Air quality P

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Santos GLNG Gas Field Development Project

Environmental Impact Statement

Air Quality Impact Assessment

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Santos GLNG Project
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Brisbane
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Environmental Impact Statement

Air Quality Impact Assessment

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ABBREVIATIONS

%	percent
°C	degrees Celsius
µg	microgram
$µg/m^3$	microgram per cubic metre of air
µm	micrometre or micron
BoM	Bureau of Meteorology
BTU	British thermal unit
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CSIRO	Australian Commonwealth Scientific and Industrial Research Organisation
DEWHA	Department of Environment, Water, Heritage and Arts (now Department of the Environment)
SEWPaC	Department of Sustainability. Environment, Water, Population and Communities (now Department of the Environment)
EHP	Department of Environment and Heritage Protection, Queensland Government
EIS	Environmental Impact Statement
EP Act	*Environment Protection Act 1994*
EPP Air	*Environment Protection Policy (Air) 2008*
g	gram
g/kg	grams per kilogram
g/s	grams per second
GFD Project	Gas Field Development Project
GHG	greenhouse gas(es)
GLNG Project	Gladstone Liquefied Natural Gas Project
ha	hectares
J	joule
kg/m^3	kilograms per cubic metre
km	kilometre
km^2	square kilometre
km E	kilometres east
km N	kilometres north
kPa	kilopascals
kW	kilowatt
m	metre
M	million
m/s	metre per second
m^2	square metre
m^3	cubic metre
mg/m^3	milligram per cubic metre
mm	millimetre
MMSCFD	million standard cubic feet per day
MW	megawatt
N_2O	nitrous oxide
NO	nitric oxide
NO_2	nitrogen dioxide
NO_5	nitrogen pentoxide
NO_X	oxides of nitrogen
NPI	National Pollutant Inventory (Australia)
NSW	New South Wales

O_3	ozone
PM	Particulate Matter
PM_{10}	particular matter with an equivalent aerodynamic diameter of 10 microns or less
$PM_{2.5}$	particular matter with an equivalent aerodynamic diameter of 2.5 microns or less
ppm	parts per million (10^6)
SLR	SLR Consulting Pty Ltd
SO_2	Sulphur dioxide
TAPM	The Air Pollution Model
TEG	Triethylene glycol
TJ	terajoule: 1.0 x 1012 J
ToR	Terms of Reference
TSP	total suspended particulate matter
UTM	Universal Transverse Mercator
VOC	Volatile organic compound
W	Watt

SI PREFIXES

Prefix	Symbol	Factor
peta-	P	1×10^{15}
tera-	T	1×10^{12}
giga-	G	1×10^{9}
mega-	M	1×10^{6}
kilo-	k	1×10^{3}
hector-	h	1×10^{2}
deci-	d	1×10^{-1}
centi-	c	1×10^{-2}
milli-	m	1×10^{-3}
micro-	µ	1×10^{-6}
nano-	n	1×10^{-9}
pico-	p	1×10^{-12}

GLOSSARY

Air dispersion model	A computer-based software program which provides a mathematical prediction of how pollutants from a source will be distributed in the surrounding area under specific conditions of wind, temperature, humidity and other environmental factors
Airshed	The geographical area associated with a given air supply
Algorithms	A step-by-step problem-solving procedure, especially an established, recursive computational procedure for solving a problem in a finite number of steps
Ambient	Pertaining to the surrounding environment or prevailing conditions
Atmosphere	A gaseous mass surrounding the planet that is retained by Earth's gravity. It is divided into five layers, with most of the weather and clouds found in the first layer
Atmospheric stability	The tendency of the atmosphere to resist or enhance vertical motion
Atmospheric pressure	The force per unit area exerted against a surface by the weight of air above that surface in the Earth's atmosphere
Background	The existing air quality in the Project area excluding the impacts from the Project
Baseline monitoring program	A monitoring program designed to measure the ambient concentration levels which currently exist prior to the Project
CALMET	A meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain
CALPOST	A post-processor used to process CALPUFF files, producing tabulations that summarise results for user-selected averaging periods
CALPUFF	A transport and dispersion model that advects "puffs" of material emitted from modelled sources, simulating dispersion and transformation processes
Climatological	The science dealing with climate and climatic phenomena
Combustion	The process of burning. A chemical change, especially oxidation, accompanied by the production of heat and light
Dust deposition	Settling of particulate matter out of the air through gravitational effects (dry deposition) and scavenging by rain and snow (wet deposition)
Dispersion	The spreading and dilution of substances emitted in a medium (e.g. air or water) through turbulence and mixing effects
Diurnal	Relating to or occurring in a 24-hour period; daily
Downwash	The grounding of an air pollution plume as it flows over nearby buildings or other structures due to turbulent eddies being formed in the downwind side of the building, resulting in elevated ground level concentrations.
Downwind	The direction in which the wind is blowing
Emissions inventory	A database that lists, by source, the amount of air pollutants discharged into the atmosphere from a facility over a set period of time (e.g. per annum, per hour)
Erodible	A term used to describe a soil that is vulnerable to erosion by the agents of wind, water, ice
Epidemiological	The branch of medicine that deals with the study of the causes, distribution, and control of disease in populations
EPP Air	*Environmental Protection (Air) Policy 2008*

