



Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

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Basis of Report

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Arrow Energy Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

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Executive Summary

SLR Consulting Pty Ltd (SLR) has been engaged by Arrow Energy (Arrow) to perform an air quality impact assessment, including a detailed air dispersion modelling study, to assess potential air quality impacts from the proposed Field Compressor Station (FCS) to be located at Girrahween in the Surat Basin, Queensland.

The proposed FCS will consist of the following main plant:

- Screw compressors (up to four) which compress low-pressure coal seam gas (CSG),
- CSG fired internal combustion power generation plant equipped with a battery energy storage system (BESS). This provides electrical power to the facility mainly used to power the compressors.
- Multi-point ground flare (MPGF, to manage distressed gas),
- Slug catcher (to remove water in gas line; and
- Cyclone separator (to remove solids/fines in gas line).

All sensitive receptors in the study area are existing dwellings/residential premises. No other sensitive receptor types were identified within the study area. All sensitive receptors are located at least two kilometres from the Girrahween FCS and all well pads are located at a distance greater than 200 metres from sensitive receptors, as per EIS commitments for the Arrow Surat Gas Project (SGP).

Meteorological and dispersion modelling was performed using a combination of The Air Pollution Model (TAPM), CALMET and CALPUFF models to predict downwind concentrations of nitrogen dioxide (NO₂) and carbon monoxide (CO) due to emissions from the proposed power plant and major potential flaring events at the proposed FCS.

Modelling of NO₂ and CO was also performed for air emissions associated with the small (60 kVA) CSG fired power generators to be installed at the single and multi-well pads, to establish required minimum separation distances between well pads and nearest sensitive receptors. Three different categories of well pad power systems (consisting of one, four and six CSG fired generators respectively) were investigated as part of this study.

All air quality modelling was conducted at maximum emission rates and maximum loads, to provide a conservative assessment of potential air quality impacts.

Based on the modelling results, the following conclusions have been drawn:

- The modelling results showed that under normal maximum operating conditions (i.e. concurrent operation of 16 power station generators at maximum load), the proposed Girrahween FCS has no potential to result in any exceedances of the relevant ambient air quality criteria at surrounding sensitive receptors.
- The modelling of NO_x and CO emissions from maximum flaring events at the proposed Girrahween FCS showed that predicted short term average NO₂ and CO concentrations would also remain well below the relevant ambient air quality guidelines.
- Modelling results for the well pad generators showed that a separation distance of 200 m between the well pad and the nearest sensitive receptors would be adequate (in relation to potential air quality constraints) for all categories of well pads (single and multi-well pads).

Based on the above, no air quality constraints were identified for the proposed Girrahween FCS or the well pad operations by this air quality impact assessment.



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1.0 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Arrow Energy (Arrow) to undertake an air quality impact assessment (AQIA) for the proposed Girraheewen Field Compressor Station (FCS) as part of their Surat Gas Project (SGP) in Queensland. The Girraheewen FCS site is located approximately 18 kilometres (km) north of Miles.

1.1 Project Description

The Girraheewen FCS will facilitate compression of low-pressure coal seam gas (CSG) and deliver medium-pressurised gas downstream to the gas sales delivery point. This FCS will consist of the following:

- Screw compressors (up to four) which compress low-pressure coal seam gas (CSG),
- CSG fired internal combustion power generation plant equipped with a battery energy storage system (BESS). This provides electrical power to the facility mainly used to power the compressors.
- Multi-point ground flare (MPGF, to manage distressed gas),
- Slug catcher (to remove water in gas line; and
- Cyclone separator (to remove solids/fines in gas line).

For the purpose of this air quality impact assessment, sixteen (16) operating CSG fired generators (1875 KVA Aggreko GE J420E) have been assessed (refer to **Appendix A** for engine specifications for this unit). There will be two standby generator units at the site that would operate during the maintenance/shutdown of any of the 16 main generators.

The proposed site layout of the Girraheewen FCS is presented in **Figure 1**. As indicated in **Figure 1**, an emergency diesel generator will also be located at the southern end of the site. This unit would only operate intermittently for short periods for maintenance and testing, or in the event of a gas feed failure to enable safe shutdown of the FCS. Given the very short-term and intermittent nature of its operation, air emissions from this unit have not been considered further.

The Girraheewen development also includes the establishment of single and multi-well pads for the extraction of CSG from coal seams. The well pads would be powered by small (60 kVA) CSG fired internal combustion engines. The potential for air quality impacts from the operation of these engines is also addressed in this assessment.

There are no other significant sources of air emissions associated with the Girraheewen development requiring assessment.



1.2 Scope of Work

The scope of work for the AQIA was as follows:

- Confirm relevant regulatory criteria for relevant air pollutants, such as those set out in the *Queensland Environmental Protection (Air) Policy (EPP Air 2019)*.
- Characterise the background ambient air quality to enable an assessment of cumulative impacts. This included a review of air quality data collected by the nearest ambient air quality monitoring station (AQMS) located at Miles.
- Perform a generic assessment of single and multi-well pad emissions to identify separation distances, based on dispersion modelling using nominal air emissions data and the three-dimensional meteorological dataset compiled for the Girrahween FCS site.
- Review the FCS site layout plan, stack parameters and emissions data for key air pollutants (NO_x and CO) provided by Arrow for the proposed FCS operations.
- Model emissions of NO_x and CO from on-site CSG combustion sources (eg. gas generators, flares) for normal and flaring operational scenarios, as well as well pad combustion engines, to predict maximum downwind ground level pollutant concentrations using the CALPUFF dispersion model.
- Based on the results of the dispersion modelling, assess the potential impacts on local air quality associated with the operation of the proposed development.

2.0 Regulatory Framework

2.1 National Environment Protection Measure for Ambient Air Quality

The *National Environment Protection (Ambient Air Quality) Measure (NEPM AAQ)* (NEPC 2021) provides a nationally consistent framework for jurisdictions to monitor and report ambient air quality through setting reporting standards for key air pollutants. The NEPM AAQ contains standards and goals for six common air pollutants, commonly referred to as *criteria pollutants*. The current NEPM AAQ standards for those pollutants relevant to this assessment (as updated on 18 May 2021) are presented in **Table 1**.

It is noted that the NEPM AAQ standards apply at performance monitoring locations. Performance monitoring stations are to be located so that they provide a representative measure of the air quality likely to be experienced by the general population in the region or sub-region. The NEPM AAQ standards are therefore not intended for use in assessing air quality impacts from individual sources, specific industries or roadside locations. Nonetheless, many State regulatory agencies, including DESI (see **Section 2.2**), have adopted them as air quality impact assessment criteria for use in AQIAs.

Table 1 NEPM AAQ Standards and Goals for Criteria Pollutants

Indicator	Maximum Concentration Standard		Averaging Period
	µg/m ³ at 0°C	ppm	
NO ₂	162	0.08	1-hour
	30	0.015	Annual
CO	11,100	9.0	8 hours



2.2 Queensland EPP (Air) Policy 2019

The *Environmental Protection (Air) Policy* (EPP (Air)) (EPP Air 2019) is designed to achieve the objectives of the *Environmental Protection Act 1994* in relation to the air environment. The purpose of the EPP (Air) is achieved by identifying environmental values to be enhanced or protected, outlining indicators and air quality objectives for enhancing or protecting these values and providing a framework for making consistent, equitable and informed decisions about the air environment.

The environmental values listed in the EPP (Air) that are to be enhanced or protected under the policy are:

- *The qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems; and*
- *The qualities of the air environment that are conducive to human health and wellbeing; and*
- *The qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property; and*
- *The qualities of the air environment that are conducive to protecting agricultural use of the environment.*

A number of air quality objectives are outlined within Schedule 1 of the EPP (Air) to protect these environmental values. Those related to this AQIA are reproduced in **Table 2**.

It is noted that the health and wellbeing air quality objectives listed in the EPP (Air) for NO₂ are based on the NEPM AAQ standards prior to the latest update of the Measure in May 2021. It is understood that the EPP (Air) is in the process of being amended to reflect the recent changes to the AAQ NEPM, so while this AQIA has adopted the current EPP Air (2019) objectives, consideration has also been given to compliance with the reduced NEPM AAQ NO₂ standards.

As shown in **Table 2**, the EPP (Air) currently also includes an air quality objective for NO₂ to protect the health and biodiversity of ecosystems. The DESI Guideline *Application requirements for activities with impacts to air* (DESI 2024) states:

'If a proposal involves the release of contaminants to air in a location where natural ecosystems may be affected (e.g. adjacent to national parks), the applicant must identify whether emissions are at levels that may impact on the health and biodiversity of the ecosystem.'

Given that the NEPM AAQ standard for annual average NO₂ concentrations is slightly lower than the EPP (Air) annual average air quality objective NO₂ for ecological impacts, only the NEPM AAQ standard has been considered, for simplicity.

Table 2 Relevant EPP (Air) 2019 Ambient Air Quality Objectives

Indicator	Environmental Value	Air Quality Objectives		Averaging Period
		µg/m ³ at 0°C	ppm	
NO ₂	Health and wellbeing	250	0.12	1-hour
		62	0.03	Annual
	Health and biodiversity of ecosystems	33	0.016	Annual
CO	Health and wellbeing	11,000	9.0	8 hours

Section 9 of the EPP (Air) also sets out a management hierarchy for all activities involving air emissions:

- Firstly - **avoid** (e.g. using technology that avoids air emissions);
- Secondly - **recycle** (e.g. re-using air emissions in another industrial process);



- Thirdly - **minimise** (e.g. treating air emissions before disposal); and
- Fourthly - **manage** (e.g. locating an activity that releases air emissions in a suitable area to minimise the impact of the air emissions).

2.3 Air Quality Criteria Adopted in this Assessment

The ground level ambient air quality criteria that are considered appropriate for this air quality assessment are summarised in **Table 3**.

Table 3 Ground Level Concentration Criteria Adopted for use in this Study

Indicator	Averaging Period	Criterion ($\mu\text{g}/\text{m}^3$ at 0°C)	Reference
NO ₂	1 hour	250	EPP (Air) 2019
		162	NEPM AAQ (2021)
	1 year	62	EPP (Air) 2019
		30	NEPM AAQ (2021)
CO	8 hours	11,000	EPP (Air) 2019

3.0 Site Description

3.1 Site Locations

As outlined in **Section 1.0**, the proposed Girraheen FCS site is located approximately 18 km north of Miles in the Surat Basin in the Darling Downs region of Queensland.

The areas surrounding the site are predominantly rural in nature, with land uses such as grazing, pre-existing gas field development and overlapping mining tenures dominating. Existing road infrastructure typically includes a number of rural secondary roads linking the major regional road network, as well as numerous CSG field access roads and mining activities.

3.2 Climate and Meteorology

The nearest available meteorological monitoring stations collecting data suitable for use in a quantitative air dispersion modelling study operated by the Bureau of Meteorology (BoM) are located at Miles. The following description of the regional climate is based on long term data reported from Miles Constance Street (Station 042112, elevation 305 m), located 19 km from the Girraheen FCS, which has data available from 1992 to 2023 for the following parameters:

- Temperature (°C)
- Rainfall (mm)
- Solar radiation (MJ/m²)
- Relative humidity (%)
- Cloud cover
- Wind speed (m/s) and wind direction (degrees).

A review of the long term data available is provided in the following sections.

3.2.1 Temperature

Long-term temperature statistics for Miles Constance Street are summarised in **Figure 2**. Mean maximum temperatures range from 20.2°C in winter to 33.9°C in summer, while mean minimum temperatures range from 4.4°C in winter to around 20.5°C in summer. Maximum temperatures above 40°C and minimum temperatures less than -4°C have been recorded.



3.2.2 Rainfall

Long-term rainfall statistics for Miles Constance Street are summarised in **Figure 3**. The average monthly rainfall is relatively high in summer, reducing from autumn to winter with the lowest average of 21.6 mm/month recorded during July. This month also recorded an average of around five rain days per month. The highest average monthly rainfall of 86.6 mm/month occurs in December, with an average of 9 rain days recorded in this month. The highest monthly rainfall recorded over the time period examined was 340 mm recorded in December 2010. Peak rainfall events occur during summer, with the maximum daily rainfall of 116 mm recorded on 9 February 1998.

Figure 2 Long Term Temperature Data for Miles Constance Street

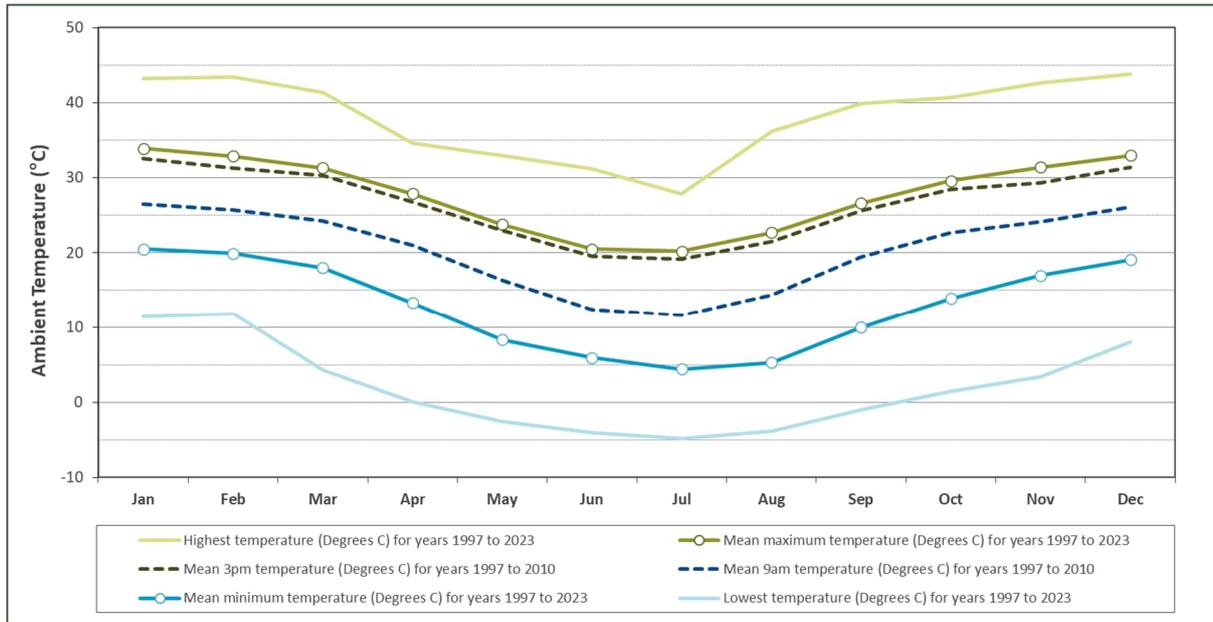
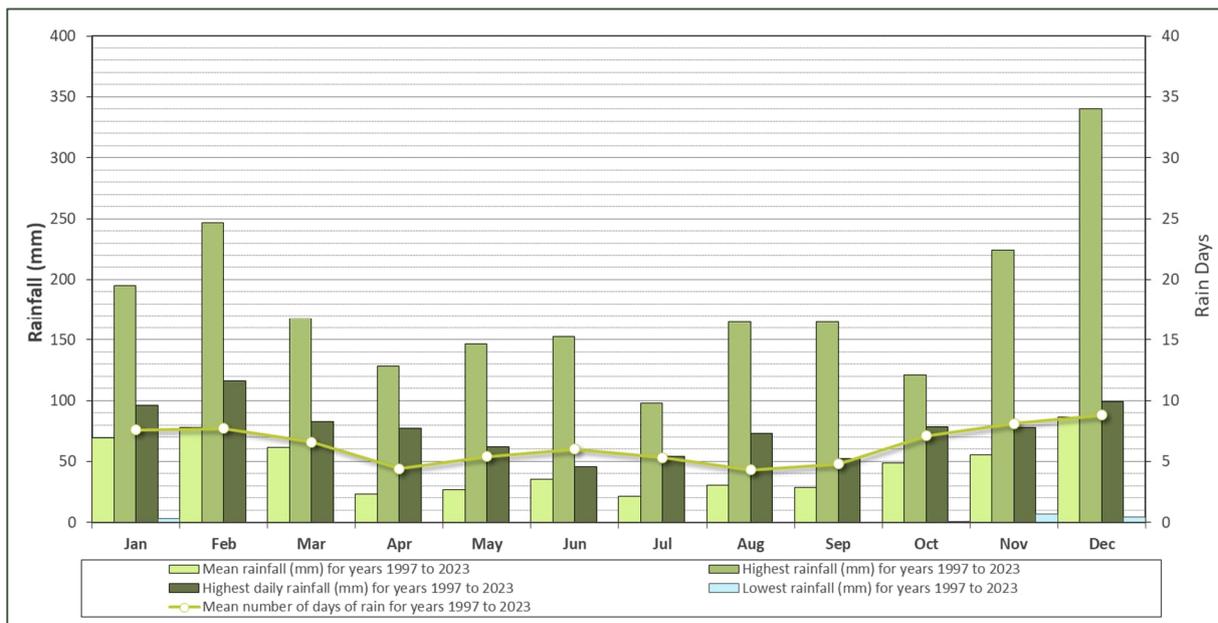


