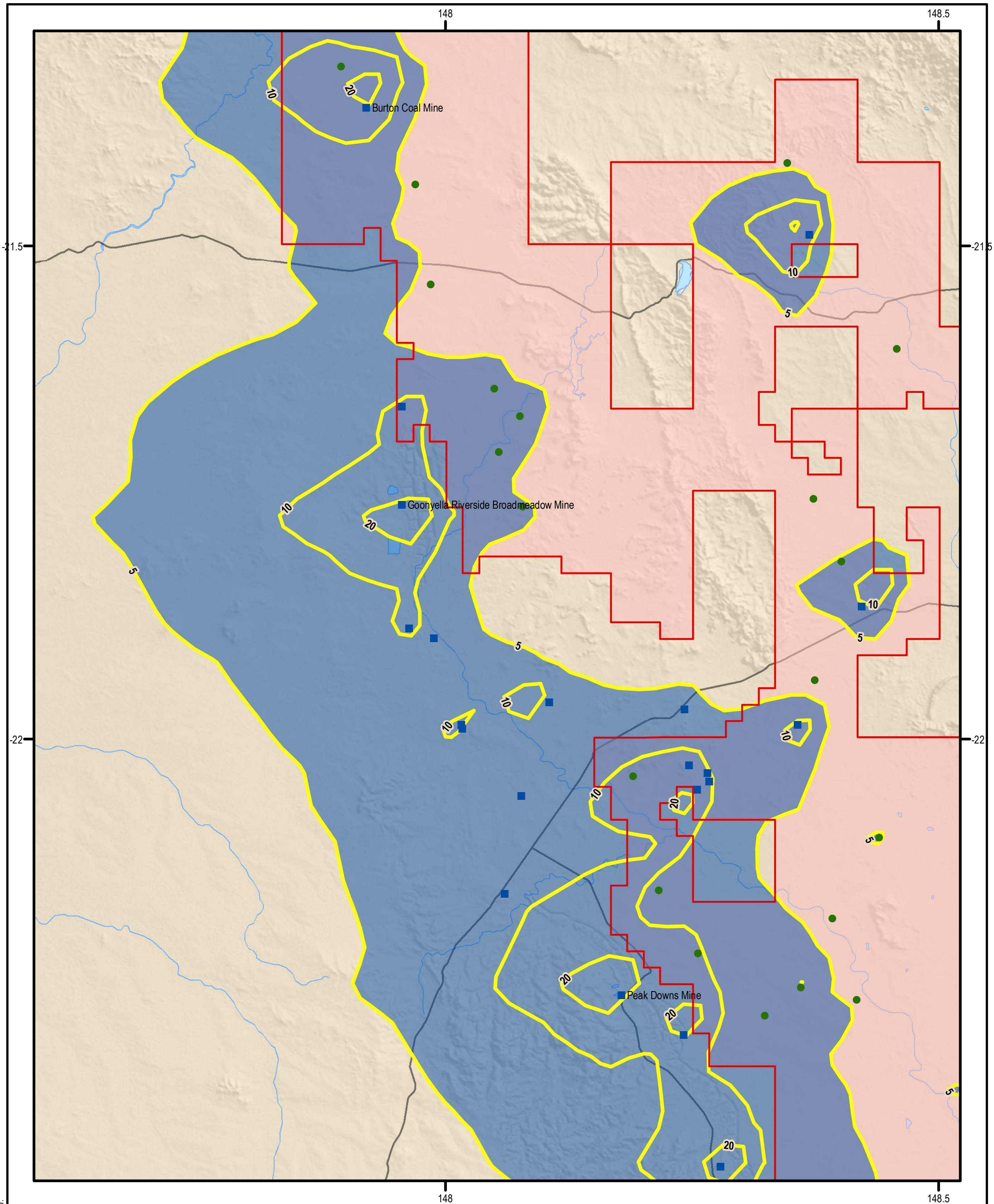

Bowen Gas Project Tenements
Non-Project Related Industrial Source
Arrow Related Source
Contour (µg/m³)
Major Road
Major Drainage

N E S W

0 2.5 5 10 15 km

1:600,000

Projection: Geographic (GDA94)