Fossil fuel	A natural fuel such as coal, diesel or gas, formed in the geological past from the remains of living organisms
Fugitive emissions	Pollutants which escape from an industrial process due to leakage, materials handling, transfer, or storage
Gas treatment	Various treatment technologies may be installed at a gas compression facility to remove heavy hydrocarbon gases (e.g. ethane, propane, butane, pentane, hexane and heptane), moisture and other impurities from the gas to meet supply specifications.
Greenhouse gas	A gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g. carbon dioxide
Guideline	A general rule, principle, or piece of advice. A statement or other indication of policy or procedure by which to determine a course of action.
Hub gas compression facility	Second stage gas compression; compresses gas to the pressure required for transmission via the Gladstone gas transmission pipeline (or third party transmission pipeline); minimum inlet pressure is 1,500 kilopascals; typically operated remotely.
LNG facility	The gas liquefaction, storage and export facility of approximately 10 million tonnes per annum capacity on Curtis Island, Gladstone. A three-train LNG Facility was approved as part of the GLNG Project via the GLNG Project EIS (Santos GLNG, 2009), and a two-train facility is currently under construction.
Meteorological	The science that deals with the phenomena of the atmosphere, especially weather and weather conditions
Mixing height	The height to which the lower atmosphere will undergo mechanical or turbulent mixing, producing a nearly homogeneous air mass
Modelling domain	The area over which the model is making predictions
Nodal gas compression facility	First stage gas compression; compresses gas collected in the gathering lines to the pressure required for transport via infield transmission pipelines to second stage compression; often co-located with hub compressors at gas compression facilities; typically operated remotely.
Production wells	A well that is designed to extract gas from one or more natural underground sources.
Particulate	Of, relating to, or formed of minute separate particles. A minute separate particle, as of a granular substance or powder
Plume	A space in air, water, or soil containing pollutants released from a point source
Point source	A pollution source that is fixed and/or uniquely identifiable, such as a stack, chimney, outlet pipe or vent
Pollutant	A substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource
Prognostic	A prediction of the value of variables for some time in the future on the basis of the values at the current or previous times
Qualitative assessment	An assessment of impacts based on a subjective, non-statistical oriented analysis
Quantitative assessment	An assessment of impacts based on estimates of emission rates and air dispersion modelling techniques to provide estimate values of ground level pollutant concentrations.
Receptor	Coordinate locations specified in an air dispersion model where ground level pollutant concentrations are calculated by the model

Sensitive receptor	Locations such as residential dwellings, hospitals, churches, schools, recreation areas etc where people (particularly the young and elderly) may often be present
Spatial variation	Pertaining to variations across an area
Standard	The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health
Synoptic meteorological data	A surface weather observation, made at periodic times (usually at 3-hourly and 6-hourly intervals), of sky cover, state of the sky, cloud height, atmospheric pressure reduced to sea level, temperature, dew point, wind speed and direction, amount of precipitation, hydrometeors and lithometers, and special phenomena that prevail at the time of the observation or have been observed since the previous specified observation
Temporal variation	Pertaining to variations with time
Topography	Detailed mapping or charting of the features of a relatively small area, district, or locality
Volatile organic compounds	Organic compounds (substances made up of predominantly carbon and hydrogen) with boiling temperatures in the range of 50-260°C, excluding pesticides. This means that they are likely to be present as a vapour or gas in normal ambient temperatures.
Wind direction	The direction from which the wind is blowing
Wind erosion	Detachment and transportation of loose topsoil or sand by the wind
Windrose	A meteorological diagram depicting the distribution of wind direction and speed at a location over a period of time

Executive Summary

The Santos GLNG Gas Field Development Project (the GFD Project) is an extension of the existing approved gas field development (known as the GLNG Project) and will involve the construction, operation, decommissioning and rehabilitation of production wells and the associated supporting infrastructure needed to provide additional gas over a project life exceeding 30 years.

Starting in 2016, the GFD Project will continue to progressively develop the Arcadia, Fairview, Roma and Scotia gas fields across Santos GLNG petroleum tenures in the Surat and Bowen basins, and associated supporting infrastructure in these tenures and in adjacent areas. The GFD Project will include the following components:

- Production wells
- Potentially underground gas storage wells, fluid injection wells and monitoring bores
- Gas and water gathering lines
- Gas and water transmission pipelines
- Gas compression and treatment facilities
- Water storage and management facilities
- Access roads and tracks
- Accommodation facilities and associated services (e.g. sewage treatment)
- Maintenance facilities, workshops, construction support, warehousing and administration buildings
- Utilities such as water and power generation and supply (overhead and/or underground)
- Lay down, stockpile and storage areas
- Borrow pits and quarries
- Communications.

The main emissions to air that would occur as a result of the GFD Project would be associated with the combustion of gas extracted from coal seams in gas-fired compressor engines, power generators, triethylene glycol (TEG) regeneration reboilers and flares at the gas compression facilities. As this infrastructure and equipment is similar to that already approved within the Arcadia, Fairview, Roma and Scotia gas fields, the GFD Project will represent an incremental increase in the quantity and spread of emissions; however the nature of those emissions would be the same as current operations.

The gas turbine alternators and gas turbine compressors may be required long term in some facilities or may only be required during commissioning and early operations in other facilities until they are powered by a connection to the electrical grid. If or once electrified, there would be no requirement for power generation from the combustion of gas or combustion of gas to drive gas turbine compressor engines and consequently no further air emissions from gas turbine alternators and/or gas compressors. The only remaining sources of emissions would be the TEG re-boilers and emergency flaring events.

Fugitive particulate emissions would generally occur during construction of infrastructure such as production wells, gas compression and water management facilities, roads and worker accommodation facilities. Decommissioning and rehabilitation will occur progressively throughout the life of the GFD Project as construction activities cease and exhausted wells are decommissioned.

Based on the review of potential air emission sources associated with the GFD Project, potential sources of air emissions from the project have been identified as presented in **Table E1**.