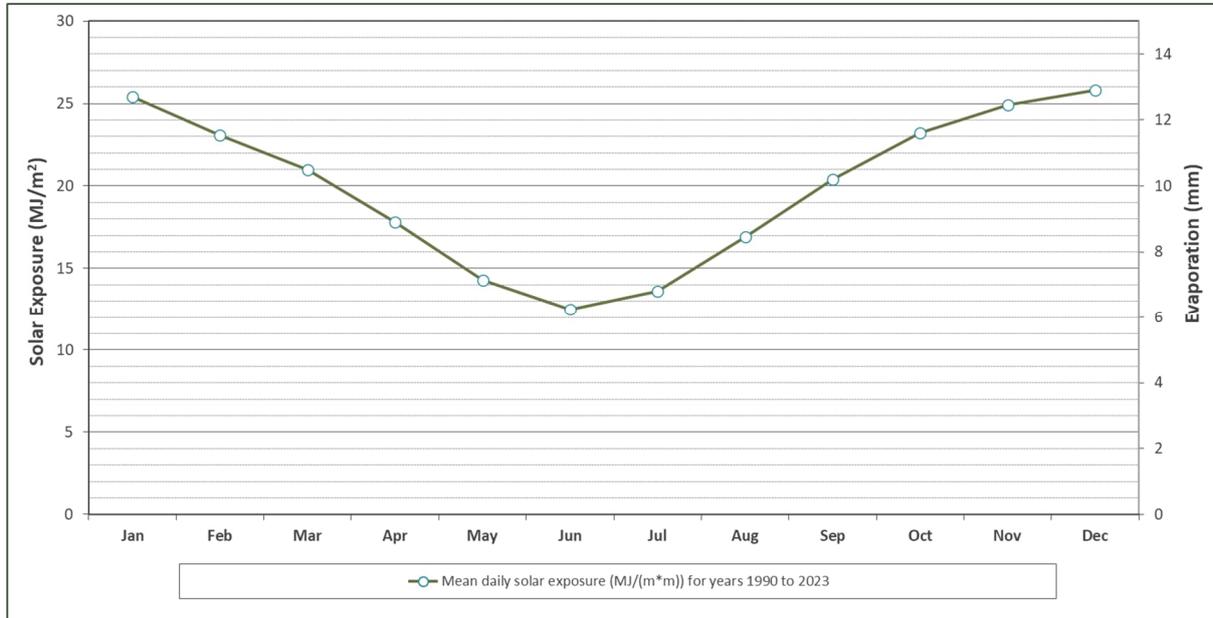
Figure 3 Long Term Monthly Rainfall Data for Miles Constance Street



3.2.3 Solar Radiation

As would be expected, the mean daily solar exposure levels recorded at Miles Constance Street (see **Figure 4**) are highest in summer (peaking at 25.8 MJ/m² in December) and lower in winter (dropping to 12.5 MJ/m² in June).

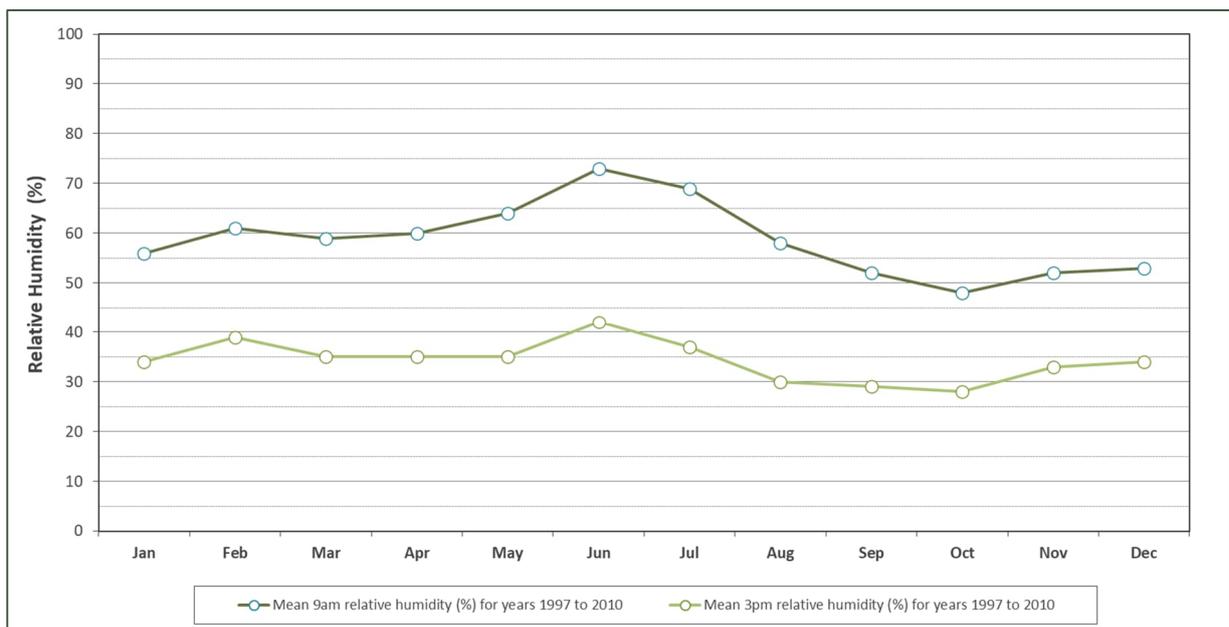
Figure 4 Long Term Solar Radiation Data for Miles Constance Street



3.2.4 Relative Humidity

Long-term humidity statistics (9 am and 3 pm monthly averages) for Miles Constance Street are summarised in **Figure 5**. Morning humidity levels range from an average of around 73% in early winter to around 59% in mid-spring. Afternoon humidity levels are lower, at around 49% in summer and dropping to a low of 48% in mid of spring.

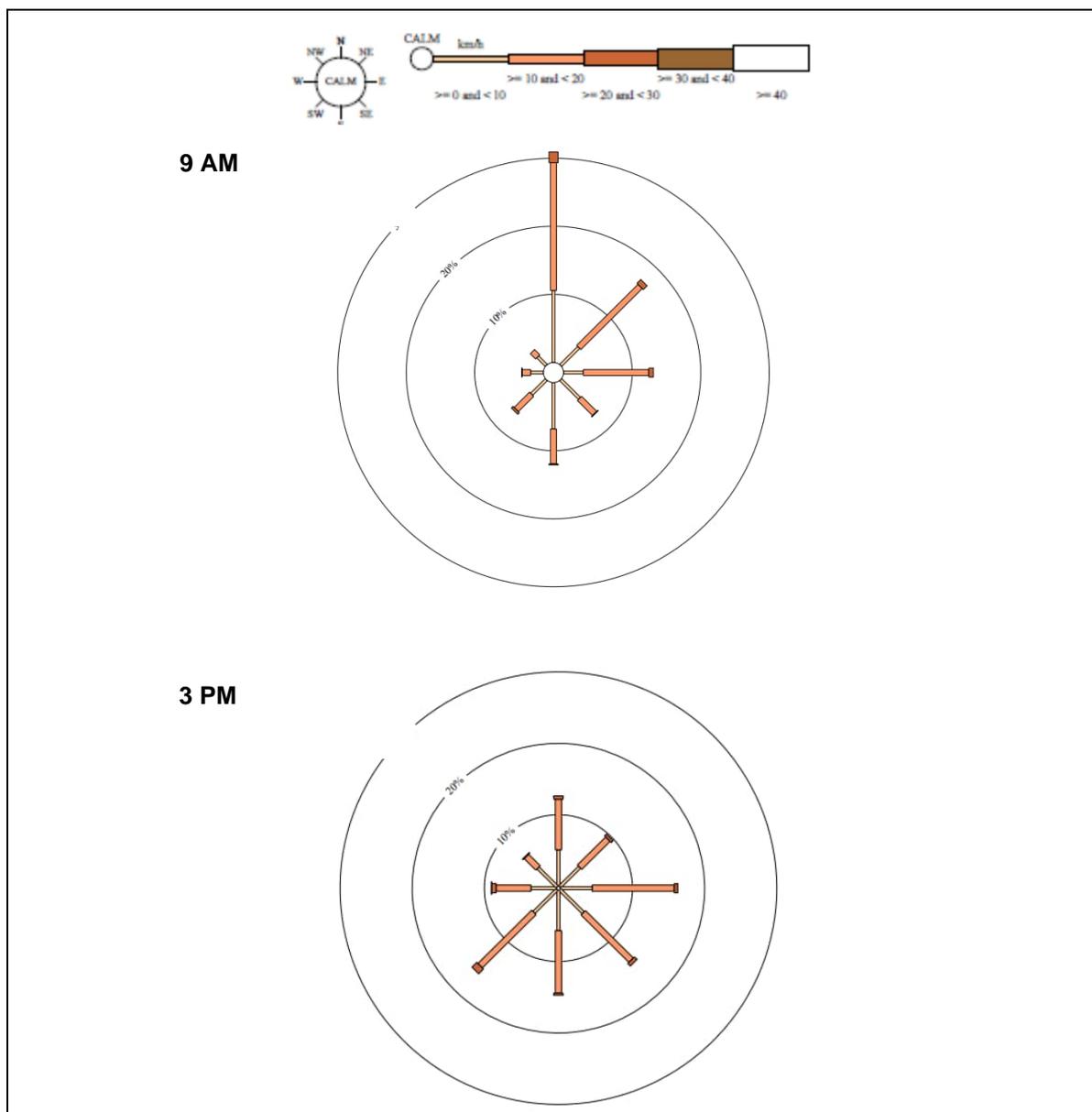
Figure 5 Long Term Humidity Data for Miles Constance Street



3.2.5 Wind Speed and Direction

Long term wind data (9 am and 3 pm) for Miles Constance Street are presented as wind roses in **Figure 6**. The wind roses show that winds from north are predominant in the morning and winds are evenly distributed in the afternoon periods, with a relatively low frequency of westerly winds also evident in the afternoon.

Figure 6 Rose of Wind Direction vs Wind Speed (km/hr) at Miles Constance Street (1992 - 2022)

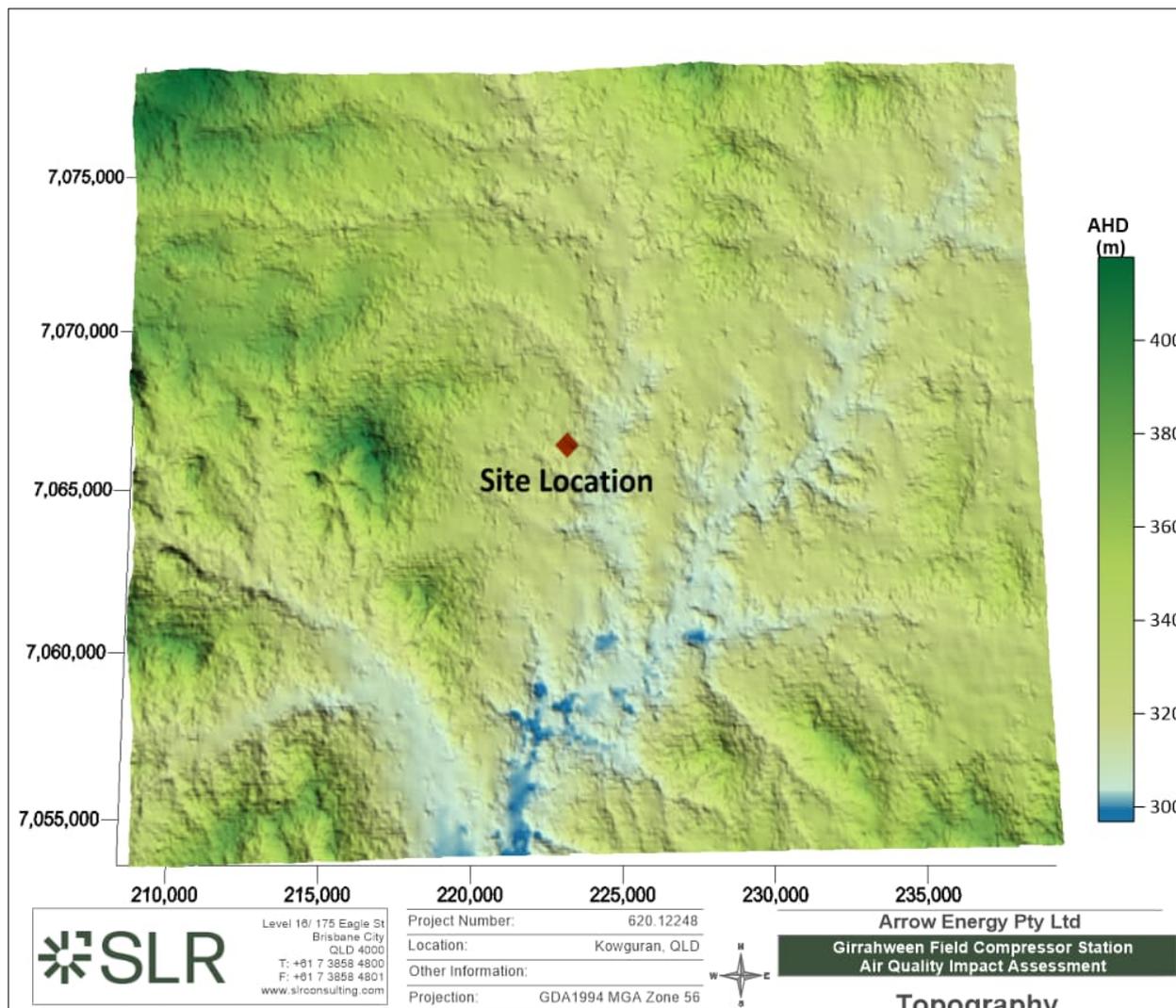


3.3 Topography and Land use

The land surrounding the Project site is rural in nature. The site is located in an area with relatively complex topography at an elevation of 380 m.

For this study, topographical data was sourced from the Shuttle Radar Topography Mission (SRTM) database, which obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. There are two resolution outputs available, 1 km and 90 m resolutions. SRTM data with 90 m resolution was input into the CALMET model to characterise terrain heights within the model domain, as presented in **Figure 7**.

Figure 7 Local Topography



3.4 Existing Air Quality Environment

Ambient air quality criteria relate to the total cumulative pollutant concentration that the population may be exposed to. Air dispersion modelling assessments therefore require the background air quality to be characterised, so that background concentrations of key pollutants of interest can be added to the incremental impacts predicted as a result of the modelled emission sources to provide an assessment of cumulative impacts.

In collaboration with industry partners, DESI operates an air quality monitoring network across southwest Queensland to monitor for any air quality impacts associated with the intensive CSG



production activities in the Western Downs region. These monitoring stations are located on properties near CSG infrastructure, including processing facilities and active gas wells. The AQMS located at Miles Airport is the nearest AQMS to the Girraheewen FCS site. Given this, ambient air quality data recorded by the Miles Airport AQMS was used to estimate background CO and NO₂ levels for assessing cumulative impacts in this study. Background ozone (O₃) concentrations have also been reviewed to inform the estimation of NO₂ concentrations from the predicted off-site NO_x concentrations (see **Section 4.4**).

Available validated NO₂, CO and O₃ concentration data recorded by the Miles AQMS during the 2019-2023 period are summarised in **Table 4** and presented as timeseries plots in **Figure 8** and **Figure 9**. It is noted that data records for the year 2019 and 2023 had a very low data capture rate (<75%). Given this, the data recorded in 2019 and 2023 have not been considered in establishing site representative background levels.

A summary of the background pollutant levels adopted for this study is presented in **Table 5**.