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BOWEN GAS PROJECT SREIS

NO_2 ANNUAL AVERAGE CONCENTRATIONS (µg/m³) PREDICTED FOR SCENARIO 1 - ALTERNATIVE CASE OR "WORST-CASE" (TEMPORARY POWER GENERATION) (PLOT EXTENT REDUCED)

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Figure: **5-4**

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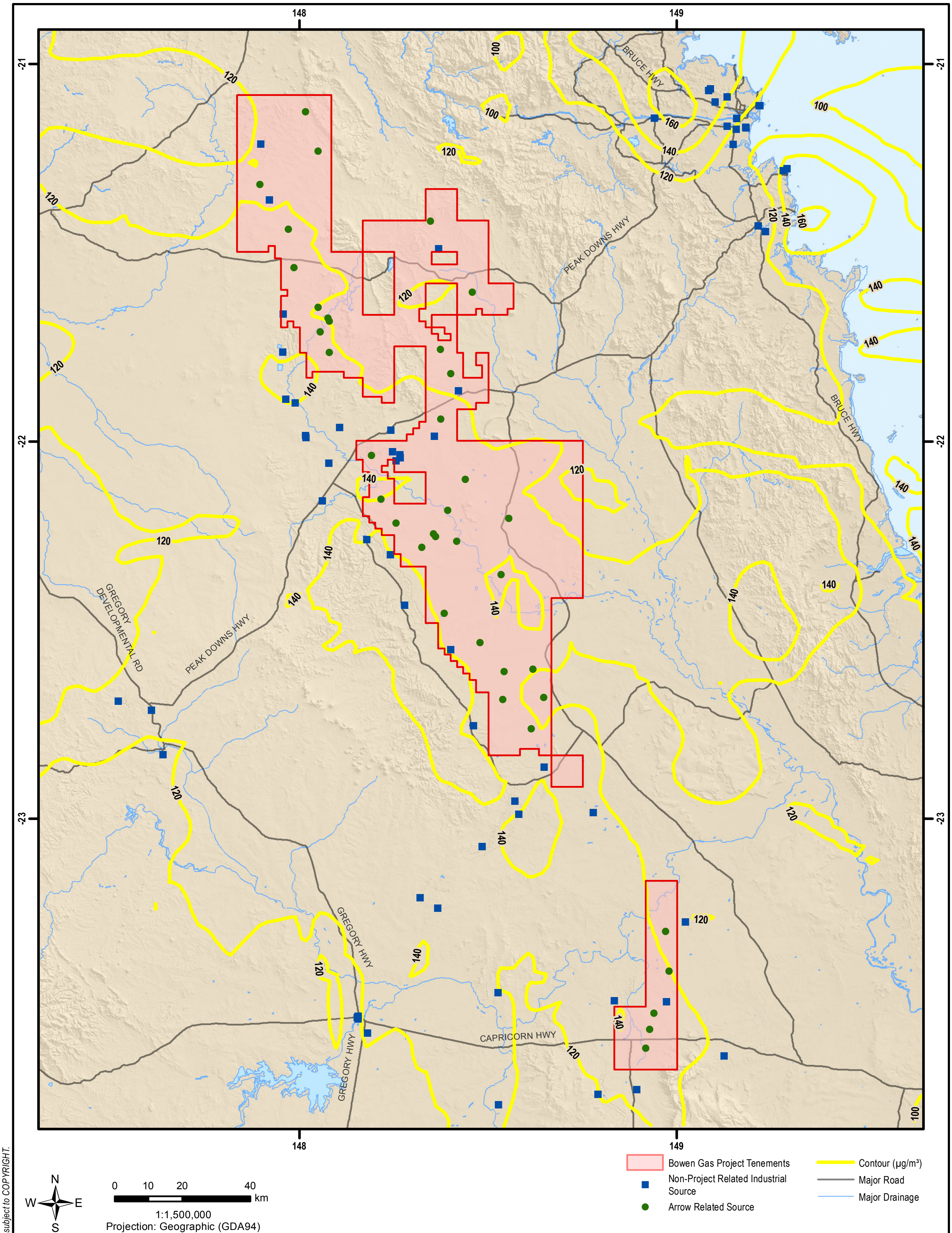

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BOWEN GAS PROJECT SREIS

SECOND HIGHEST O_3 (1-HR AVG) CONCENTRATIONS (µg/m³) PREDICTED FOR SCENARIO 1 - ALTERNATIVE CASE OR "WORST-CASE" (TEMPORARY POWER GENERATION)