Table E1 Summary of identified emissions to air and assessment methodologies

Potential Air Pollutants	Sources of Emissions			Assessment Methodology
	Construction Phase	Operations Phase	Decommissioning Phase	
Particulate matter	Clearing, topsoil removal, earthworks Vehicles, trucks and other mobile equipment Concrete batching plants	Vehicle movements on unpaved roads Wind erosion of disturbed soils	Rehabilitation activities such as grading and topsoil spreading Vehicles, trucks and other mobile equipment Demolition activities (possibly including blasting)	Emissions of particulate matter have been assessed qualitatively. Quantitative assessment of particulate emissions from vehicles travelling on unpaved roads is subject to an extremely high level of uncertainty. These emissions are most appropriately managed through the implementation of appropriate planning and mitigation measures.
Oxides of nitrogen (NO_X) Carbon monoxide (CO) Volatile organic compounds (VOCs)	Vehicles, trucks and other mobile equipment	Gas-fired turbine or engine compressors and alternators and TEG reboilers Flares Reciprocating engines at wellheads Vehicles, trucks and other mobile equipment	Vehicles, trucks and other mobile equipment	An atmospheric dispersion modelling has been performed to assess local impacts of NO_X and CO emissions from gas compression facilities for three scenarios: • a nominal large integrated hub gas compression facility (240 TJ/day) – normal operations • a nominal large integrated hub gas compression facility (240 TJ/day) – major flaring event • a typical nodal gas compression facility (80 TJ/day). The modelling study was performed using the AUSPLUME dispersion model and a series of four meteorological files representative of a range of locations across the project area. Non-methane VOC emissions from gas compression facilities will be minor and have been assessed qualitatively. Emissions of NO_X, CO and VOCs from traffic emissions have been assessed qualitatively based on the projected maximum increase in vehicle numbers relative to existing traffic levels.
Sulfur dioxide (SO_2)	Diesel-fired vehicles, trucks, generators and other equipment	Diesel-fired backup generators, pumps and other stationary equipment Diesel-fired vehicles, trucks and other mobile equipment	Diesel-fired vehicles, trucks, generators and other equipment	Emissions of SO_2 from diesel-fired vehicles and other equipment will be minor and have been assessed qualitatively.
Methane	Fugitive gas emissions during well construction or losses from infrastructure (valves, manifolds, pipelines, etc.)	Fugitive gas emissions Venting	N/A	Methane is a greenhouse gas and does not have the potential to give rise to impacts on local or regional air quality. These emissions are beyond the scope of the air quality impact assessment.
Odour	Sewage treatment plants at accommodation camps	Sewage treatment plants at accommodation camps	Sewage treatment plants at accommodation camps	Potential odour emissions will be highly localised to the source and be dispersed within the immediate environment; therefore odour-related nuisance impacts are not expected. Should Santos GLNG receive complaints related to odour, an odour impact assessment would be performed for the activity/facility of concern in accordance with the EHP guideline Odour Impact Assessment from Developments (EHP, 2013).

The final number, size and location of the GFD Project components will be determined progressively over the project life and will be influenced by the location, size and quality of the gas resources identified through ongoing field development planning processes. This means that detailed site-specific modelling cannot be performed. The approach used in this assessment has therefore been designed to provide a conservative assessment of downwind impacts from:

- A nominal large integrated hub gas compression facility (240 terajoules per day (TJ/day)) – normal operations
- A nominal large integrated hub gas compression facility (240 TJ/day) – major flaring event
- A typical nodal gas compression facility (80 TJ/day) – normal operations.

In addition to the large facilities, small gas-fired generators may be present at well leases. These emissions are considered to minimal and in aggregate (wells combined) have order of magnitude lower emissions than the gas compression facilities.

The results of this modelling can be used to assess potential air impacts at sensitive receptors and therefore identify avoidance and mitigation controls such as indicative minimum separation distances that would potentially be required for such facilities. As preferred locations for individual facilities are identified, and details of the required size and number of engines and other fuel-burning equipment are known, more detailed modelling would be performed to enable site-specific factors such as the surrounding topography and land use to be accounted for in the modelling to quantify the impacts of these factors of the predicted downwind concentrations.

As part of the modelling study, a regional modelling study was performed using the TAPM/CALMET/CALPUFF modelling suite and publicly available emissions data for major emission sources in the area, including power stations, mines, quarries, existing gas extraction activities and general industry. The results of this modelling were used to provide a conservative estimate of worst case background NO_2 and CO concentrations in each gas field to enable a cumulative impact assessment to be performed.

Four two-dimensional meteorological files were compiled from the regional CALMET model; one for each of the four gas fields (Acacia, Fairview, Roma and Scotia). These meteorological datasets were then used in the AUSPLUME dispersion model to predicted maximum downwind concentrations of NO_2 and CO from the three emission scenarios listed above. These predicted impacts were then assessed against relevant regulatory criteria for ambient air quality, based on the background concentrations predicted by CALPUFF.

The results of the dispersion modelling study showed that predicted concentrations from gas compression activities under normal operations and during flaring (commissioning and emergency) would comply with air quality objectives for the preservation of health and wellbeing and biodiversity of ecosystems for activities undertaken greater than 100 metres (m) from receptors. Air pollutant emissions have therefore been assessed as having low potential for impacts.

There is potential for particulate matter (dust) and vehicle emissions associated with unmitigated construction works to result in a moderate to high magnitude impact within 500 m of receptors. Where construction activities are undertaken greater than 500 m from receptors potential particulate matter and vehicle emissions are considered to be a low magnitude impact with pollutant levels compliant to the adopted air quality assessment objectives. Through the implementation of existing management and mitigation controls from the Santos GLNG project environmental management plans and protocols, such as minimising the duration of exposed surfaces, watering access tracks, soil stockpiles and spoil and a no burning policy, it is expected potential impacts from particulate matter and vehicle emissions for construction activities can be mitigated to comply with relevant air quality objectives resulting in a low magnitude impact at receptors.

Santos GLNG will implement control processes that accord to the management hierarchy for air emissions in the EPP Air to avoid, recycle, minimise and manage impacts from air emissions associated with the GFD Project.

1 INTRODUCTION

Santos GLNG intends to further develop its Queensland gas resources to augment supply of natural gas to its existing and previously approved Gladstone Liquefied Natural Gas (GLNG) Project.

The Santos GLNG Gas Field Development Project (the GFD Project) is an extension of the existing approved gas field development and will involve the construction, operation, decommissioning and rehabilitation of production wells and the associated supporting infrastructure needed to provide additional gas over a project life exceeding 30 years. SLR Consulting Australia Pty Ltd (SLR) has been engaged by URS Australia Pty Ltd, on behalf of Santos GLNG, to conduct an assessment of the potential impacts on local and regional air quality associated with the construction, operation, decommissioning and rehabilitation of the GFD Project.

Air emissions have been assessed with reference to the GFD Project *Terms of reference* (ToR) *for an environmental impact statement* (EIS), dated March 2013. The purpose of this report is to present the findings of the assessment and detail management and mitigation measures for the GFD Project to comply with the requirements of the ToR.

1.1 Project description

1.1.1 Current operations

Santos GLNG has existing approvals for the exploration and production of gas from the petroleum tenures making up the Arcadia, Fairview, Roma and Scotia gas fields. To expand the Santos GLNG business to supply liquefied natural gas (LNG) to export markets, Santos GLNG completed an EIS for the GLNG Project in 2009 (2009 EIS), receiving approval from the State and Federal Governments in 2010. The GLNG Project has approval to develop 2,650 exploration and production wells and supporting infrastructure across 6,887 square kilometres (km^2) of the Arcadia, Fairview and Roma gas fields, as well as approval for a 420 kilometre (km) long gas transmission pipeline to connect the gas fields to an approved three-train LNG processing facility located at Curtis Island, Gladstone.