Table 4 Summary of Review of Available Monitoring Data

Percentile	1-Hour Average NO ₂ (µg/m ³)			1-Hour Average O ₃ (µg/m ³)			8- Hour Average CO (µg/m ³)		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
Maximum	63.6	49.2	32.8	128.4	117.7	98.4	500	946	667
95 th percentile	16.4	14.4	12.3	92.0	85.6	72.8	339	250	250
90 th Percentile	12.3	10.3	10.3	87.7	79.2	68.5	281	214	218
70 th Percentile	6.2	6.2	6.2	72.8	68.5	55.6	232	125	125
Average	5.9	6.1	5.3	59.6	57.7	47.0	172	136	143



Figure 8 Measured 1-Hour Average NO₂ and O₃ Concentrations – Miles

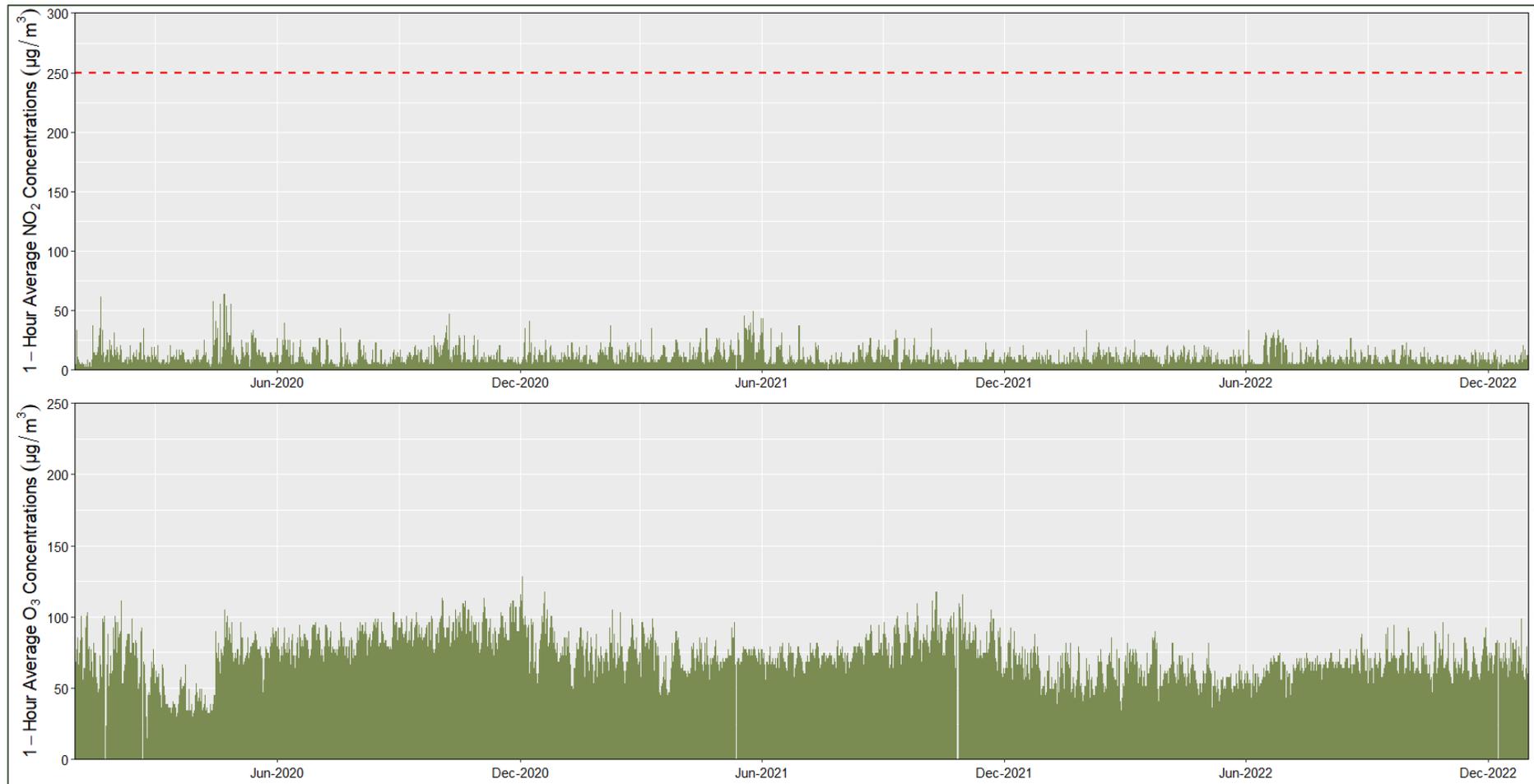


Figure 9 Measured 8-Hour Average CO Concentrations – Miles

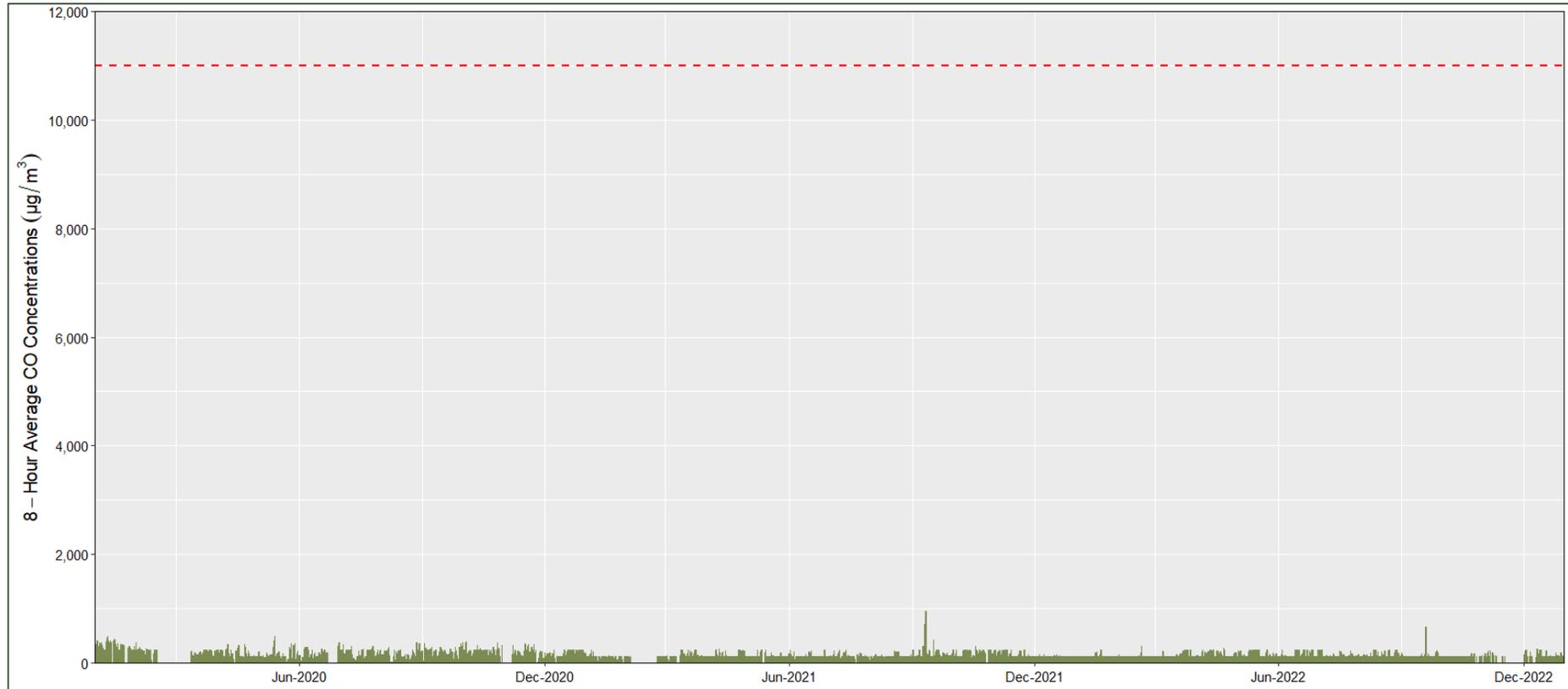


Table 5 Adopted Background Levels for Assessing Cumulative Impacts

Pollutant	Averaging Period	Adopted Background Concentration ($\mu\text{g}/\text{m}^3$)	Basis
NO ₂	1-Hour	6.2	Maximum 70 th percentile 1-hour average concentration recorded in 2020-2022 period
	Annual	6.1	Maximum annual average concentration recorded in 2020-2022 period
CO	8-Hour	232	Maximum 70 th percentile 8-hour average concentration recorded in 2020-2022 period
O ₃	1-Hour	72.8	Maximum 70 th percentile 1-hour average concentration recorded in 2020-2022 period

3.5 Sensitive Receivers

The DESI guideline, *Application requirements for petroleum activities* (DESI 2024) defines sensitive receptors as follows:

A sensitive place could include but is not limited to:

- *A dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises*
- *A motel, hotel or hostel*
- *A kindergarten, school, university or other educational institution*
- *A medical centre or hospital*
- *A protected area under the Nature Conservation Act 1992, the Marine Parks Act 2004 or a World Heritage Area*
- *A public park or garden*
- *A place used as a workplace including an office for business or commercial purposes.*

Where there is potential for rezoning or subdivision of nearby land that may be impacted by air emissions, the applicant should also identify potential future land uses.

Information on sensitive receptors located in and around the Girraheen FCS site were provided by Arrow. Receptors identified as being located within 5 km of the Girraheen FCS are listed in **Table 6** and shown in **Figure 10**.

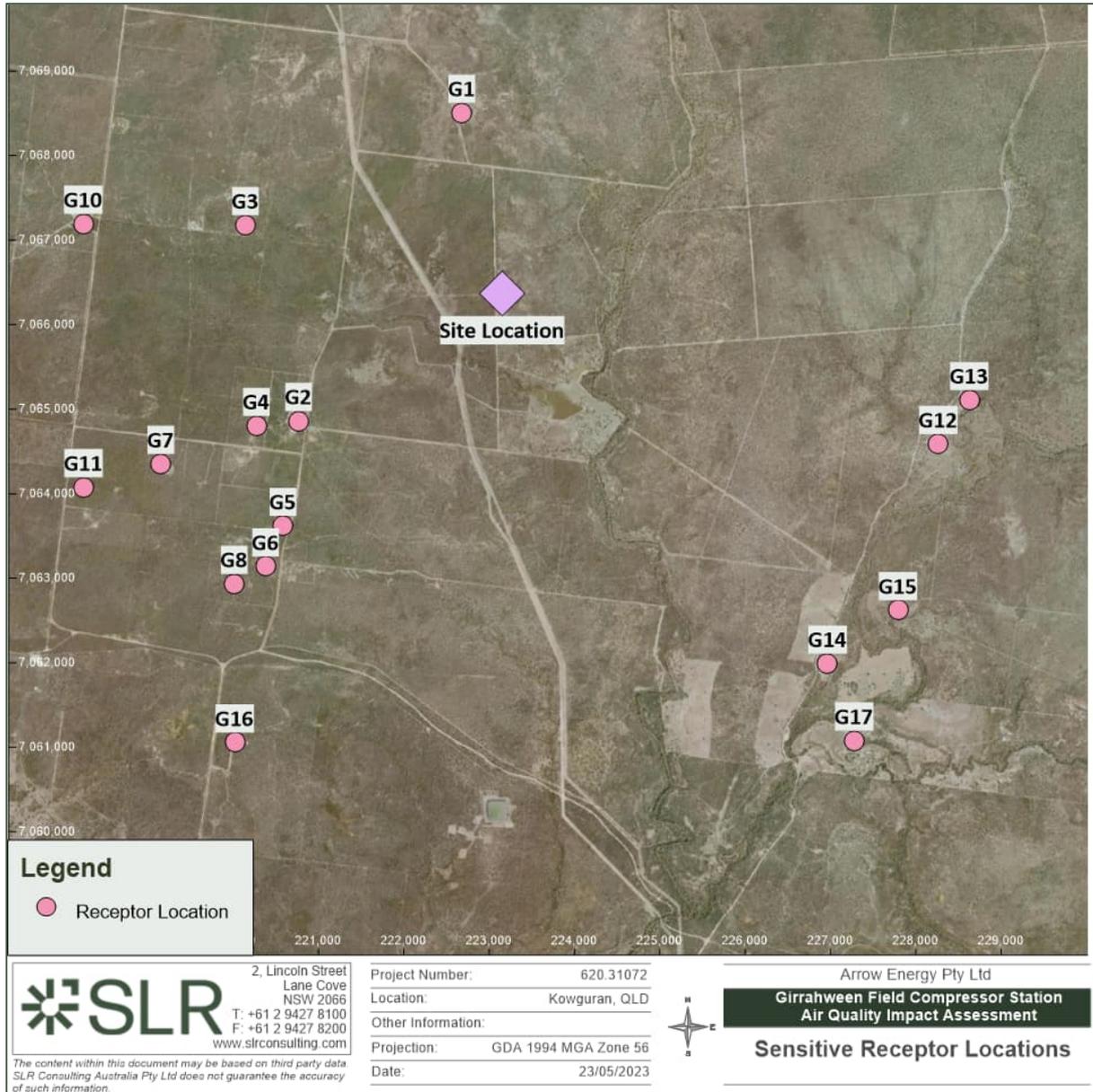
Note that all identified sensitive receptors in **Table 6** and **Figure 10** are dwellings/residential premises. No national parks or protected areas under the *Nature Conservation Act 1992*, the *Marine Parks Act 2004* or a World Heritage Area are identified in the study domain.

Table 6 Identified Sensitive Receptors within 5 km of Girraheen FCS

Receptor ID	Coordinates (GDA 94 zone 56)		Receptor ID	Coordinates (GDA 94 zone 56)	
	Easting	Northing		Easting	Northing
G1	222,680	7,068,507	G10	218,243	7,067,196
G2	220,766	7,064,862	G11	218,247	7,064,078
G3	220,144	7,067,178	G12	228,263	7,064,589
G4	220,272	7,064,803	G13	228,626	7,065,108
G5	220,584	7,063,619	G14	226,966	7,061,991
G6	220,381	7,063,139	G15	227,791	7,062,623
G7	219,152	7,064,353	G16	220,018	7,061,057
G8	220,013	7,062,935	G17	227,278	7,061,081



Figure 10 Identified Sensitive Receptors – Girraheen FCS



4.0 Assessment Methodology

4.1 Model Selection

Emissions from the proposed sources associated with the Girrahween FCS operation have been modelled using a combination of the The Air Pollution Model (TAPM), CALMET and CALPUFF models. CALPUFF is a transport and dispersion model that ejects “puffs” of material emitted from modelled sources, simulating dispersion and transformation processes along the way. In doing so it typically uses the fields generated by a meteorological pre-processor CALMET, discussed further below. Temporal and spatial variations in the meteorological fields selected are explicitly incorporated in the resulting distribution of puffs throughout a simulation period. The primary output files from CALPUFF contain either hourly concentration or hourly deposition fluxes evaluated at selected receptor locations. The CALPOST post-processor is then used to process these files, producing tabulations that summarise results of the simulation for user-selected averaging periods.

CALPUFF is a widely used model in assessing potential air quality impacts associated with CSG operations in Queensland and has been adopted for this assessment.

4.2 Selection of Representative Year

SLR conducted a review of the latest five years (2019-2023) of meteorological data recorded by the BoM’s Miles Constance Street station (Station ID 42112) to identify a suitable representative year for use in the modelling. Based on this analysis, the 2023 calendar year was identified as a suitably representative year. A summary of wind data recorded by the BoM Miles Constance Street station during 2023 compared to data extracted from the meteorological modelling for this year at the same location is presented in **Appendix B** validate the meteorological modelling methodology.

4.3 Meteorological Modelling

4.3.1 TAPM

In order to calculate all required meteorological parameters required by the dispersion modelling process, meteorological modelling using TAPM, v 4.0.4 has been performed. TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a prognostic model which may be used to predict three-dimensional meteorological data and air pollution concentrations. TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rainfall and atmospheric turbulence. The model allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations at user-defined levels within the atmosphere.

Additionally, the TAPM model may assimilate actual local wind observations so that they can optionally be included in a model solution. The wind speed and direction observations are used to realign the predicted solution towards the observation values. Hourly wind speed and wind direction data from the nearest BoM station located at Miles Constance Street were used to ‘nudge’ the TAPM model run.

Table 7 outlines the input data used in the TAPM modelling.