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AIR QUALITY

Figure: **5-5**

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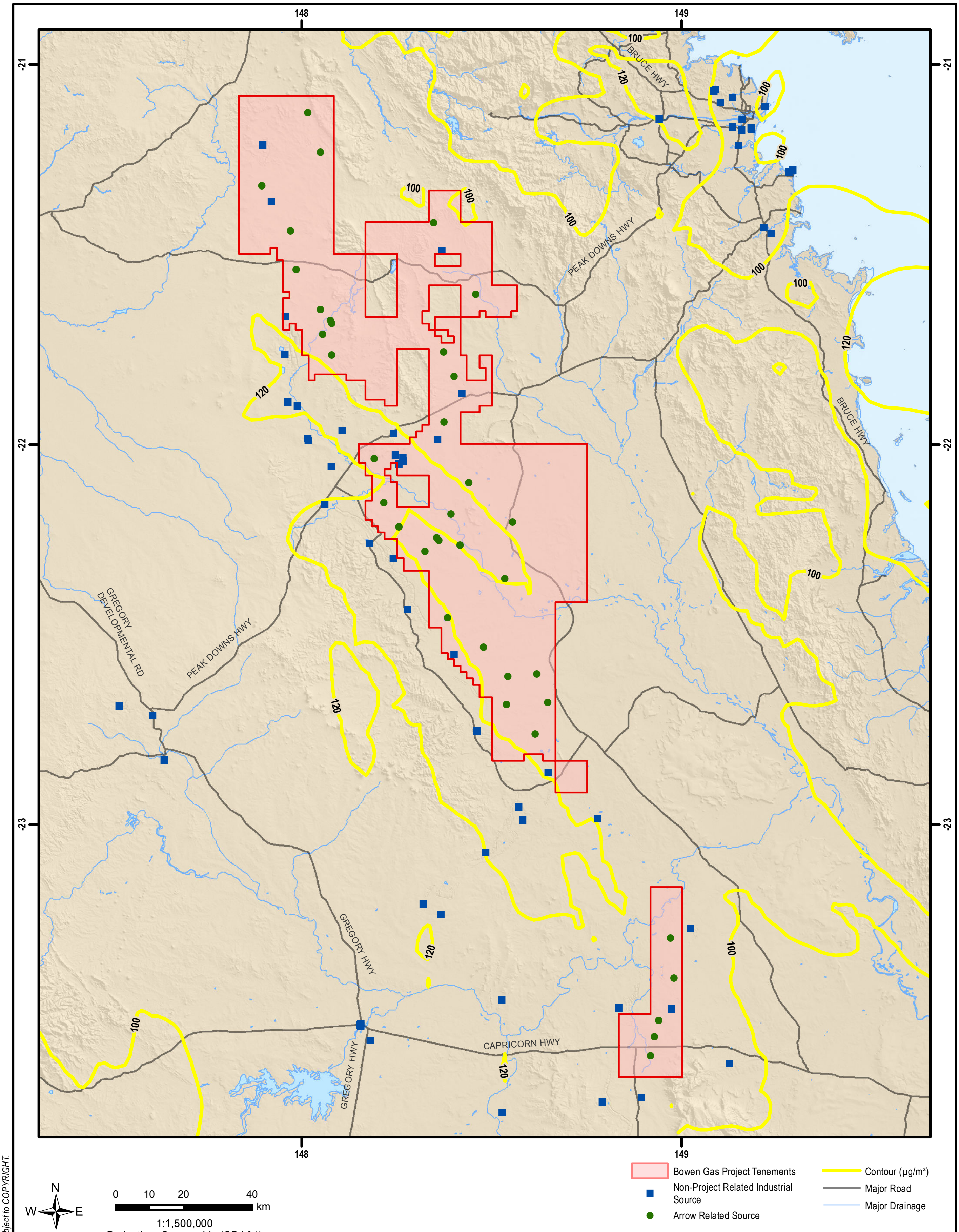

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BOWEN GAS PROJECT SREIS

SECOND HIGHEST O_3 (4-HR AVG) CONCENTRATIONS (µg/m³) PREDICTED FOR SCENARIO 1 - ALTERNATIVE CASE OR "WORST-CASE" (TEMPORARY POWER GENERATION)

URS

AIR QUALITY

Figure: **5-6**

File No: **42627140-g-1034.mxd** Drawn: **RG** Approved: **DS** Date: **24-03-2014** Rev. **A** A4

Figure 5-2 to Figure 5-6 show that Project operations were predicted to increase ground level concentrations of 1-hour average NO_2 and 1-hour average O_3 by 2 to 3%. The highest 1-hour average NO_2 concentrations 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 presented in Table 5-10.