Production wells, associated connecting pipelines, gas compression and water management infrastructure, the Gladstone gas transmission pipeline, and a two-train LNG facility are currently under construction. The 2009 EIS indicated that 2,650 wells would not be sufficient to support the gas supply needs for the approved three-train LNG facility, and that Santos GLNG would seek approval for additional wells at a later stage.

1.1.2 Proposed operations

Specifically, the GFD Project seeks approval to expand the GLNG Project's gas fields tenure from 6,887 km^2 to 10,676 km^2 to develop up to 6,100 production wells beyond the currently authorised 2,650 wells; resulting in a maximum of up to 8,750 production wells. Current understanding of the gas resource indicates that production will be required to commence in 2016 in the Scotia gas field, followed by the Roma, Arcadia and Fairview gas fields in mid-2019.

The GFD Project will continue to progressively develop the Arcadia, Fairview, Roma and Scotia gas fields across 35 Santos GLNG petroleum tenures in the Surat and Bowen basins, and associated supporting infrastructure in these tenures and in adjacent areas. The location of the GFD Project area and primary infrastructure is shown on **Figure 1**.

This GFD Project will include the following components:

- Production wells
- Fluid injection wells, monitoring bores and potentially underground gas storage wells
- Gas and water gathering lines

- Gas and water transmission pipelines
- Gas compression and treatment facilities
- Water storage and management facilities
- Access roads and tracks
- Accommodation facilities and associated services (e.g. sewage treatment)
- Maintenance facilities, workshops, construction support, warehousing and administration buildings
- Utilities such as water and power generation and supply (overhead and/or underground)
- Lay down, stockpile and storage areas
- Borrow pits and quarries
- Communications.

The final number, size and location of the components will be determined progressively over the GFD Project life and will be influenced by the location, size and quality of the gas resources identified through ongoing field development planning processes, which include consideration of land access agreements negotiated with landholders, and environmental and cultural heritage values.

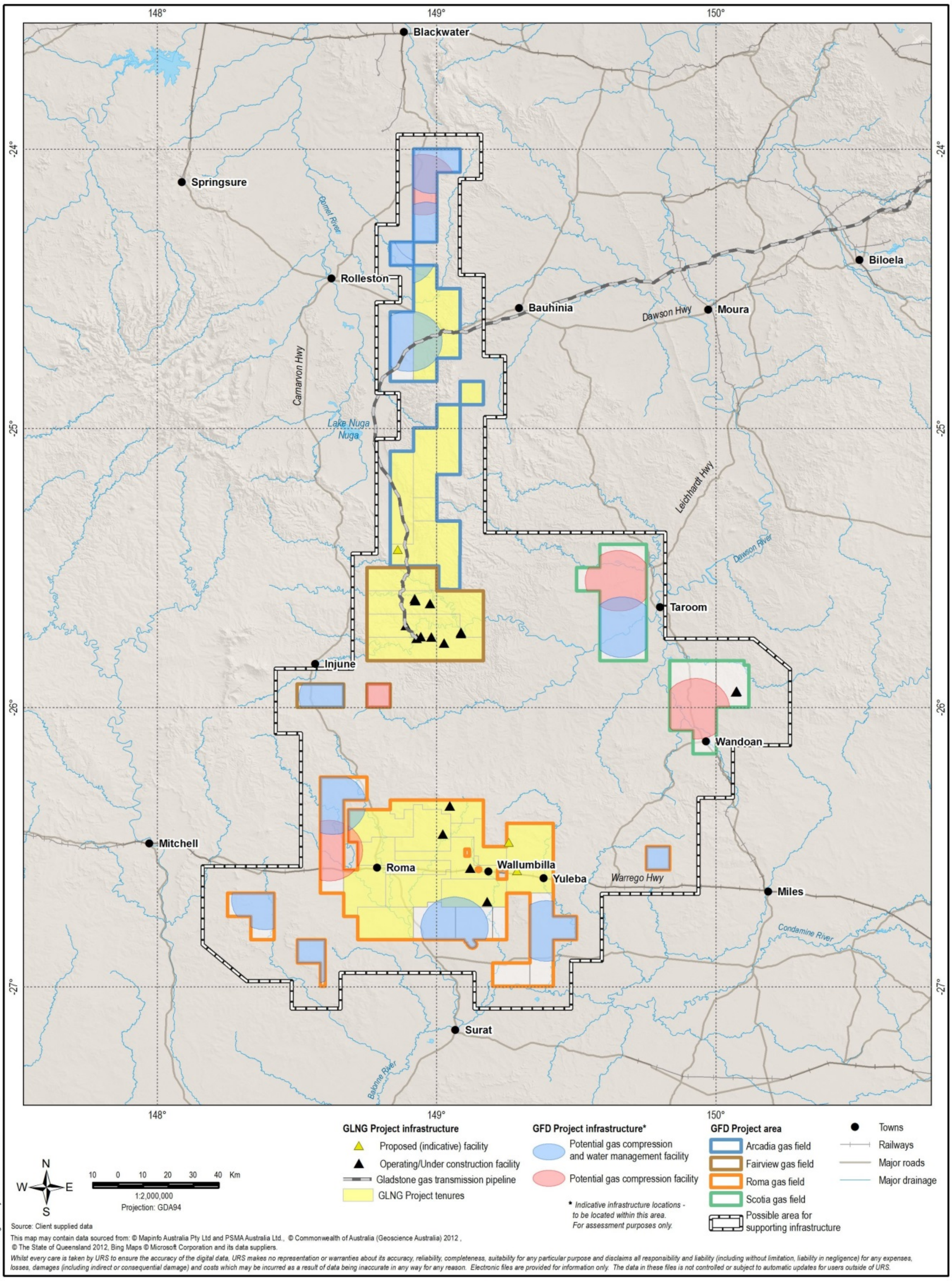
Where practicable, the GFD Project will utilise existing or already approved infrastructure (e.g. accommodation camps, gas compression and water management facilities) from the GLNG Project or other separately approved developments. The GFD Project may also involve sourcing gas from third-party suppliers, as well as the sharing or co-location of gas field and associated facilities with third parties.