Table 7 Meteorological Parameters Adopted (TAPM v 4.0.4)

Parameter	Data
Modelling Period	1 January 2023 to 31 December 2023
Centre of analysis	222,666 mE; 7,063,153mS (UTM 56 Coordinates)
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Data assimilation	Miles Constance Street – BoM Station ID 42112
Terrain	AUSLIG 9 second DEM

4.3.1.1 CALMET

CALMET is a diagnostic meteorological model that develops wind and temperature fields on a 3-dimensional gridded modelling domain. Associated 2-dimensional fields such as mixing height, surface characteristics, and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final wind field thus reflects the influences of local topography and land uses.

CALMET modelling was conducted for a 36 km x 36 km domain with a resolution of 250 m. TAPM-generated three dimensional meteorological data was used as the initial guess wind field. The local topographical data and available surface weather observations in the area were then used to refine the initial guess wind field predetermined by the TAPM data. The surface weather observations were obtained from the Miles Constance Street BoM station.

The topographical data was sourced from the United States Geological Service’s Shuttle Radar Topography Mission database that has recorded topography across Australia with a 3 arc second (approximately 90 m) spacing. The land use data file was created using the latest publicly available aerial imagery.

Table 8 details the parameters used in the meteorological modelling to drive the CALMET model.

Table 8 CALMET Configuration Used for this Study

Domain	Data
Meteorological grid	36 km x 36 km
Meteorological grid resolution	0.25 km
Initial guess field	3D output from TAPM
Data Assimilation	Miles Constance Street – BoM Station ID 42112



4.3.2 Summary of Meteorological Data Used in the Modelling

4.3.2.1 Wind Speed and Direction

A summary of the annual and seasonal wind behaviour predicted by CALMET for the Girraheen FCS site is presented as wind roses in **Figure 11**. Further information on the wind speed distribution is provided in **Figure 12**. These plots indicate that on an annual basis, the site predominantly experiences low to moderate wind speed conditions (between 1.5 m/s and 5.5 m/s), mainly from the northern quadrant. Calm wind conditions (wind speeds less than 0.5 m/s) were predicted to occur for 0.5% of the time throughout the modelling period.

Figure 11 Wind Roses as Predicted by CALMET for the Girraheen FCS Site (2023)

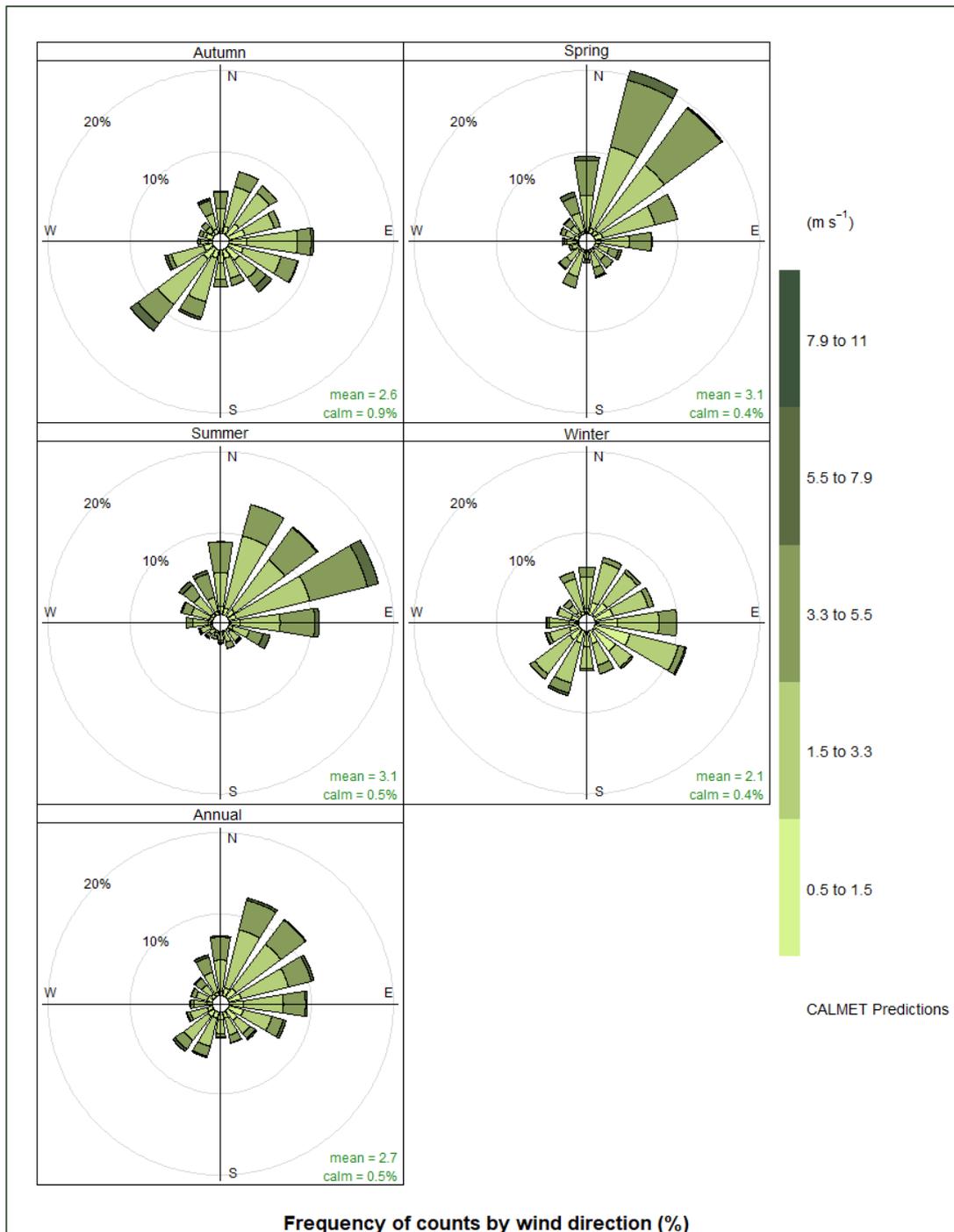
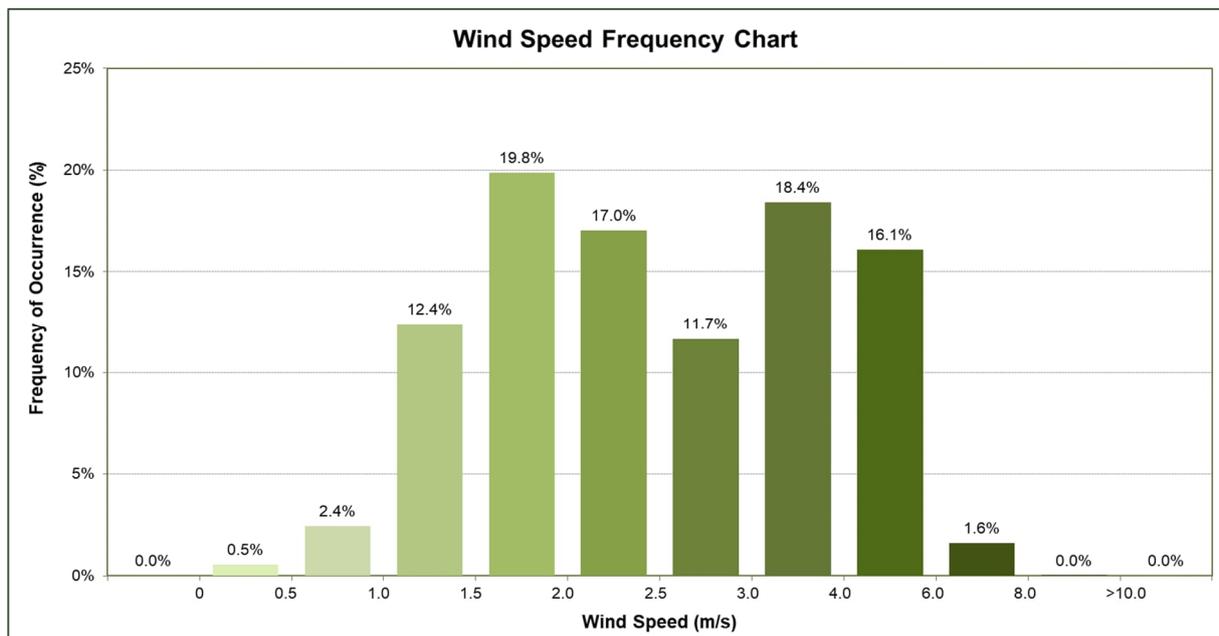


Figure 12 Wind Speed Distribution as Predicted by CALMET (2023) at Girraheewen FCS Site



4.3.2.2 Atmospheric Stability

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford-Turner (PGT) assignment scheme identifies six Stability Classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each PGT stability class are shown in **Table 9**. The frequency of each stability class predicted by CALMET at the site during the modelling period is presented in **Figure 13**.

The results indicate a high frequency of conditions typical to stable conditions (Stability Class F) and neutral (Stability Class D) with a low frequency of very unstable conditions (Stability Class A). Stability Classes F and D represent stable stability conditions that inhibit pollutant dispersion and neutral conditions respectively.

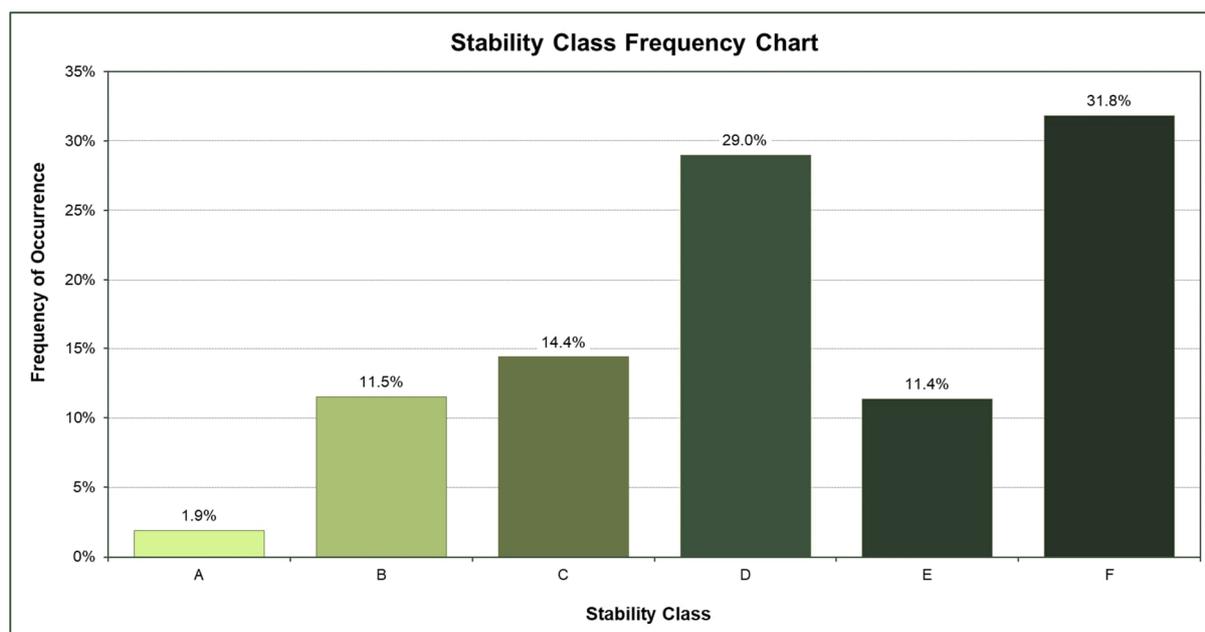


Table 9 Meteorological Conditions Defining PGT Stability Classes

Surface Wind Speed (m/s)	Day-time Insolation			Night-time Conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	≤ 4/8 Cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

SOURCE: (NOAA 2018)
 Notes:
 1. Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.
 2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.
 3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

Figure 13 Stability Class as Predicted by CALMET (2023) at Girraheen FCS Site

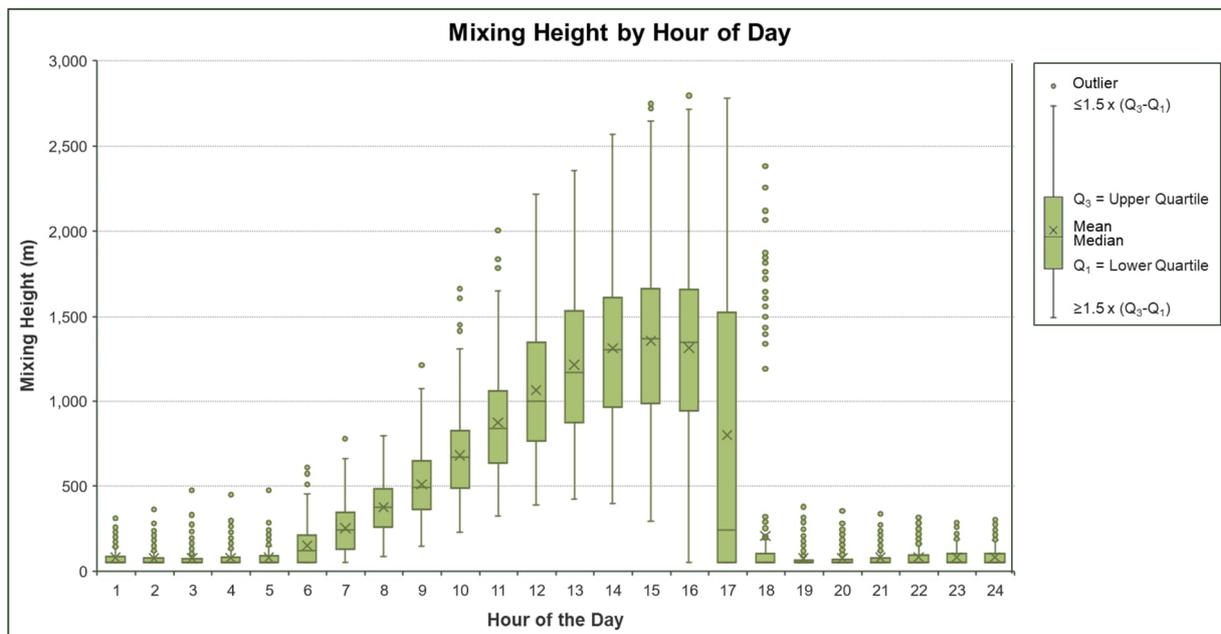


4.3.2.3 Mixing Heights

Plots showing the diurnal variations in maximum and average mixing heights predicted by CALMET at the Girraheen FCS site during 2023 are provided in **Figure 14**. As would be expected, an increase in the mixing height during the morning is apparent at all locations, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer.



Figure 14 Mixing Heights as Predicted by CALMET (2023) at Girraheewen FCS Site



4.4 NO_x to NO₂ Conversion

NO_x emitted from combustion processes mainly consists of NO with a small portion (approximately 10%) of NO₂. In the atmosphere however, NO emitted from the source oxidises to NO₂ in the presence of O₃ and sunlight as it travels further from the source. The rate of oxidation depends on a number of parameters including the ambient O₃ concentration.

The *Approved Methods for Modelling and Assessment of Air Pollutants in NSW* (NSW EPA 2022) lists the following methods that can be applied to take account the oxidation of NO to NO₂ in estimating downwind NO₂ concentrations at receptor locations.

Method 1 – 100% Conversion

This method is usually used as a screening level assessment and assumes 100% conversion of NO to NO₂ before the plume arrives at the receptor location. Use of this method can significantly over-predict NO₂ concentrations at nearfield receptors.

Method 2 – Ambient Ozone Limiting Method (OLM)

This method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O₃ or all the NO is used up. NO₂ concentrations can be estimated by this method using the following equation:

$$[NO_2]_{total} = \{0.1 \times [NO_x]_{pred}\} + \text{MIN}\{(0.9) \times [NO_x]_{pred} \text{ or } (46/48) \times [O_3]_{bkgd}\} + [NO_2]_{bkgd}$$

Again, when sensitive receptors are located close to the source, resulting in relatively short transport durations, Method 2 can be highly conservative as it assumes that the atmospheric reaction is instantaneous when in reality, the reaction takes place over a number of hours (NSW EPA 2022).

Method 3 – NO to NO₂ Conversion using Empirical Relationship

This method uses an empirical equation to estimate the oxidation rate of NO in power plant plumes dependent on distance downwind from the source and the parameters A and α, which has the following form:

$$NO_2 = NO_x \times A(1 - e^{-\alpha x})$$

where x is the distance from the source and A and α are classified according to the O₃ concentration, wind speed and season (Janssen, et al. 1988) as provided in **Table 10**.