No EPP (Air) objective for human health and well-being was predicted to be exceeded in the study area. However, as in the modelling of the background concentrations, 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 the same areas close to existing coal mines (Figure 5-4). 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 the Air Quality Technical Report (Appendix B) of this SREIS. No EPP (Air) objective was predicted to be exceeded at the sensitive receptor locations.

In the EIS, no exceedences of any of the Project criteria were predicted in the regional scale modelling for all pollutants and averaging periods. Therefore, the conclusions drawn from the EIS assessment remain unchanged as a result of the re-assessment of regional scale emissions resulting from the refined project description.

5.4.2 Localised Impacts on Air Quality

The Project has the potential to adversely impact on local air quality through emissions released from power generation (NO_2, particulate matter and VOCs) and flaring (NO_2, particulate matter and CO). As in the EIS, NO_2 was considered as a pollutant with the highest potential to cause an adverse impact on local air quality. The potential impacts of VOCs and CO are expected to be very minor in comparison with NO_2, with predicted values much lower than their respective guidelines.

To reassess the potential impacts on local air quality for the updated project description, atmospheric dispersion modelling using Aermod was conducted for the four meteorological subregions. This enabled the assessment to capture the effect of spatially varying meteorological conditions on the modelling results.

5.4.2.1 Background Concentrations

Background NO_2 concentrations were extracted from the regional scale atmospheric dispersion modelling results 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 5-11.

Table 5-11 Background NO_2 Concentrations

Meteorological Subregion*	Second Highest 1-hour Average Background NO_2 Concentration (µg/m³)	Annual Average Background NO_2 Concentration (µg/m³)
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 – north east; S – south; N – north; C - central

The highest predicted value of 99.0 µg/m³ was used to represent background 1-hour average and annual average NO_2 concentrations for all subregions. These values are conservative because they were selected from a location with high density of existing industrial sources, 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 5-12.

Table 5-12 Background Particulate Matter and CO Concentrations

Pollutant	Background Concentration (µg/m³)	Averaging Period	EPP (Air) Objective (µg/m³)
PM_{10}	28	24-hour	**50**
$PM_{2.5}$	8	24-hour	**25**
	6	Annual	**8**
CO	646	8-hour	**11,000**

5.4.2.2 Temporary Gas Fired Power Generation (Alternative Case)

Modelled Emissions

Temporary gas fired power generation may be required in approximately the first two years of Project if the Network Service Provider is unable to deliver the infrastructure prior to commissioning (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.

NO_2 is the pollutant with the highest potential to adversely impact on local air quality from power generation. The potential impacts of other pollutants are expected to be very minor. A power generation facility located at the largest CGPF was selected to represent emissions from gas fired power generation. Table 5–13 shows a comparison of CGPF emissions modelled in the EIS and

SREIS, which are based on different engine configurations. In order to determine how the refined power generation configuration adopted for the SREIS would affect local air quality, Aermod modelling was conducted for NO_x emissions.

Table 5–13 Comparison of Emissions Modelled in the EIS and SREIS for CGPF Located Gas Fired Power Generation