For the purposes of transparency this EIS shows an area off-tenure that may be used for infrastructure such as pipelines and temporary camps (supporting infrastructure area). While not assessed specifically in this EIS, any infrastructure that may be located within this area would be subject to further approval processes separate to this EIS.

Approved exploration and appraisal activities are currently underway across the GFD Project's petroleum tenures to improve understanding of the available gas resources. As the understanding of gas resources improves, investment decisions will be made about the scale, location and timing of the next stages of field development.

For the purposes of this EIS, a scenario based on the maximum development case was developed at the approval of the ToR. This scenario assumed that production from the wells and upgrading of the gas compression facilities in the Scotia gas field would commence in 2016, followed by the GFD Project wells in the Roma, Arcadia and Fairview gas fields in mid-2019. This schedule is indicative only and was used for the purpose of the impact assessment in this EIS.

Figure 1 GFD Project area and primary infrastructure

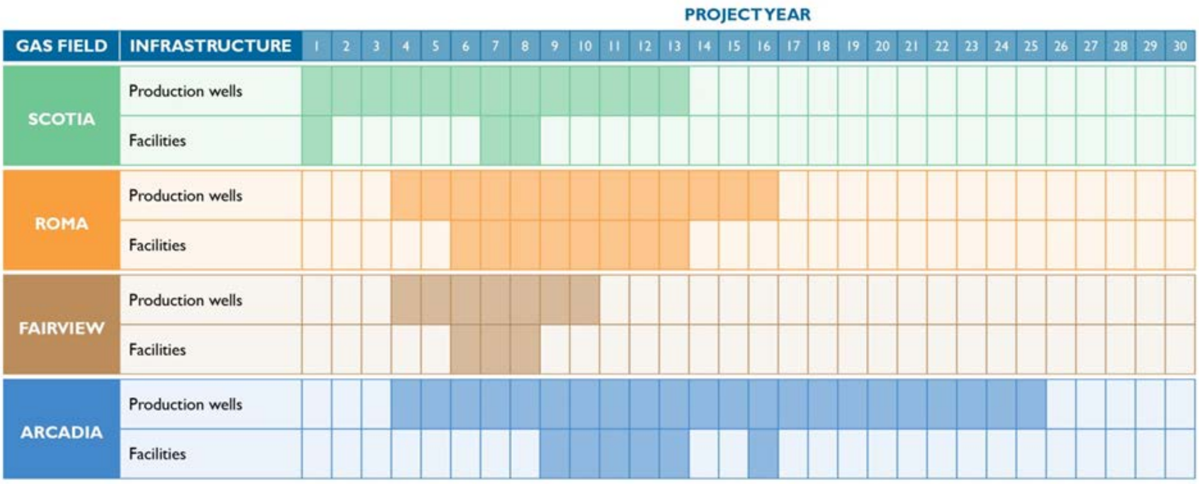


Source: URS, 2014; File No. 42627064-g-1051j.mxd

The proposed GFD Project schedule is outlined in **Figure 2**. This schedule provides an overall field development scenario for the purposes of assessment in this EIS.

Decommissioning and rehabilitation will occur progressively throughout the life of the GFD Project as construction activities cease and exhausted gas wells are decommissioned. However, final decommissioning and rehabilitation will occur at the end of gas production in accordance with relevant approvals and regulatory requirements.

Figure 2 Proposed GFD Project development schedule



2 EMISSIONS TO AIR

2.1 Pollutants of interest

2.1.1 Products of combustion

The main emissions to air that would occur as a result of the GFD Project would be associated with the combustion of gas extracted from coal seams in gas-fired compressor engines, power generators, triethylene glycol (TEG) regeneration reboilers and flares at the gas compression facilities. As this infrastructure and equipment has already been approved and commenced development in the Arcadia, Fairview, Roma and Scotia gas fields, the GFD Project would represent an incremental increase in the quantity and spread of emissions; however the nature of those emissions would be the same as current operations.

The composition of typical processed gas is detailed in **Table 1** Gas from coal seams does not contain appreciable or significant concentrations of aromatics, sulphur compounds, heavy gases or mercury.

Table 1 Composition of gas extracted from coal seams

Gas Component	Concentration (mol %)
Methane	97.1 – 97.5
Nitrogen	2.3 – 2.6
Carbon dioxide	0.1
Ethane	0 – 0.1
Propane	<0.01
Butane	<0.001
Pentane	<0.001

(Source: Santos GLNG, 12 June 2013)

Pollutants emitted from the combustion of gas include the following.

- **Oxides of nitrogen (NO_X)**: NO_X is a mixture of gases that are composed of nitrogen and oxygen. Two of the most toxicologically significant compounds are nitric oxide (NO) and nitrogen dioxide (NO_2). Other gases belonging to this group are nitrous oxide (N_2O) and nitrogen pentoxide (NO_5). The majority of NO_X (90 to 95%v/v) generated by the combustion of fossil fuels is in the form of NO, with NO_2 contributing the remaining 5 to 10%v/v along with traces of N_2O. The NO reacts in the atmosphere to form additional NO_2 as the plume travels downwind.
- **Carbon monoxide (CO)**: CO is formed due to the incomplete combustion of carbon in fuels (e.g. petrol, wood, coal, natural gas). Industrial and diffuse (e.g. motor vehicles) emissions of CO can therefore produce an elevation in ambient concentrations around the source.
- **Sulfur dioxide (SO_2)**: Emissions of SO_2 from fossil fuel combustion are directly proportional to the sulfur content of the fuel. As the sulfur content of gas from coal seams is very low (negligible) typically less than 1 ppm, emissions of SO_2 from the gas compression facilities and other gas-fired equipment will also be negligible and have not been considered further.
- **Particulate matter**: Small quantities of particulate matter are formed during gas combustion, predominantly in the fine particulate size range, from carryover of non-combustible trace constituents in the fuel and lubricating oil and as products of incomplete combustion. Emissions of particulate matter from natural gas-fired engines are minimal, typically less than 0.0029 g/kWh (DEWHA, 2008) and have not been considered further.
- **Volatile organic compounds (VOCs):** VOCs is a collective term used to describe organic carbon-based compounds with the ability to enter the atmosphere as a vapour. Due to the ubiquitous nature of organic compounds emitted from natural and anthropogenic processes, there is a myriad of organic compounds that fall under the definition of VOCs.