Table 10 Classification of Values for A and α by Season

Season	Ozone (ppb)	Wind Speed (m/s)		
		5	15	>15
Winter	40	A = 0.87 α = 0.07	A = 0.87 α = 0.07	A = 0.87 α = 0.15
	30	A = 0.82 α = 0.07	A = 0.83 α = 0.07	A = 0.83 α = 0.07
	20	A = 0.74 α = 0.07	A = 0.74 α = 0.07	A = 0.74 α = 0.07
	10	A = 0.49 α = 0.05	A = 0.49 α = 0.05	A = 0.49 α = 0.05
Spring/Autumn	60	A = 0.85 α = 0.10	A = 0.85 α = 0.15	A = 0.85 α = 0.30
	40	A = 0.80 α = 0.10	A = 0.80 α = 0.10	A = 0.80 α = 0.25
	30	A = 0.74 α = 0.10	A = 0.74 α = 0.10	A = 0.74 α = 0.15
	20	A = 0.635 α = 0.10	A = 0.635 α = 0.10	A = 0.635 α = 0.10
Summer	200	A = 0.93 α = 0.40	A = 0.93 α = 0.65	A = 0.93 α = 0.80
	120	A = 0.88 α = 0.20	A = 0.88 α = 0.35	A = 0.88 α = 0.45
	60	A = 0.81 α = 0.15	A = 0.81 α = 0.25	A = 0.81 α = 0.35
	40	A = 0.74 α = 0.10	A = 0.74 α = 0.15	A = 0.74 α = 0.25
	30	A = 0.67 α = 0.10	A = 0.67 α = 0.10	A = 0.67 α = 0.10

Method 2, conversion of NO_x to NO₂ using the OLM was adopted for this assessment. A constant background 1-hour average ozone concentration data presented in **Section 3.4** was used in calculating NO₂ concentrations based on the model predicted NO_x concentrations in the surrounding areas.

5.0 Source Parameters

5.1 Modelling Scenarios

The emission sources modelled for both normal operating conditions and flare events are shown in **Table 11**.

Table 11 Modelling Scenarios

Source	Operational Scenario	Sources Modelled
Multi-well pads	1 Genset skid	1 Shellby 60 kVA Genset
	4 Genset skid	4 Shellby 60 kVA Gensets
	6 Genset skid	6 Shellby 60 kVA Gensets
Girraheen FCS	Normal operations	16 × 1875 kVA Aggreko GE J42 CSG-fired engines operating at full load (17 th and 18 th units on standby)
	Worst case upset operations	Multi point ground flare operating at flare design capacity All generators off-line

As per the definitions provided in Schedule 2 *Queensland Environmental Protection Regulation 2019*, a “fuel burning or combustion facility” means permanent equipment that can burn more than 500 kg of fuel in an hour (DESI 2019). A six genset multi-well pad has the capacity of burning only 80 kg fuel per hour at maximum load.



Any fuel burning or combustion facility capable of burning less than 500 kg in an hour is not considered a significant risk to the environment, does not have an aggregate environmental score and has not been included as an environmentally relevant activity (ERA) in Schedule 2 of the *Environmental Protection Regulation 2008* (DESI 2019).

Air emissions for multi-well pads are included in this assessment for completeness, and to demonstrate that air emissions from multi-well pads would not give rise to any potential for exceedances of ambient air quality criteria.

5.2 Stack and Emission Data

5.2.1 Well Pad Emissions

Emissions from the well pad engines have been estimated based on measured engine testing data for the Shelby 60 kVA engine. Measured engine testing data provided to SLR by Arrow are summarised in **Table 12**. It is understood that, on an annual basis, these generators run at 50% load, however, are required to run at higher loads during initial dewatering.

Based on a review of the emission data presented in **Table 12** and considering the operational requirements, the stack parameters and emission rates associated with maximum load operating conditions were adopted for this assessment to predict the potential highest level of impacts within the receiving environment.

Modelling was performed based on the following:

- Locating the sources in a nominally central location within the meteorological file compiled for this study and described in **Section 1.2**.
- Three scenarios were assessed: representing operations of a well pad with one, four and six gensets.

The incremental impacts predicted by the modelling were added to the adopted background levels outlined in **Section 3.4** to estimate minimum recommended separation distances for these sources, which will be used by Arrow as part of the constraints analysis for locating well pads in the gas field.

Table 12 Measured Emission Data - Shellby 60 kVA Generator

Load	Exhaust Temperature	Stack Diameter	Exhaust Velocity	NO _x Emission	CO Emission
(kW)	(°C)	(m)	(m/s)	(g/s)	(g/s)
13	409	0.1	5.5	0.008	0.15
26	448	0.1	12.3	0.038	0.21
39	475	0.1	19.4	0.105	0.28
48	487	0.1	23.0	0.319	0.33

Air emissions were assessed at the maximum load and emission rates, in order to assess maximum potential air quality impacts from single and multi-well pad operation. The stack and emission data adopted for the gas gensets are presented in **Table 13**.

Table 13 Stack Parameters and Emission Data – Multi-well Pad Genset

Parameter	1 Genset Skid	4 Genset Skid	6 Genset Skid
Number of generators	1	4	6
Stack height (m)	2.5	2.5	2.5
Stack diameter (m)	0.1	0.1	0.1
Exit velocity (m/s)	23	23	23



Parameter	1 Genset Skid	4 Genset Skid	6 Genset Skid
Exit temperature (°C)	487	487	487
NO _x (g/s, per engine)	0.32	0.32	0.32
CO (g/s, per engine)	0.33	0.33	0.33

5.2.2 Girrahween FCS Power Station

The stack and emission data provided by Arrow for the Girrahween FCS power station engines are summarised in **Table 14**. The proposed emission limits shown in this table were used for dispersion modelling to present worst case impacts. As shown by the table, actual emissions are anticipated to be well within these proposed emission limits.



Table 14 Model Inputs for the Girraheewen Power Station – Normal Operations

Generator Stack	Easting (m)	Northing (m)	Stack Height (m)	Exhaust Temperature (°C)	Stack Diameter (m)	Minimum Velocity (m/s)	NO _x Emission (g/s)		CO Emission (g/s)	
							Design Data	Proposed Limit	Design Data	Proposed Limit
1	223,644	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
2	223,649	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
3	223,665	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
4	223,670	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
5	223,675	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
6	223,680	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
7	223,696	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
8	223,701	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
9	223,706	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
10	223,711	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
11	223,726	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
12	223,731	7,065,402	5.5	400	0.4	12	0.6	0.8	1.2	1.5
13	223,644	7,065,383	5.5	400	0.4	12	0.6	0.8	1.2	1.5
14	223,649	7,065,383	5.5	400	0.4	12	0.6	0.8	1.2	1.5
15	223,665	7,065,383	5.5	400	0.4	12	0.6	0.8	1.2	1.5
16	223,670	7,065,383	5.5	400	0.4	12	0.6	0.8	1.2	1.5
17	223,675	7,065,383	Standby—not included in model scenario							
18	223,680	7,065,383	Standby—not included in model scenario							



5.2.3 Multi Point Ground Flares

Flaring may occur at the Girraheewen FCS when a compressor trips or downstream capacity is restricted such that the gas being delivered to the facility exceeds the delivery capacity. In these situations, gas must be flared until the well field can be turned down or compression/delivery capacity is restored. Flaring of gas occurs on rare occasions and is minimised to as low as reasonably practical (ALARP) through Arrow’s advanced gas management.

In this study, modelling has been performed for the worst-case flaring scenario, based on the maximum design capacity of the flare. This scenario would only be expected to occur during unplanned events when plant is at full load and full facility shutdown occurs (eg. emergency shut down, loss of electrical power) which would be a highly infrequent event and has been chosen to provide an assessment of the maximum potential air quality impact from flaring operations.

The design data provided by Arrow for the MPGF is summarised in **Table 15**.

Table 15 MPGF Design Data

Flare	Easting	Northing	Design Capacity	Flare Height	Flare Diameter	Maximum Flaring Rate
	(m)	(m)	(MMscfd)	(m)	(m)	(MMscfd)
Girraheewen flare	223,600	7,065,475	163	16.7	64.8	162.8

The following methodology was used to compile the stack and emission data required for modelling:

- NO₂ and CO emission rates were estimated based on the maximum flaring rate of each flare (converting from million standard cubic feet per day (MMscfd) to tonnes/day using a conservative gas density value of 0.73 kg/Sm³) and emission factors of 1.5 kg/tonne NO_x and 8.7 kg/tonne CO from the National Pollutant Inventory (NPI) *Emission Estimation Technique Manual (EETM) for Oil and Gas Extraction and Production* (NPI 2013).
- Assumed flare temperature of 750°C
- Assumed vertical exit velocity of 20 m/s

6.0 Air Quality Impact Assessment

6.1 Normal Operations

The estimated NO_x and CO emissions listed in **Table 14** for the Girraheewen FCS under normal operating conditions have been modelled to predict maximum downwind, ground level NO₂ and CO concentrations. The maximum 1-hour and annual average NO₂ concentrations and 8-hour average CO concentrations predicted at the nearest identified sensitive receptors are presented in **Table 16** compared to the relevant ambient air quality criteria. As outlined in **Section 4.4**, the OLM was used to convert the NO_x predictions to NO₂ concentrations and the background concentrations estimated in **Table 5** have been used to estimate cumulative impacts.

Table 16 shows that the downwind NO₂ and CO concentrations predicted at the nearest sensitive receptors under normal operating conditions are far below the relevant air quality criteria and would not have potential to give rise to adverse air quality impacts at these locations. The modelling results presented in **Table 16** also show that the predicted cumulative air quality impacts at the surrounding identified sensitive receptors are well below the more stringent NEPM criteria for NO₂.

Contour plots of the maximum concentrations predicted across the modelling domain are presented in **Appendix C**.



Table 16 NO_x and CO Concentrations Predicted at the Nearest Sensitive Receptors – Girrahween FCS, Normal Operations

Receptor ID	NO ₂ Concentrations (µg/m ³)				CO Concentrations (µg/m ³)	
	Maximum* 1-Hour Average		Annual Average		Maximum 8-Hour Average	
	Incremental Impact	Including Background	Incremental Impact	Including Background	Incremental Impact	Including Background
G1	94	100	2.5	8.6	286.9	519
G2	98	104	5.8	11.9	309.8	542
G3	100	106	4.9	11.0	424.8	657
G4	97	103	5.8	11.9	340.7	573
G5	106	112	8.1	14.2	576.5	809
G6	101	107	6.9	13.0	489.9	722
G7	95	101	5.3	11.4	312.1	544
G8	100	106	7.3	13.4	429.9	662
G10	89	96	3.5	9.6	296.4	529
G11	89	95	4.1	10.2	262.7	495
G12	62	68	0.5	6.6	67.9	300
G13	79	85	0.7	6.8	112.3	344
G14	57	63	0.4	6.5	87.2	319
G15	59	65	0.4	6.5	68.0	300
G16	88	94	5.1	11.2	224.9	457
G17	70	77	0.4	6.5	98.1	330
EPP (Air) Objective	-	250	-	62	-	11,000
NEPM AAQ Std	-	162	-	30	-	11,000

* Based on the 99.9th percentile prediction

6.2 Flaring Event

The estimated NO_x and CO emissions listed in **Table 15** for a flaring event at the Girrahween FCS have been modelled to predict maximum downwind, ground level NO₂ and CO concentrations. The maximum incremental 1-hour NO₂ concentrations and 8-hour CO concentrations predicted at the nearest identified sensitive receptors are presented in **Table 17**. The OLM was used to convert the NO_x predictions to NO₂ concentrations as per **Section 4.4**

Annual average concentrations have not been presented as major flaring events occur on rare occasions and for a short period only, hence a compliance assessment against annual average criteria is not warranted.

Table 17 shows that the downwind incremental NO₂ and CO concentrations predicted at the nearest sensitive receptors during a major flaring event at the Girrahween FCS are negligible compared to the relevant air quality criteria presented in **Table 3**, and would not have potential to give rise to any significant adverse air quality impacts at these locations.

Contour plots of the maximum concentrations predicted across the modelling domain are presented in **Appendix C**.



Table 17 NO₂ and CO Concentrations Predicted at the Nearest Sensitive Receptors – Girrahween FCS, Flaring

Receptor ID	Incremental Impacts (µg/m ³)	
	99.9 th Percentile 1-Hour Average NO ₂	Maximum 8-Hour Average CO ^a
G1	0.1	0.5
G2	0.1	0.4
G3	0.1	0.4
G4	0.1	0.4
G5	0.1	0.3
G6	0.1	0.5
G7	0.1	0.4
G8	0.1	0.5
G10	0.1	0.3
G11	0.1	0.4
G12	0.1	0.4
G13	0.1	0.4
G14	0.1	0.3
G15	0.1	0.4
G16	0.1	0.8
G17	0.1	0.3
EPP (Air) Objective	250	11,000
NEPM AAQ Std	162	11,000

6.3 Well Pad Emissions

The estimated maximum NO_x emissions listed in **Table 12** for the well pad gensets have been modelled using the meteorological file compiled for the Girrahween FCS site, with the emission sources nominally located at the centre of the modelling domain. To enable a more refined assessment of near source predictions, the modelling was performed using a 1 km by 1 km computational domain centred on the emission source with a 25 m grid spacing.

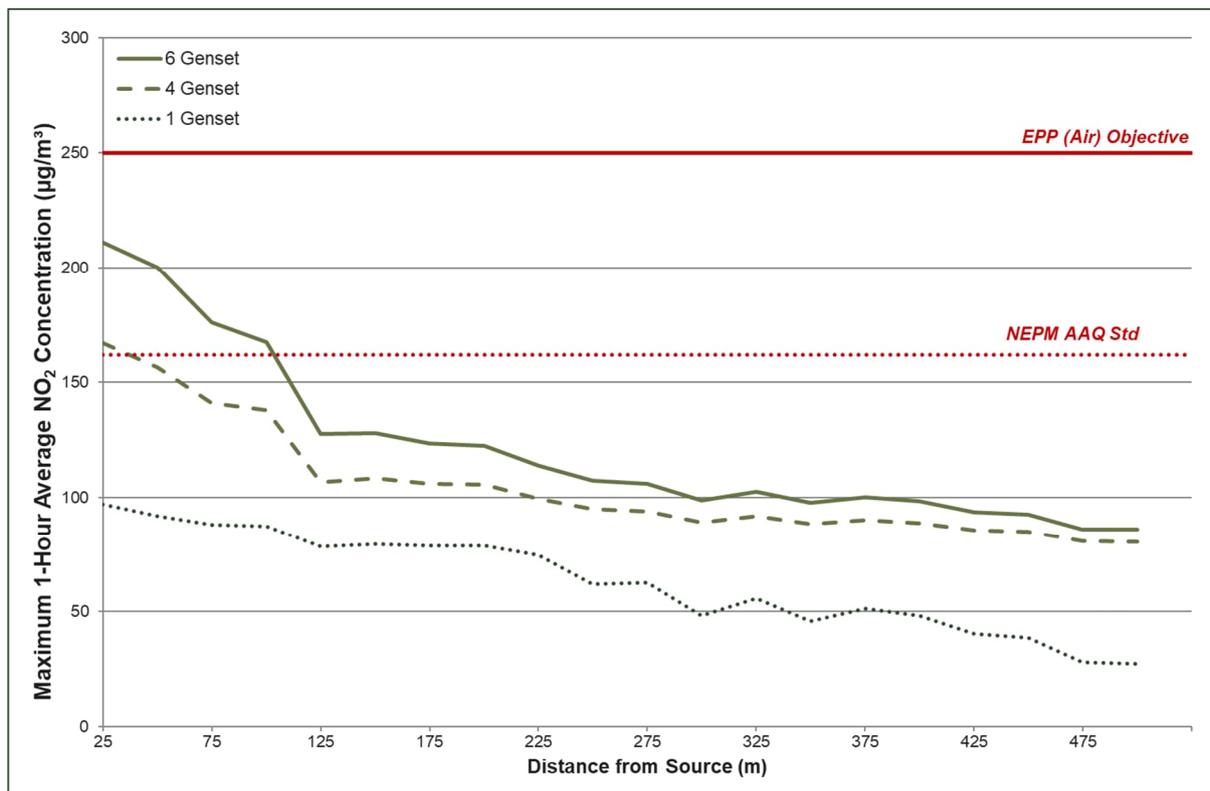
The predicted downwind NO_x concentrations were then post-processed to calculate the maximum ground level NO₂ concentration predicted in any direction downwind (using OLM for NO_x to NO₂ conversion calculation as per **Section 4.4**). The resulting incremental concentration-distance profile for each type of well pad is shown in **Figure 15**.