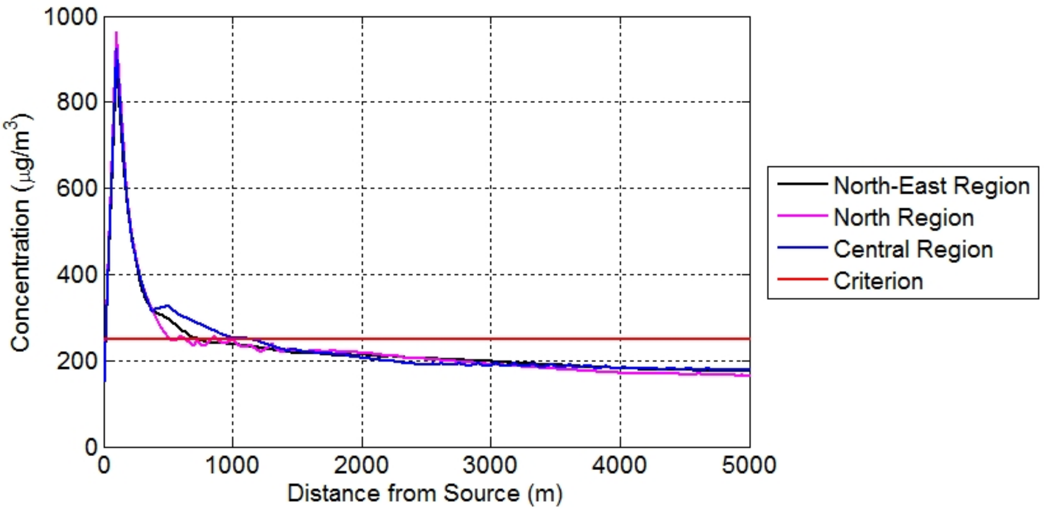
Local Power Generation Source	NO_x Emission Rate (g/s)
SREIS configuration based on 40 engines (1.16 MW)	22.0
EIS configuration based on 21 engines (3 MW)	31.5

Table 5–13 shows that the NO_x emission rates modelled for the largest of the EIS related CGPFs were higher than for the largest of the SREIS related CGPFs.

Modelling Results

The maximum predicted ground level NO_2 concentrations are presented in Figure 5-7 as line plots showing the maximum 1-hour NO_2 concentration as a function of distance from the proposed power generation source at a CGPF for each meteorological subregion.

Figure 5-7 Second Highest Predicted 1-Hour Average NO_2 Concentrations as Function of Distance from Proposed CGPF Source (Alternative Case – Temporary Power Generation)



The second highest concentration of NO_2 was 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 was determined for each subregion. The estimated minimum separation distances are presented in Table 5-14.

Table 5-14 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*	Indicative Separation Distance (m) from Largest CGPF
1 (NE)	735
2 (N)	1,000
3 (C)	1,160

* NE – north east; N – north; C – central

The estimated separation distance required from a power generation source, co-located with a CGPF, ranges from 735 m to 1,160 m depending upon the meteorological 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 located at CGPFs and FCFs will only be required in the event that the Network Service Provider is unable to deliver the infrastructure prior to commissioning of the Project. These distances will be recalculated as part of the detailed design process to assist with site selection and the EA application.

5.4.2.3 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. Using anticipated engine loadings, Aermod was used to predict the impacts from diesel power generation sources, with physical stack parameters and mass emission rates presented in Table 5-4.

Table 5-15 shows the predicted ground level concentrations of modelled pollutants for diesel power generation for drilling operations in the modelling domain.

Table 5-15 Predicted Concentrations for Power Generation for Drilling and Completions

Meteoro-logical Subregion*	Pollutant	Averaging Period	EPP(Air) Objective (µg/m³)	Background Concentra-tion (µg/m³)	Predicted Ground Level Concentra-tion (µg/m³)	Background plus Predicted Ground Level Concentra-tion (µg/m³)
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

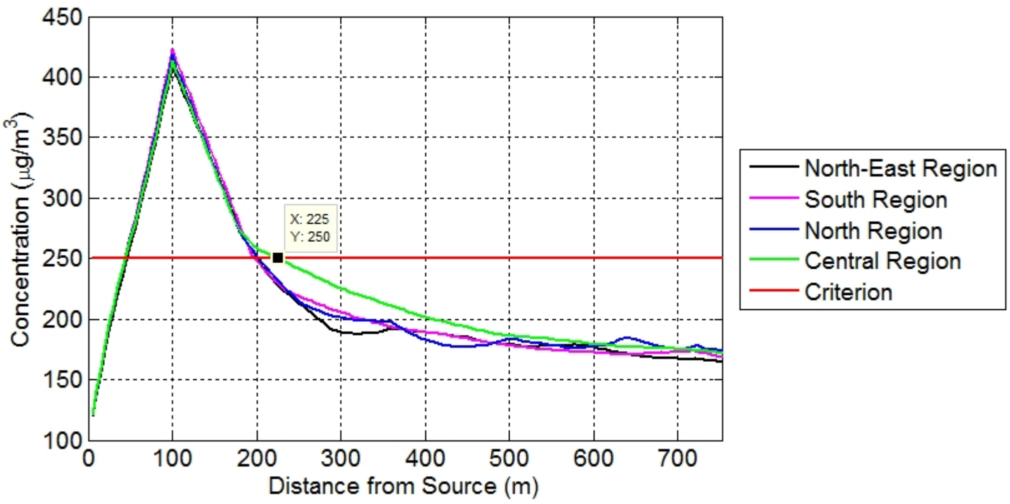
Meteoro-logical Subregion*	Pollutant	Averaging Period	EPP(Air) Objective (µg/m³)	Background Concentration (µg/m³)	Predicted Ground Level Concentration (µg/m³)	Background plus Predicted Ground Level Concentration (µg/m³)
2 (S)	NO_2	1-hour	250	99	**324**	**423**
		Annual	62	5	22	27
	CO	8-hour	11,000	646	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 – north east; N – north; S – south; C – central