The environmental, human-health and amenity (i.e. odour) impacts of ambient concentrations of VOCs depend on the composition of the gases; hence there are no ambient air quality criteria for "Total VOCs", only for selected key speciated VOC constituents.

Emissions of VOCs from gas-fired engines are primarily the result of incomplete combustion, with some organics being carryover, unreacted trace constituents of the gas, while others may be pyrolysis products of the heavier hydrocarbon constituents. Gas from coal seams is predominantly (greater than 97%v/v) methane (CH_4) and contains a limited mixture of VOCs such as ethane, propane etc. Ambient air quality guidelines do not typically consider CH_4 as a VOC as it contributes little to the formation of ground level ozone (O_3) although it is noted to be a significant greenhouse gas.

In addition to the combustion of gas, emissions will also arise as road traffic vehicle exhaust emissions from the combustion of diesel and petrol in employee and visitor cars, delivery trucks, heavy good vehicles and other mobile plant and equipment accessing the gas field and compression hub facilities during the construction, operations and decommissioning phases. Back-up diesel generators will also be installed to provide emergency power in the event the electrical connection to the transmission network is lost. The pollutants emitted from diesel and petrol combustion in vehicles are the same as those listed above for gas combustion; however the quantities of SO_2, particulate matter and VOCs are higher than for gas.

2.1.2 Fugitive gas emissions

Fugitive emissions of gas from coal seams will occur during the construction of wells and during the operations phase as a result of leaks or failures of valves and flanges and other devices associated with surface equipment at well leases, compression facilities, pipework, etc. These emissions are predominantly methane (CH_4), as discussed above, and do not have the potential to give rise to impacts on local air quality (i.e. impacts on human health or flora/fauna) and rapidly disperse (due to their lower density than air) in the atmosphere. However, methane is a contributor to the GFD Project's greenhouse gas (GHG) emission inventory. These GHG emissions are beyond the scope of the air quality impact assessment and are not discussed further in this report.

2.1.3 Fugitive particulate emissions

Fugitive particulate emissions would also occur during construction of infrastructure such as production wells, gas compression facilities, water management facilities, roads and accommodation facilities.

For the purpose of assessing air quality impacts, particulate matter is characterised by matter such as total suspended particulates (TSP) that comprises finer material PM_{10} (≤10 micrometres (µm) in diameter) and $PM_{2.5}$ (≤2.5 µm in diameter).

Particulate matter generated from these open sources is termed 'fugitive' because it is not discharged to the atmosphere in a confined flow stream. The dispersion of fugitive emissions is dependent upon the wind speed and wind direction and the size and mass of the particles, where larger and heavier material settles out closer to the source. The finer materials remain in the atmosphere longer and are dispersed over greater distances.

2.1.4 Odour

Gas from coal seams does not contain sulphurous compounds, such as hydrogen sulfide (H_2S), and therefore has no potential for odour impacts.

Small scale sewage treatment plants will be required at the accommodation camps and at the major gas compression facilities, which may have the potential to generate odour. Odour emissions however, are expected to be infrequent and temporary in nature and are likely to be highly localised to the source and be dispersed within the immediate environment. Potential impacts would be low and managed by existing air quality management measures implemented by Santos GLNG. A detailed odour assessment has therefore not been performed.

However, should Santos GLNG receive complaints related to odour, an odour impact assessment would be performed for the activity/facility of concern in accordance with the EHP guideline *Odour Impact Assessment from Developments* (EHP, April 2013).

2.1.5 Ozone

In general, ozone (O_3) is not emitted directly from an emission source. It is a secondary pollutant formed via a complex series of photochemical reactions.

In the upper atmosphere, ozone plays an important role reducing and blocking harmful wavelengths of sunlight. However, ozone at the earth's surface has the potential for harm where it can damage lung tissues, reduce lung function and aggravate asthma. It can also prevent plant respiration by blocking the opening in leaves where respiration occurs; hampering photosynthesis at a high rate and ultimately stunting plant growth.

This is a regional air pollution issue and is addressed in **Section 6.3**.

2.2 Sources of air emissions

2.2.1 Gas compression facilities

The main sources of potential air emissions associated with the GFD Project would be exhausts associated with the new gas compression facilities and power generation. Air emission sources at a typical hub gas compression facility will include exhaust emissions from gas combustion in the gas turbine alternators, gas turbine compressors, TEG re-boilers (reheating gas stream) and emergency flare.

The gas turbine powered alternators and compressors may be required in the long term in some locations or may only be required during commissioning and early operations, until facilities are connected to the electrical transmission grid. If (or once) electrified, there would be no requirement for power generation by gas turbines and engines would be replaced with electric motors. As a consequence the air emissions from gas turbine and gas engines would be curtailed and emissions would be limited to the TEG reboilers and flare.

Flaring of gas at facilities is only initiated during emergency shutdown events and only for short periods of time. Shutdown of the above-mentioned plant initiates a series of actions including throttling (choking) of gas production wells, isolation of process units, flaring (burning) of surplus gas at the plant (via the emergency flare) and if required complete shut-in (isolation) of the plant from wells and pipelines. Flaring of surplus gas will also occur as part of the commissioning of the plant, typically within the initial three months of operation; thereafter flaring is not part of routine operations unless in the event of emergency or maintenance event. The flare system at the gas compression facility will operate a continuous lighted pilot.

Ancillary sources, such as back-up diesel generators will also be installed to provide emergency power to maintain control systems and communications (but not maintain full operation such as compression of gas), in the event the electrical connection to the transmission network is lost or shutdown of electrical generation facilities. It is anticipated that the diesel generators would operate temporarily and for very short periods of time and would result in far less emissions than when the GFD Project is operating normally.

2.2.2 Production wells

Once operational, the gas production wells are not expected to be significant sources of emissions as the electricity requirement is limited to an approximate maximum of 100 kilowatts (kW) per well during water pumping/depressurisation. Electrical power to the wells is provided either by an electrical reticulation system that does not yield direct air emissions or a gas-fired reciprocating engine at or near the well lease. Once wells become free flowing they no longer require a significant power source (except for remote monitoring telemetry equipment) and would not be an air emission source. Typically less than 50% of the operational wells require power sources for water pumping at any one time, on average across a development or gas field.

2.2.3 Vehicle emissions

Emissions are anticipated to arise from the combustion of fuel from employee and visitor cars, delivery trucks and heavy good vehicles accessing the gas field during construction, operation, decommissioning and rehabilitation phases. Additional emissions of particulate would also occur whenever vehicles are travelling on unpaved roads as wheel-generated dust.