Figure 15 shows that the maximum predicted incremental NO₂ concentrations are below the current EPP (Air) 1-hour average ground level NO₂ criterion of 250 µg/m³ within a very short distance (<25 m) of the source for both categories of well pad. Considering the adopted background 1-hour average NO₂ concentration of 6.2 µg/m³ and given that the CALPUFF dispersion model is likely to overestimate the impacts in the very nearfield, as well as the low probability of these gensets operating at maximum load for a prolonged period, the cumulative 1-hour average ground level NO₂ concentrations are highly unlikely to exceed the current EPP (Air) air quality objective of 250 µg/m³ at the surrounding area in the vicinity of the well pads.

Multi-well pads are all located much greater than 500 m from a sensitive receptor due to noise constraints. Given this, and considering that a separation distance greater than 500 m would be required for noise mitigation, the NO₂ modelling results do not identify any air quality constraints for well pad operations.



Figure 15 Maximum Predicted Incremental NO₂ Concentrations



If the more stringent NEPM AAQ guideline of 162 µg/m³ was adopted, a separation distance of 200 m would be adequate to avoid the potential for any non-compliances at nearby areas for either category of well pad.

Considering that CO emission rates for the well pad gensets are similar to those estimated for the NO_x emissions (see **Table 12**) and the relevant CO guideline outlined in **Table 3** is much higher, CO emissions can be concluded to also not result in any air quality constraints for well pad operations.

Based on the above, a minimum recommended separation distance of 200 m for well pads would be adequate for avoiding any adverse air quality impacts at nearby sensitive receptors.



7.0 Mitigation and Monitoring

This AQIA impact assessment has not identified any potential for adverse air quality impacts associated with the proposed FCS or well pad operations. Nonetheless, the design and operation of the facilities will be undertaken to minimise and manage emissions from the plant as outlined below.

7.1 Mitigation Measures

Arrow is committed to applying a hierarchy of controls in order to minimise environmental impact. Arrow has standard operating procedures determining how selection of equipment will be completed in regard to protecting environmental values. Equipment that results in environmental impact will be:

- Avoided
- Substituted out
- Have mitigations imposed to reduce the impact.

In order to determine what equipment should be installed for the project (and therefore what equipment should be avoided), equipment selection will consider as part of the assessment process:

- Low source of noise emissions
- Low emissions to air
- High energy efficiency and fuel efficiency
- Low generation of waste
- Low greenhouse gas emissions
- Avoidance of ozone depleting substances
- Avoidance of particularly hazardous chemicals
- Low emissions of pollutants to water
- Low water use.

Across all of Arrow's SGP activities, Arrow has committed to the mitigation measures listed in **Table 18** to minimise air quality impacts. These measures are recorded in standard operating procedures included in the Surat Gas Project operating model.

In addition to these measures, Arrow is committed to selecting sites for project infrastructure that will protect the environmental values of the project development area wherever practicable. The objectives of site selection are to:

- Ensure the selection of optimal, environmentally acceptable sites for infrastructure placement.
- Avoid or eliminate potential impacts to environmental values.
- Minimise, to the greatest extent practicable, potential impacts to environmental values unable to be avoided or eliminated during design.
- Identify environmental measures for low, moderate and highly constrained areas and 'No Go' such areas.

Modelling of emissions from CSG-fired generators that would be installed at well pads as part of the SGP, as presented in this report, indicates that to ensure that ground-level NO₂ concentrations meet guideline criteria, well pads should be located no closer than 200 m from sensitive receptors.



Table 18 Mitigation Commitments

Project Phase	Mitigation Measures
Operational Phase	<ul style="list-style-type: none"> • Implement a preventative maintenance program to ensure engines are operating efficiently to minimise NO_x, CO, methane and VOC emissions. • Implement a quantifiable monitoring and measuring program. • Roads, access tracks and other areas may be watered to suppress dust. Vehicle travelling speeds will be restricted, and movements will be limited to approved access tracks. • Selection of gaskets, seals and vehicle exhaust systems that are suitable for the task, and maintained according to manufacturer’s recommendations. • Manufacturer’s recommendations and guidelines with respect to air emissions control systems are followed at all times. • Air pollution control technologies are to be maintained in good working order and kept in place at all times the equipment is operating. • Air emissions will be monitored at the source in accordance with the corresponding Environmental Authority conditions. • Equipment that produces abnormal monitoring results will trigger maintenance /review procedures to return emissions to acceptable levels. Where practical, the equipment should not be brought back into service until normal operational emissions are achieved.
Vehicles and machinery	<ul style="list-style-type: none"> • Ensure all vehicles and machinery are fitted with appropriate emission control equipment, maintained frequently and serviced to the manufacturer’s specifications. • Smoke from internal combustion engines should not be visible for more than ten seconds.

7.2 Air Monitoring Programmes

As shown in **Section 8**, ambient air quality monitoring is currently being performed by DESI in the area surrounding the SGP. Given that the downwind concentrations of NO₂ and CO predicted in this assessment are far below ambient air quality guidelines, no additional ambient monitoring is recommended for the FCS or well pad operations assessed in this AQIA.

Based on DESI’s streamlined conditions for petroleum activities (DESI 2024), fuel burning and combustion equipment included in this assessment that would warrant air emissions monitoring are limited to the FCS power station engines. Consistent with the emission rates modelled in this AQIA, the point source emission limits for NO_x presented in **Table 19** are proposed for assessing compliance.

The air dispersion modelling results showed that the potential for adverse impacts due to CO emissions is negligible, and as such, annual monitoring of CO is not considered necessary.



Table 19 Proposed Point Source Emission Limits for Girrahween FCS

Source	Minimum Release Height	Minimum Exit Velocity	NOx as Nitrogen Dioxide	
			Maximum Concentration	Maximum Mass Emission Rate
	(m)	(m/s)	(mg/Nm ³ , 5% O ₂)	(g/s)
Generator Stack 1	5.5	12	500	0.8
Generator Stack 2	5.5	12	500	0.8
Generator Stack 3	5.5	12	500	0.8
Generator Stack 4	5.5	12	500	0.8
Generator Stack 5	5.5	12	500	0.8
Generator Stack 6	5.5	12	500	0.8
Generator Stack 7	5.5	12	500	0.8
Generator Stack 8	5.5	12	500	0.8
Generator Stack 9	5.5	12	500	0.8
Generator Stack 10	5.5	12	500	0.8
Generator Stack 11	5.5	12	500	0.8
Generator Stack 12	5.5	12	500	0.8
Generator Stack 13	5.5	12	500	0.8
Generator Stack 14	5.5	12	500	0.8
Generator Stack 15	5.5	12	500	0.8
Generator Stack 16	5.5	12	500	0.8
Generator Stack 17	Standby			
Generator Stack 18	Standby			

7.3 Proposed Air Conditions

In line with the streamlined model conditions for petroleum activities, the recommended streamlined conditions for this development are provided by model conditions Air 1 to Air 3 as follows:

Venting and flaring

Air 1.

Unless venting is authorised under the *Petroleum and Gas (Production and Safety) Act 2004* or the *Petroleum Act 1923*, waste gas must be flared in a manner that complies with all of (Air 1(a)) and (Air 1(b)) and Air 1 (c)), or with (Air 1(d)):

- (a) an automatic ignition system is used, and
- (b) a flame is visible at all times while the waste gas is being flared, and
- (c) there are no visible smoke emissions other than for a total period of no more than 5 minutes in any 2 hours, or
- (d) it uses an enclosed flare.

Fuel burning and combustion facilities – authorised point sources

Air 2A.

A fuel burning or combustion facility must not be operated unless it is listed in **Protecting air values, Table 1–Authorised point sources.**



Air 2B.

If a fuel burning or combustion facility is listed in Protecting air values, Table 1—Authorised point sources, the fuel burning or combustion facility must be operated so that the releases to air do not exceed the limits specified in **Protecting air values, Table 1—Authorised point sources** at the specified release point reference.

Protecting air values, Table 1 – Authorised Point Sources

Resource Authority	Facility	Release Point Reference	Equipment Description	Minimum Release Height	Minimum Efflux Velocity	NO _x as Nitrogen Dioxide			
						Maximum Concentration	Maximum Mass Emission Rate		
						(mg/Nm ³ , 5% O ₂)	(g/s)		
PL305	Girraheewen FCS	A1	Generator Stack 1	5.5	12	500	0.8		
		A2	Generator Stack 2	5.5	12	500	0.8		
		A3	Generator Stack 3	5.5	12	500	0.8		
		A4	Generator Stack 4	5.5	12	500	0.8		
		A5	Generator Stack 5	5.5	12	500	0.8		
		A6	Generator Stack 6	5.5	12	500	0.8		
		A7	Generator Stack 7	5.5	12	500	0.8		
		A8	Generator Stack 8	5.5	12	500	0.8		
		A9	Generator Stack 9	5.5	12	500	0.8		
		A10	Generator Stack 10	5.5	12	500	0.8		
		A11	Generator Stack 11	5.5	12	500	0.8		
		A12	Generator Stack 12	5.5	12	500	0.8		
		A13	Generator Stack 13	5.5	12	500	0.8		
		A14	Generator Stack 14	5.5	12	500	0.8		
		A15	Generator Stack 15	5.5	12	500	0.8		
		A16	Generator Stack 16	5.5	12	500	0.8		
		A17	Generator Stack 17	Standby					
		A18	Generator Stack 18	Standby					

Point source air monitoring

Air 3.

Point source air monitoring for each fuel burning or combustion facility listed in **Protecting air values, Table 1—Authorised point sources** must:

- (a) be undertaken once:
 - i. in the first three months after first commissioned, and then
 - ii. every year thereafter (for seven of eight listed release points)
- (b) be carried out when the facility the subject of the sampling is operating under maximum operating conditions for the annual period; and
- (c) demonstrate compliance with the limits listed in **Protecting air values, Table 1—Authorised point sources** at each release point reference.



8.0 Conclusions

An air quality impact assessment, including a detailed air dispersion modelling study, has been performed to assess potential air quality impacts from the proposed Girrahween FCS operation. Dispersion modelling was performed for both normal maximum operating conditions and for flaring events. Modelling was also performed for air emissions associated with single and multi-well pad operations to confirm the required separation distances between well pads and sensitive receptors.

Based on the modelling results, the following conclusions have been drawn for the proposed Girrahween FCS:

- The modelling of NO_x and CO emissions from the proposed, Girrahween FCS showed that under normal maximum operating conditions (i.e. concurrent operation of 16 power station generators at maximum load) these emissions have no potential to give any significant rise to ground level exceedances of the relevant ambient air quality criteria at surrounding sensitive receptors. The incremental impacts predicted by the modelling of CO emissions are negligible.
- The modelling of NO_x and CO emissions from maximum flaring events at the proposed, Girrahween FCS showed that maximum predicted cumulative NO₂ and CO concentrations at all nearby sensitive receptors would remain well below the relevant ambient air quality guidelines.
- Modelling results for the well pad generators showed that a separation distance of 200 m between the well pad and the nearest sensitive receptors would be adequate (in relation to air quality constraints) for all categories of well pads (single and multi-well pads).

Based on the above, no air quality constraints have been identified for these facilities by this air quality impact assessment.

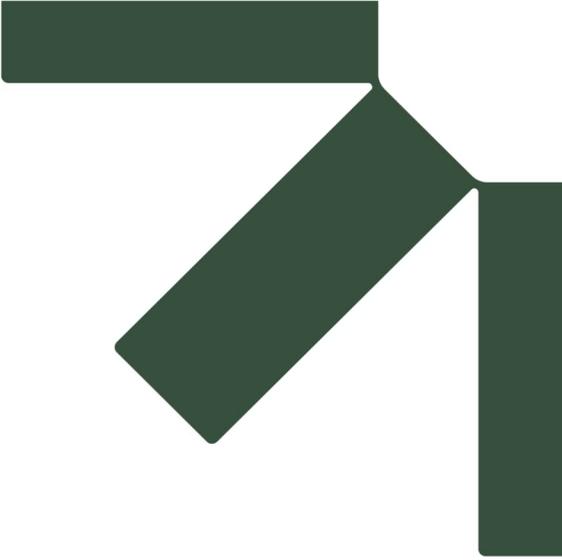
Mitigation and monitoring measures are presented in this report to minimise emissions to air and assist in the management of air quality impacts associated with these facilities.



9.0 References

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- DESI. 2024. *Guideline Application requirements for activities with impacts to air*. Brisbane: Department of Environment, Science and Innovation.
- DESI. 2024. *Streamlined model conditions for petroleum activities*. Department of Environment, Science and Innovation.
- EPP Air. 2019. *Environmental Protection (Air) Policy*. Brisbane: Queensland State Government.
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- NEPC. 2021. *National Environment Protection (Ambient Air Quality) Measure*. National Environment Protection Council.
- NOAA. 2018. *Air Resources Laboratory*. 14 February. Accessed February 20, 2018. <https://www.ready.noaa.gov/READYpgclass.php>.
- NSW EPA. 2022. "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales." August.





Appendix A Gas Engine Specifications

Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

Arrow Energy Pty Ltd

SLR Project No.: 620.12248.01605

16 July 2024

EQUIPMENT DATA SHEET

Generator Gas NGG J420E GEN II

Model

Model reference	GG1950GASCSK, GG1875GASCSK
Model size and rating	1950 kVA, 1875 kVA
Bill of Material reference number	611033 B, 611032 B, 611034 A, 611034 C, 611034 B, 611033 A, 611032 A

Manufacturer

Model Reference	J420E605 CGT GEN II; J420E605 J420E685 CGT GEN II; J420E685 LS GEN II; J420E602 CGT GEN II; LS GEN II J420E602 LS GEN II
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Electrical Output

Electrical Output	Hz (Hz)	50.0 (50)	60.0 (60)
Voltage Capability Three Phase		380V - 440V	400V - 480V

Performance Data

Maximum Ambient Before Derate (JW)	See document E1400012 for full genset de-rate data	See document E1400013 for full genset de-rate data
Single Step Load Application	See Genset Transient Response Doc G48000122	See Genset Transient Response Doc G48000122

Electrical (ISO 8528-1) *

Continuous Power (COP)	See Engine Variant Doc G56000526	See Engine Variant Doc G56000526
Parasitic Load	47.56kW (F02000645-A)	53.58 (F02000803-A)
Allowable block loads	See Genset Transient Response Doc G48000122	See Genset Transient Response Doc G48000122

Gas Energy Input - LHV (ISO 3046-1) **

Gas Input Reference Document No	See Engine Variant Doc G56000526	See Engine Variant Doc G56000526
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Alternator

Class F Temp Rise (105°C) Three	kW (kVA)	1800.0 (2250)	2200.0 (2750)
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EQUIPMENT DATA SHEET

Generator Gas NGG J420E GEN II

Phase (CGT)

Ends Out (CGT)	6	6
Make & Type (CGT)	CGT S7L1D-J4 Wdg.312	CGT S7L1D-J4 Wdg.312
AVR (CGT)	DVC550	DVC550
Regulation (CGT)	±0.25%	±0.25%
Number of Bearings (CGT)	2	2
Class F Temp Rise (105°C) Three	kW (kVA) 1600.0 (2000)	1784.0 (2230)

Phase (LS)

Ends Out (LS)	6	6
Make & Type (LS)	LEROY SOMER LSA 52.3	LEROY SOMER LSA 52.3
AVR (LS)	DVC550	DVC550
Regulation (LS)	±0.25%	±0.25%
Number of Bearings (CGT)	2	2

Circuit Breaker

Make & Model	Schnieder NW32	Schnieder NW32
Number of Poles	4	4
Rating	Amp (Amp) 3200.0 (3200)	3200.0 (3200)
Trip Unit Type	Micrologic 5.0	Micrologic 5.0
Overload Protection Range	1280 – 3200 Amps (Adjustable by selector)	1280 – 3200 Amps (Adjustable by selector)
Short Circuit Protection Range	1920 – 32000 Amps (Adjustable by selector)	1920 – 32000 Amps (Adjustable by selector)

Load Terminals

Type	Busbar M12	Busbar M12
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Engine