Table 5-15 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 5-8 as a function of distance from the power generation source for each modelled meteorological subregion.

Figure 5-8 Second Highest Predicted 1-Hour Average NO_2 Concentrations as Function of Distance from Drilling Power Generation Source



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 as shown in Table 5–16.

Table 5–16 Indicative 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 – north east; N – north; S – south; C – central

Table 5–16 shows the estimated minimum separation distance from the power generation source ranges from 198 m to 225 m depending upon the meteorological data modelled. Therefore, the indicative separation distance should be approximately 225 m to achieve compliance with the NO_2 health-based objective. These distances will be recalculated as part of the detailed design process to assist with site selection and the EA application.

5.4.2.4 Flaring

The refined project description shows that ramp-up flaring is no longer expected to be required. Flaring during well completions and workovers is a new flaring scenario included in the SREIS. 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. The new maximum flaring rate represents upset flaring conditions, which might take place only once in 2 years with approximately 21 hours duration.

A summary of flare gas consumption rates, physical stack parameters and emission rates adopted for the SREIS are presented in Table 5-5 and Table 5-6.

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.

Upset Conditions Flaring

The second highest ground level NO_2 concentrations predicted for upset condition flaring for each meteorological subregion are presented in Table 5-17.

Table 5-17 NO_2 Concentrations (including background) Predicted for Upset Conditions Flaring

Meteorological Subregion*	Second Highest 1-hour Average NO_2 Ground Level Concentration (µg/m³)
1 (NE)	103
2 (S)	104
3 (N)	104
4 (C)	106
EPP (Air) objective (µg/m³)	**250**

* NE – north east; N – north; S – south; C – central

The proposed gas consumption rates associated with planned and unplanned upset conditions flaring have increased in the SREIS compared to the EIS. However, the predicted concentrations of NO_2 presented in Table 5-17 are still well below the Project objective in the whole sub-region including all sensitive receptors.

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 5-18 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 5-18 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 (µg/m³)	2nd Highest 8-hour Average CO Ground Level Concentra-tion (µg/m³)	2nd Highest 24-hour Average PM_{10} Ground Level Concentra-tion (µg/m³)	2nd Highest 24-hour Average $PM_{2.5}$ Ground Level Concentra-tion (µg/m³)	Annual Average $PM_{2.5}$ Ground Level Concentra-tion (µg/m³)
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 (µg/m³)	**250**	**11,000**	**50**	**25**	**8**

* NE – north east; N – north; S – south; C – central

Table 5-18 shows that all relevant Project objectives are not predicted to be exceeded at any location, including sensitive receptors, in each meteorological subregion.

5.5 Avoidance, Mitigation and Management Measures

Arrow committed to implement a number of avoidance, mitigation and management measures to reduce impacts on values in the Project development area. The commitments pertaining to air quality presented in the EIS are listed in Table 5-19.

A full list of all Project commitments, including those that remain unchanged from the EIS, and details of those that have changed, are included in the Commitments Update (Appendix O) of this SREIS.