Road traffic would not be continuous, with main periods of vehicle use at the start and end of shifts. The highest intensity of traffic movements would be experienced during construction phases. Accordingly, it is anticipated that the vehicle emissions will only occur for short periods of time and will be well dispersed during hourly and daily activities.

2.2.4 Construction, decommissioning and rehabilitation activities

Particulate matter is considered to be the primary emission during the construction, decommissioning and rehabilitation phases of the GFD Project. Potential sources of particulate emissions have been identified as follows:

- Clearing of groundcover and topsoil, and earthmoving activities (ground levelling, backfilling and grading)
- Disturbance and handling of soils during development of access roads (paved and unpaved)
- Vehicle and mobile plant movements on paved, unpaved roads, haulage routes and other work areas
- Wind erosion of unconsolidated stockpiles (structural fill, excess and unsuitable material) and freshly exposed areas
- Handling, transfer and storage of materials including the delivery and load out of spoil and structural fill
- Heavy earthwork operations such as excavation
- Construction of borrow pits, earthen pits, flare pits and water storage
- Hammering of concrete
- Drilling of wells (rotary drilling)
- Digging trenches for the installation of gas and water gathering lines, transmission pipelines and utilities, where buried underground
- Operation of temporary concrete batching plant facilities (if required).

2.3 Assessment approaches used for identified emissions to air

Based on the review of potential air emission sources outlined above, potential sources of air emissions from the GFD Project have been identified and are summarised in **Table 2**.

Due to the nature of the GFD Project, details of the infrastructure locations and equipment requirements will be determined as the development progresses, and as such the potential sources identified are representative of plant and equipment that may be required. In addition, as noted previously, the emission sources and types of emissions listed in **Table 2** already occur as a result of the currently approved activities within the Arcadia, Fairview, Roma and Scotia gas fields. The GFD Project would only result in an incremental increase in the quantity and geographical spread of those emissions in the event that infrastructure development and activities are undertaken in parallel.

Table 2 Summary of identified emissions to air and assessment methodologies

Potential Air Pollutants	Sources of Emissions			Assessment Methodology
	Construction Phase	Operations Phase	Decommissioning Phase	
Particulate matter (PM)	Clearing, topsoil removal, earthworks Vehicles, trucks and other mobile equipment Concrete batching plants	Vehicle movements on unpaved roads Wind erosion of disturbed soils	Rehabilitation activities such as grading and topsoil spreading Vehicles, trucks and other mobile equipment Demolition activities (possibly including blasting)	Emissions of particulate matter have been assessed qualitatively. Quantitative assessment of particulate emissions from vehicles travelling on unpaved roads is subject to an extremely high level of uncertainty. These emissions are most appropriately managed through the implementation of appropriate planning and mitigation measures.
Oxides of nitrogen (NO_X) Carbon monoxide (CO) Volatile organic compounds (VOCs)	Vehicles, trucks and other mobile equipment	Gas-fired turbine compressors, alternators and TEG reboilers Reciprocating engines at wellheads Flares Vehicles, trucks and other mobile equipment	Vehicles, trucks and other mobile equipment	An atmospheric dispersion modelling has been performed to assess local impacts of NO_X and CO emissions from gas compression facilities for three scenarios: • a nominal large integrated hub gas compression facility (240 TJ/day) – normal operations • a nominal large integrated hub gas compression facility (240 TJ/day) – major flaring event • a typical nodal gas compression facility (80 TJ/day). The modelling study was performed using the AUSPLUME dispersion model and a series of four meteorological files representative of a range of locations across the project area. Non-methane VOC emissions from gas compression facilities will be minor and have been assessed qualitatively. Emissions of NO_X, CO and VOCs from traffic emissions have been assessed qualitatively based on the projected maximum increase in vehicle numbers relative to existing traffic levels.
Sulfur dioxide (SO_2)	Diesel-fired vehicles, trucks, generators and other equipment	Diesel-fired backup generators, pumps and other stationary equipment Diesel-fired vehicles, trucks and other mobile equipment	Diesel-fired vehicles, trucks, generators and other equipment	Emissions of SO_2 from diesel-fired vehicles and other equipment will be minor and have been assessed qualitatively.
Methane (CH_4)	Fugitive gas emissions during well construction or losses from infrastructure (valves, manifolds, pipelines, etc.)	Fugitive gas emissions Venting	N/A	Methane is a greenhouse gas and does not have the potential to give rise to impacts on local or regional air quality. These emissions are beyond the scope of the air quality impact assessment.
Odour	Sewage treatment plants at accommodation camps	Sewage treatment plants at worker accommodation camps	Sewage treatment plants at accommodation camps	Potential odour emissions will be highly localised to the source and be dispersed within the immediate environment; therefore odour-related nuisance impacts are not expected. Should Santos GLNG receive complaints related to odour, an odour impact assessment would be performed for the activity/facility of concern in accordance with the EHP guideline Odour Impact Assessment from Developments (EHP, 2013).

3 REGULATORY FRAMEWORK

3.1 National Environment Protection Measures

A national environment protection measure (NEPM) is legislation designed to protect particular aspects of the environment in a consistent way across state, territory and Commonwealth jurisdictions in Australia. The objectives of a NEPM are to ensure:

- that people enjoy the benefit of equivalent protection from air, water and soil pollution, wherever they live
- that decisions by businesses are not distorted and markets not fragmented by variations between jurisdictions in relation to the adoption or implementation of the NEPMs.

The *National Environment Protection (Ambient Air Quality) Measure* as varied 2003 (the AAQ NEPM) and its five schedules provide a framework and guidelines about standards and methods for monitoring ambient air quality across Australia. These standards cover seven common pollutants:

- PM_{10}
- $PM_{2.5}$
- ozone
- sulfur dioxide
- nitrogen dioxide
- carbon monoxide
- lead.

The objective of the *National Environment Protection (Air Toxics) Measure 2004* (the Air Toxics NEPM) and is to provide a nationally consistent approach to monitoring air toxics at a range of locations across Australia. The Air Toxics NEPM covers the following compounds:

- benzene
- benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons)
- formaldehyde
- toluene
- xylenes.