Make & Type	See Engine Variant Doc G56000526	See Engine Variant Doc G56000526
Cylinders & Form	V20	V20
Aspiration	Turbocharged & Low Temperature Aftercooled	Turbocharged & Low Temperature Aftercooled
Governor Make & Type	Electronic	Electronic

EQUIPMENT DATA SHEET

Generator Gas NGG J420E GEN II

Governor Type	DIA.NE XT4 (GEN II ENGINE CONTROLS)	DIA.NE XT4 (GEN II ENGINE CONTROLS)
Steady State Frequency	±0.5% (±0.25Hz)	±0.5% (±0.25Hz)
Battery Voltage	24V	24V
Engine Prime Power (100% Max Power)	See Engine Variant Doc G56000526	See Engine Variant Doc G56000526

Engine Gas Supply Pressures

Minimum Pressure @ 50 LHV (MJ/kg)	25mbar	25mbar
Maximum Pressure	66mbar	66mbar
Over Pressure Shutdown Threshold	250mbar	250mbar
Under Pressure Shutdown Threshold	13mbar	13mbar
MP Gas Train Supply Pressure Range	2 – 6 bar	2 – 6 bar
Minimum Methane Index	40	40
Minimum Pressure at Tecjet Inlet	21.7mbar	21.7mbar
Minimum Pressure at Pressure Sensor	51.8mbar	51.8mbar
Standard Gas Train Outlet Pressure Adjustment Range	60 – 100mbar (±10%)	60 – 100mbar (±10%)
Target Gas Train Outlet Pressure Setpoint	60mbar	60mbar

Exhaust Emissions

Specific Load	100% Load ±2%	100% Load ±2%
NOx – Oxides of Nitrogen (E605/E685)	500mg/m3	500mg/m3
CO - Carbon Monoxide	1000mg/m3	1000mg/m3

Exhaust Silencer

Make & Type	DURR Universal Silencers	DURR Universal Silencers
Current Back Pressure (Gen Set Only)	6.35mm (0.25in) Hg	6.35mm (0.25in) Hg
Maximum Allowable Back Pressure	30mbar - target / 60mbar – max allowed (based on Jenbacher IQA). Above 30mbar Jenbacher cannot	30mbar - target / 60mbar – max allowed (based on Jenbacher IQA). Above 30mbar Jenbacher cannot

EQUIPMENT DATA SHEET

Generator Gas NGG J420E GEN II

Noise

Sound Power - EEC	106dBA	
Sound Pressure at 1m/3ft	85dBA	90dBA
Sound Pressure at 7m/21ft	76.5dBA	81dBA
Noise Test Reference Document No	F03000343-A	

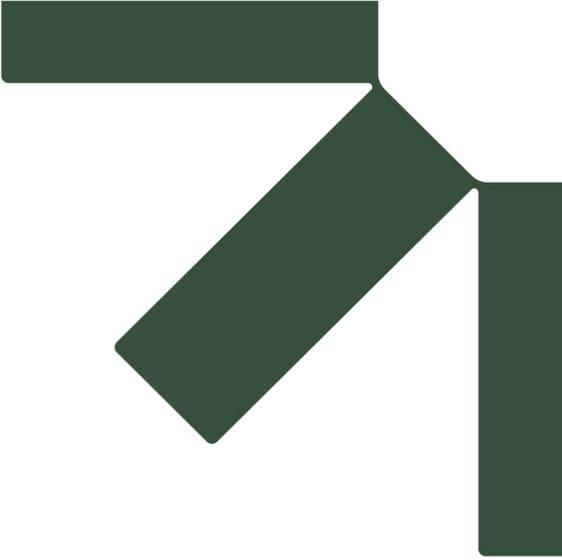
Catalyst

Make & Type	Johnson Matthey GMBH 3 way catalyst (EPA only)
Part Number	03-0033259 (Part of Engineered kit)
Back Pressure	40mbar (1.18inHg) additional backpressure @100% C.O.P.

Other Capacities and Dimensions

Lube Oil Capacity - Total	L (US gal)	875.0	(231)	875.0	(231)
Lube Oil Capacity - Sump and Additional Oil Top Up	L (US gal)	745.0	(196.68)	745.0	(196.68)
Coolant Capacity (JW)	L (US gal)	635.0	(167.64)	635.0	(167.64)
Coolant Capacity (LTA)	L (US gal)	166.0	(43.824)	166.0	(43.824)
GCM Weight	kg (lb)	7980.0	(17592.868)	7980.0	(17592.868)

Physical Characteristics



Appendix B Meteorological Data Validation

Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

Arrow Energy Pty Ltd

SLR Project No.: 620.12248.01605

16 July 2024

Meteorological Data Validation

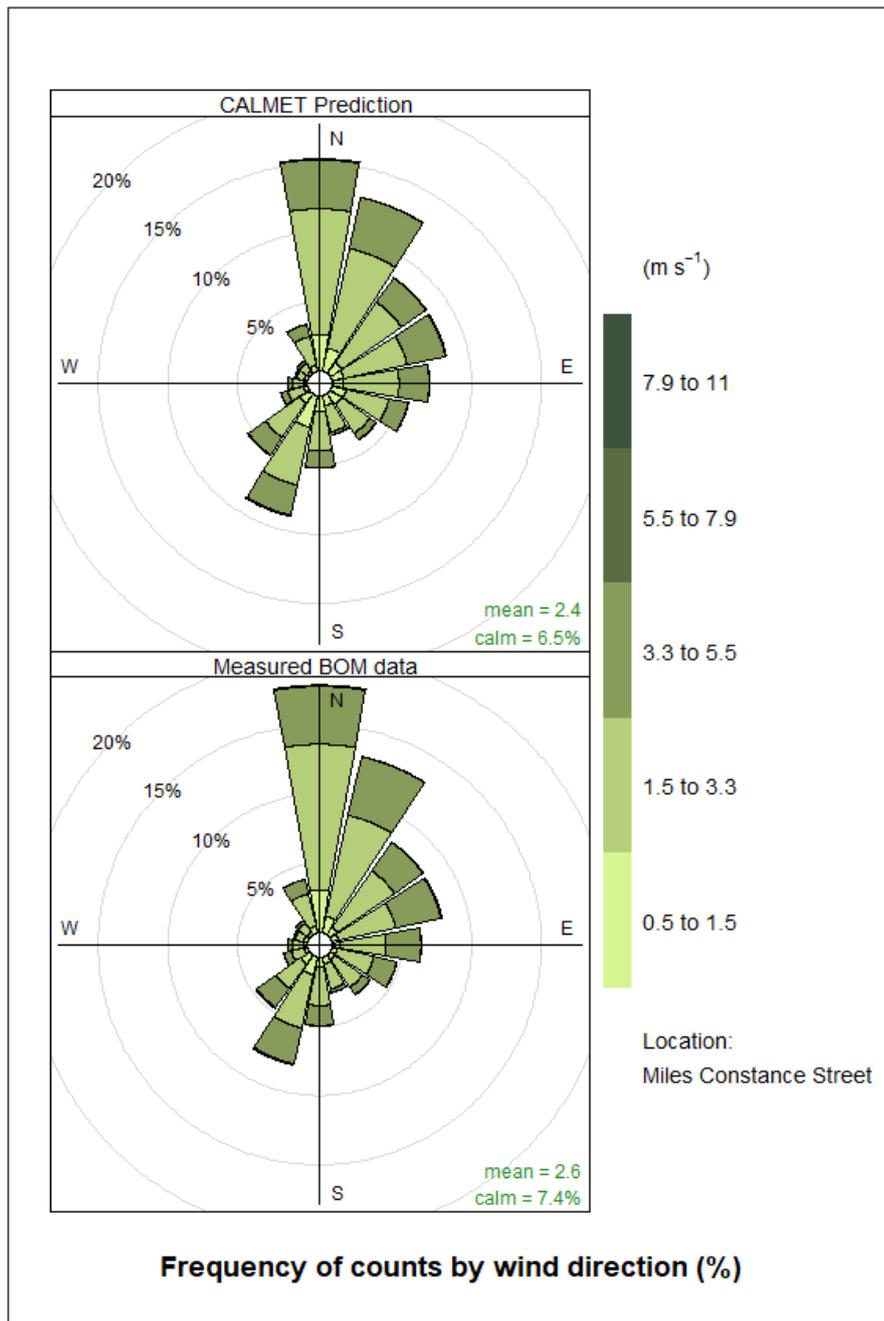
Figure B-1 shows annual wind roses compiled from observational data from the Miles Constance Street station for the 2023 calendar year alongside the CALMET model predictions extracted at the same location. It can be observed from these roses that there is close correlation between the predominant wind speed and wind directions predicted for the modelling period of 2023.

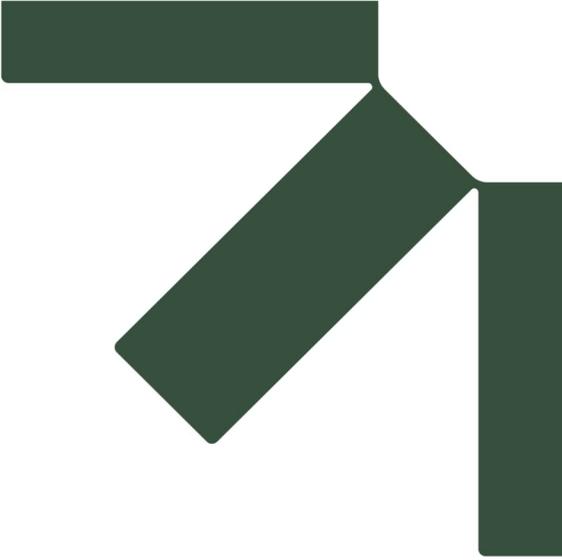
Mean wind speeds are also very consistent across the two roses and a slight difference in calm conditions were observed.

Given this, it is concluded that the meteorological modelling conducted for 2023 adequately represents meteorological conditions for the region for the purposes of this study.



Figure B-1 Wind Rose - Model Prediction vs Observed Data at Miles Constance Street (2023)





Appendix C Isopleth Plots

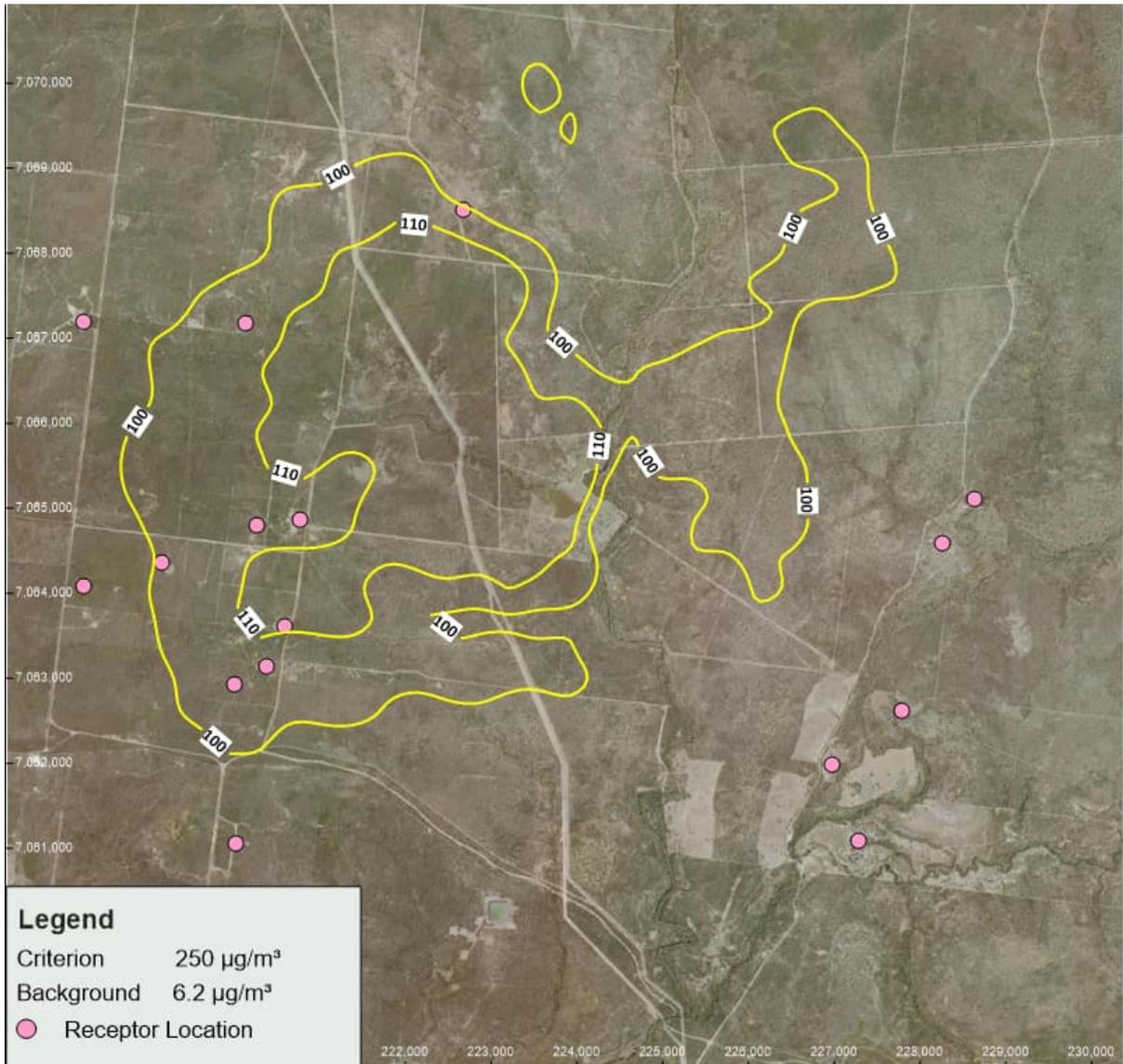
Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

Arrow Energy Pty Ltd

SLR Project No.: 620.12248.01605

16 July 2024



Legend
 Criterion 250 µg/m³
 Background 6.2 µg/m³
 ● Receptor Location

SLR
 Level 16, 175 Eagle Street
 Brisbane QLD 4000
 T: +61 7 3858 4800
 F: +61 7 3858 4801
 www.slrconsulting.com

Project Number: 620.31072
 Dispersion Model: CALPUFF
 Modelling Period: 2023
 Projection: GDA 1994 MGA Zone 55

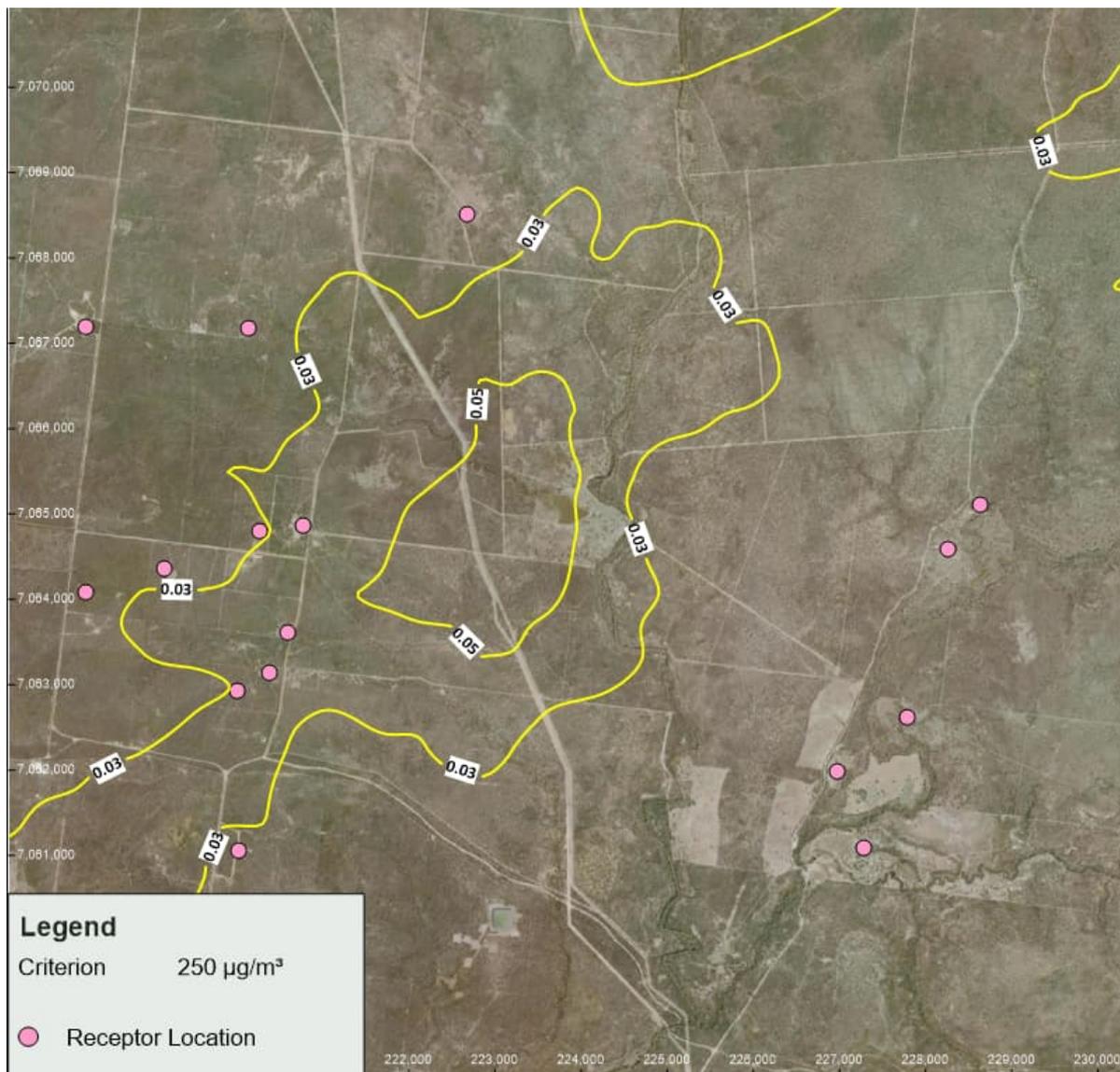


Arrow Energy Pty Ltd
**Girraheewen Field Compressor Station
 Air Quality Impact Assessment**
 Cumulative Impact - Normal Operations