Table 5-19 Air Quality Commitments Presented in the EIS

Number	Commitment
B001	Further assessment of cumulative impacts from all emission sources in the local airshed is recommended once potential Project facility and well locations have been identified, especially in the case of possible clustering and the suitability of these locations.
B002	To construct and operate in a manner that minimises impacts on ambient air quality. Ensure relevant air quality guidelines are met at sensitive receptors to maintain human and environmental health.
B003	Conduct site-specific air quality modelling once site locations are known to ensure Project-related air emissions meet EPP (Air) objectives at the nearest sensitive receptor.
B004	Select equipment with consideration for low emissions to air (NOx, SOx), high energy efficiency and fuel efficiency.
B005	Design facilities to meet relevant EPP (Air) objectives at sensitive receptors.

Number	Commitment
B006	Minimise fuel consumption of vehicles by optimising transport logistics.
B007	Select gaskets, seals and vehicle exhaust systems that are suitable for the task.
B011	Consider supporting gas industry initiatives that seek to improve technology or processes, such as contributions to or sponsorship of research and development.
B012	Consider supporting through corporate community involvement programs the development of energy efficiency initiatives in the areas where Arrow operates.
B013	Ensure all engines, machinery equipment and pollution control mechanisms are operated and maintained in accordance with manufacturer's recommendations.
B014	Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance.
B015	Cover dust-generating materials prior to transportation.
B016	Consult with potentially affected landowners prior to undertaking activities.
B017	Minimise the disturbance footprint and vegetation clearing.
B018	The land cleared for construction purposes will be kept to the minimum necessary, especially during the drier months of the year.
B019	The number and sizes of stockpiles will be kept to minimum.
B020	Dust suppression shall be undertaken during construction and clearing activities, particularly during high wind conditions. Haul roads and other unsealed areas will be watered to suppress dust.
B021	The cleared areas and stockpiles will be progressively rehabilitated through revegetation and/or mulching.
B022	Prevent venting and flaring of gas as far as practicable and where safe to do so, in accordance with the P&G Act.
B023	Ensure that odour emissions are considered during design to prevent nuisance or harm to sensitive receptors.
B024	Implementation of a preventative maintenance program to ensure gas engines are operating efficiently to minimise emissions of incomplete combustion products – CO and hydrocarbons (primarily methane, with minor VOC emissions).
B025	Minimise potential fugitive emissions from construction and operation of production wells and gas production infrastructure.
B026	Use of low NOx equipment, where practical.
B028	Minimisation of emissions from gas dehydration.
B029	Optimisation of gas driven generator operations to minimise time periods of operation at low efficiency levels that may result in excess greenhouse gas emissions and higher than normal levels of NOx emissions.
B030	Implementation of a quantifiable monitoring and measuring program.
B031	Use of efficient gas and water separation methods on wellheads, gathering and process facilities to minimise fugitive gas release.
B036	The method of measurement and reporting of air emissions will comply with the relevant sections of the DERM Air Quality Sampling Manual.

Constraints will be applied to the site selection of the proposed power generation facilities and drilling and completion operations, based on the indicative separation distance to sensitive receptors found through preliminary modelling. As detailed design progresses the modelling will be further refined.

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, modelling indicated that a separation distance of up to 225 m may be required between the source and sensitive receptor, to achieve the hourly NO_2 objective for human health.

5.6 Conclusion

The key project description change from the EIS which impacts on air emissions from the Project is power generation. In the EIS, the Project generated electricity from combustion of gas. Grid power supply based on the connection to existing electricity infrastructure is the preferred (base case) SREIS power supply scenario. 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. Other changes to the EIS assessment include an evaluation of emissions from diesel combustion for power generation for drilling operations, which were not assessed in the EIS. Further design optimisation has changed the projected flare emission sources, and ramp-up the removal of ramp-up flaring and the inclusion of flare emissions from well completions and workovers.

The same atmospheric dispersion modelling methodology for regional scale air quality impacts applied in the EIS was used in the SREIS.

For the alternative worst case scenario, Project operations were predicted to increase ground level concentrations in the region. However, none of the EPP (Air) objectives for human health and well-being were predicted to be exceeded at receptor locations or anywhere in the study area. This is consistent with the EIS. 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. The impact of Project emissions on ground level concentrations in these areas is very small or negligible.

For the base case, 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. 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 surrounding coal mines as a result of background sources.

In the local air quality assessment, the preliminary indicative separation distance between the largest power generation source, located at the largest CGPF, and sensitive receptors was 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, and will be further refined during detailed design. For emissions from power generation for drilling and well completions, the minimum separation distance was estimated to be 225 m. 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 condition 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.