The content within this document may be based on third party data. SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

Date:	10/07/2024	Pollutant	NO ₂	Avg Period	1-Hour	Unit	µg/m³
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Legend
 Criterion 250 µg/m³
 ● Receptor Location

SLR
 Level 16, 175 Eagle Street
 Brisbane QLD 4000
 T: +61 7 3858 4800
 F: +61 7 3858 4801
 www.slrconsulting.com

Project Number: 620.31072
 Dispersion Model: CALPUFF
 Modelling Period: 2023
 Projection: GDA 1994 MGA Zone 55

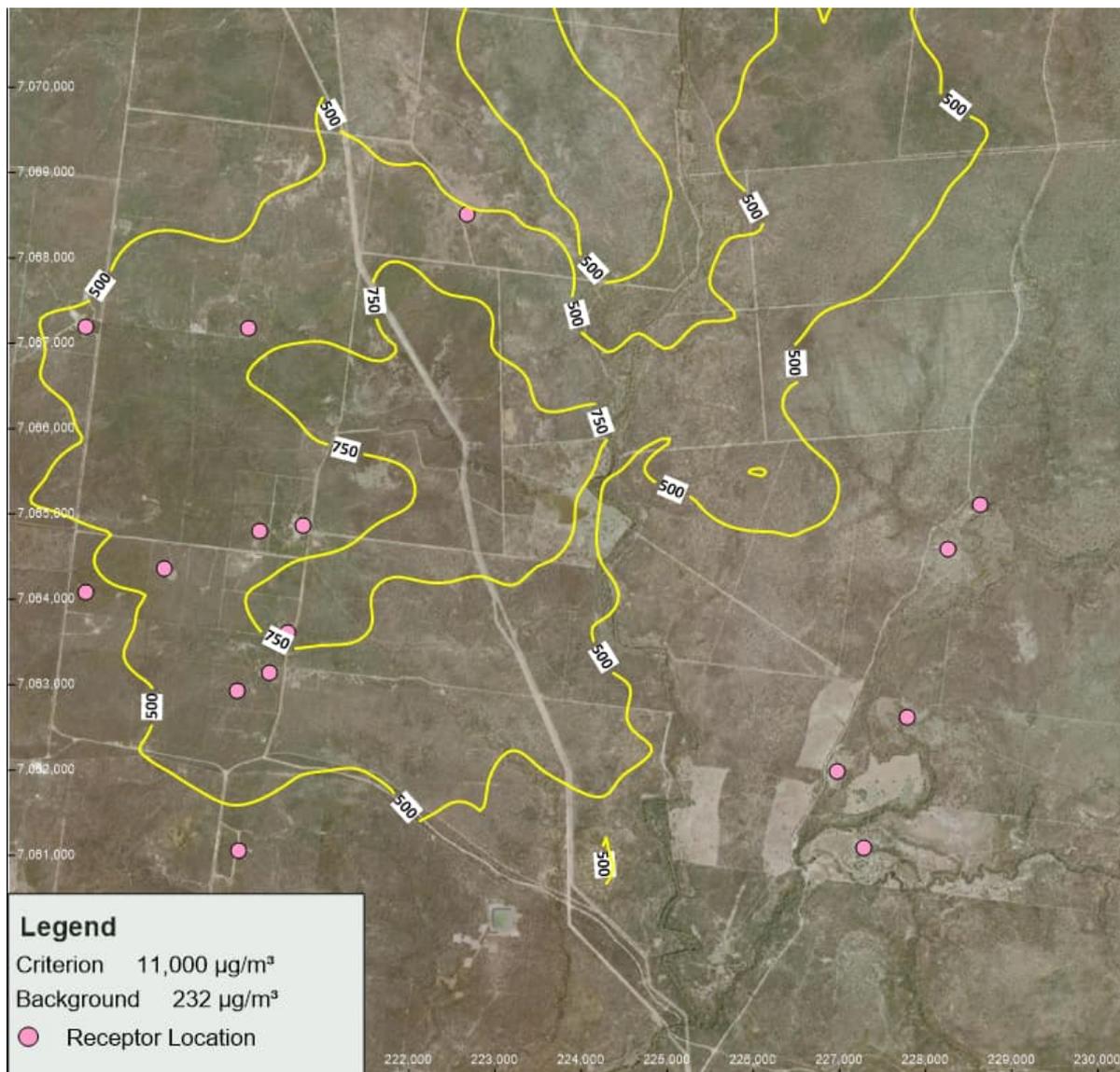


Arrow Energy Pty Ltd
**Girraheewen Field Compressor Station
 Air Quality Impact Assessment**
 Incremental Impact - Flaring

Date:	10/07/2024	Pollutant	NO ₂	Avg Period	1-Hour	Unit	µg/m ³
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The content within this document may be based on third party data. SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.





Legend
 Criterion 11,000 µg/m³
 Background 232 µg/m³
 ● Receptor Location

SLR
 Level 16, 175 Eagle Street
 Brisbane
 QLD 4000
 T: +61 7 3858 4800
 F: +61 7 3858 4801
 www.slrconsulting.com

Project Number: 620.31072
 Dispersion Model: CALPUFF
 Modelling Period: 2023
 Projection: GDA 1994 MGA Zone 55
 Date: 10/07/2024

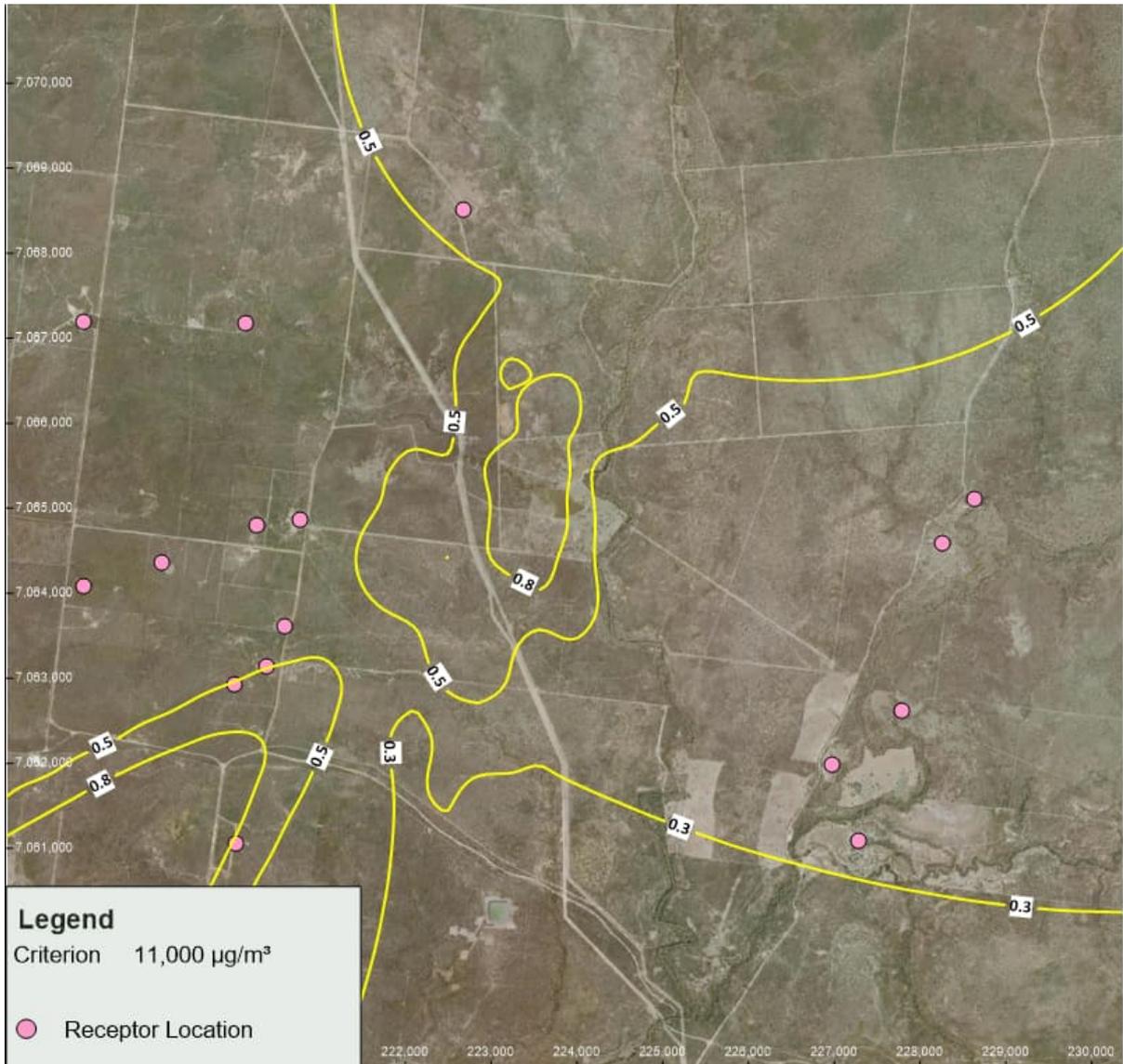


Arrow Energy Pty Ltd
**Girraheen Field Compressor Station
 Air Quality Impact Assessment**
 Cumulative Impact - Normal Operations

The content within this document may be based on third party data. SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

Pollutant	Avg Period	8-Hour	Unit	µg/m³
CO				





Legend
 Criterion 11,000 $\mu\text{g}/\text{m}^3$
 ● Receptor Location

SLR
 Level 16, 175 Eagle Street
 Brisbane
 QLD 4000
 T: +61 7 3858 4800
 F: +61 7 3858 4801
 www.slrconsulting.com

The content within this document may be based on third party data. SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

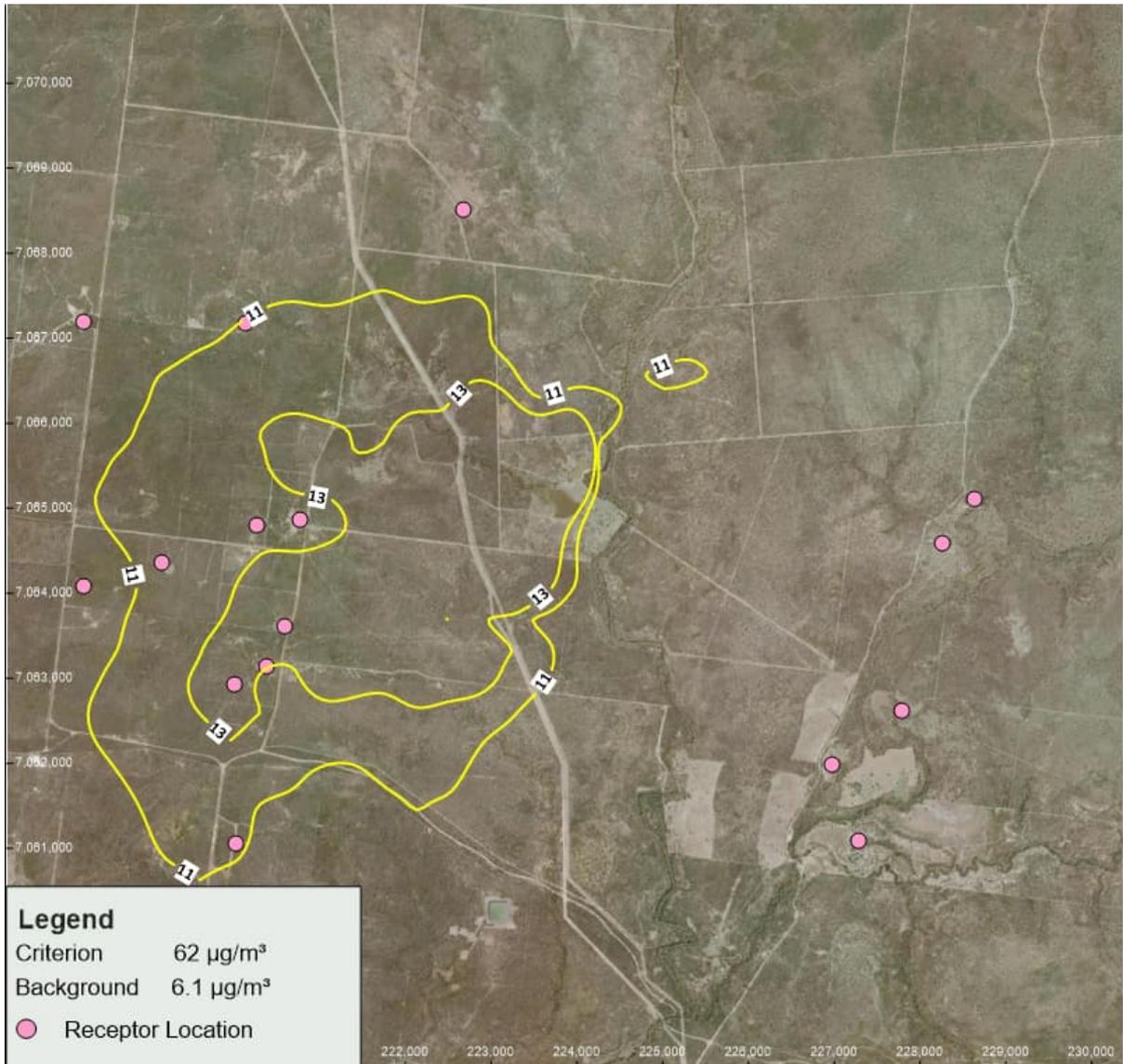
Project Number: 620.31072
 Dispersion Model: CALPUFF
 Modelling Period: 2023
 Projection: GDA 1994 MGA Zone 55
 Date: 10/07/2024



Arrow Energy Pty Ltd
**Girraheen Field Compressor Station
 Air Quality Impact Assessment**
 Incremental Impact - Flaring

Date:	10/07/2024	Pollutant	CO	Avg Period	8-Hour	Unit	$\mu\text{g}/\text{m}^3$
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Legend
 Criterion 62 µg/m³
 Background 6.1 µg/m³
 ● Receptor Location

SLR
 Level 16, 175 Eagle Street
 Brisbane QLD 4000
 T: +61 7 3858 4800
 F: +61 7 3858 4801
 www.slrconsulting.com

Project Number: 620.31072
 Dispersion Model: CALPUFF
 Modelling Period: 2023
 Projection: GDA 1994 MGA Zone 55



Arrow Energy Pty Ltd
**Girraheen Field Compressor Station
 Air Quality Impact Assessment**
 Cumulative Impact - Normal Operations

The content within this document may be based on third party data. SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

Date:	10/07/2024	Pollutant	NO ₂	Avg Period	Annual	Unit	µg/m³
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Making Sustainability Happen