The ambient air quality standards set out in the AAQ NEPM and the Air Toxics NEPM have been adopted by the Queensland Government in the *Environmental Protection (Air) Policy 2008*, which is discussed below.

3.2 Environmental Protection (Air) Policy 2008

State air quality guidelines formulated by the Queensland Department of Environment and Heritage Protection (EHP) are published in the *Environmental Protection (Air) Policy 2008* (hereafter, EPP Air). The air quality objectives prescribed in Schedule 1 of the EPP Air (in micrograms per cubic metre ($\mu g/m^3$) and parts per million (ppm)) are shown in **Table 3** for the pollutants of concern in this study.

Table 3 EPP Air ambient air quality guidelines

Indicator	Environmental Value	Air Quality Objectives		Averaging Period	Allowable Exceedances
		$\mu g/m^3$ at 0°C	ppm		
NO_2	Health and wellbeing	250	0.12	1 hour	1 day/year
		62	0.03	1 year	None
	Health and biodiversity of ecosystems	33	0.016	1 year	None
CO	Health and wellbeing	11,000	9	8 hours	1 day/year
PM_{10}	Health and wellbeing	50	-	24-hours	5 days/year
$PM_{2.5}$	Health and wellbeing	25	-	24-hours	
		8	-	Annual	

Section 9 of the EPP Air states:

To the extent that it is reasonable to do so, air emissions must be dealt with in the following order of preference -

*(a) firstly - **avoid**;*

Example for paragraph (a) - using technology that avoids air emissions

*(b) secondly - **recycle**;*

Example for paragraph (b) - re-using air emissions in another industrial process

*(c) thirdly - **minimise**;*

Example for paragraph (c) - treating air emissions before disposal

*(d) fourthly - **manage**.*

Example for paragraph (d) - locating a thing that releases air emissions in a suitable area to minimise the impact of the air emissions

An assessment of how the proposed emission control processes accord with the management hierarchy for air emissions in the EPP Air is provided in **Section 7**.

3.3 Source emission standards

There are no source emission standards set in Queensland, instead the in-stack limits specified in the New South Wales (NSW) *Protection of the Environment Operations (Clean Air) Regulations 2010* are often used as guidance by the EHP. The relevant limits set for NO_X and CO emissions from new plant under Schedule 4 '*Standards of concentration for scheduled premises: general activities and plant*' (in milligrams per cubic metre (mg/m^3) are shown in **Table 4.**

Table 4 Relevant NSW emission standards for gas combustion sources

Pollutant	Activity or Plant	Stack Concentration Limit *
Nitrogen dioxide (NO_2) or nitric oxide (NO) or both, as NO_2 equivalent	Any turbine operating on gas, being a turbine used in connection with an electricity generating system with a capacity less than 30 MW	70 mg/m^3
	Stationary reciprocating internal combustion engines	450 mg/m^3
	Any boiler operating on gas	350 mg/m^3

* Dry, 273 K, 101.3 kPa, 3% O_2

3.4 Policy framework

The corporate Environment Policy sets out the environmental vision of the company to adopt the principles of sustainable development. To achieve this Santos GLNG has committed to:

To achieve this we will:

- Maintain and continuously improve the Environment, Health and Safety Management System across the organisation.
- Ensure that employees and contractors receive appropriate training to fulfil their individual Environment, Health and Safety Management System and environmental responsibilities.
- Proactively pursue the identification of hazards and eliminate or, if not practical, manage the risk to as low as reasonably practicable.
- Establish annual environmental objectives and targets and implement programs to achieve them.
- As a minimum comply with relevant legal and other requirements.
- Ensure that we have the resources and skills necessary to achieve our environmental commitments.
- Incorporate environmental performance in the annual appraisal of employees and contractors and recognise accordingly.
- Implement strategies to minimise pollution, manage waste effectively, use water and energy efficiently and address relevant cultural heritage and biodiversity issues.
- Formally monitor, audit, review and report annually on our environmental performance and Environment, Health and Safety Management System requirements against defined objectives.
- Require that companies providing contract services to Santos GLNG manage their environmental performance in line with this Policy.
- Steward the environmental performance of Joint Venture activities operated by others.

The Santos GLNG-wide Environment Health and Safety Management System provides a structured framework for effective environmental and safety practices across Santos GLNG's activities and operations. Under this system the issue of air quality is addressed through *EHS05: Air emissions*.

The purpose of EHS05 is to achieve compliance with applicable air quality guidelines thereby minimising potential for adverse impacts.

Key requirements of the EHS 05 include the following.

- New projects and modifications to existing facilities will be assessed during the design phase for potential air quality impacts.
- Where required, an atmospheric dispersion modelling study will be performed by appropriately qualified personnel using accepted modelling techniques to enable assessment against ambient air quality guidelines.
- Measures to minimise potential impacts will be incorporated into design and operating controls.
- The final design criteria will be approved by the relevant environmental adviser.
- Exceedences of criteria will require authority notification and actions to minimise environmental harm.
- Facilities will be operated to maintain acceptable levels of pollutants and emissions.
- Santos GLNG facilities that trigger reporting thresholds will report their emissions of relevant substances to the National Pollutant Inventory on an annual basis.
- Odour emissions will be managed to avoid environmental nuisance.

In addition, *EHS 01: Land Disturbance* requires that environmental impact is minimised during land disturbance activities which may be associated with construction and decommissioning and rehabilitation works.

3.5 Post-EIS field planning and development process

The constraints approach is based upon the *GFD Project environmental protocol for constraints planning and field development* (Constraints protocol) (Santos GLNG, 2014). The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to:

- Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation
- Support Santos' environmental policies and the General Environmental Duty (GED) as outlined in the *Environmental Protection Act 1994* (Qld) (EP Act)
- Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances
- Minimise cumulative impacts on environmental values.

The Constraints protocol details the process that Santos GLNG will use to identify, assess and manage potential impacts to the environment during field planning and development. This process has been successfully used for the approved GLNG Project, which increases the certainty of GFD Project environmental outcomes.

The general principles of the Constraints protocol, in order of preference, are to:

- Avoid — avoid direct and indirect impacts
- Minimise — minimise potential impacts
- Mitigate — implement mitigation and management measures to minimise adverse impacts
- Remediate and rehabilitate — actively remediate and rehabilitate impacted areas
- Offset — offset residual risk in accordance with regulatory requirements.

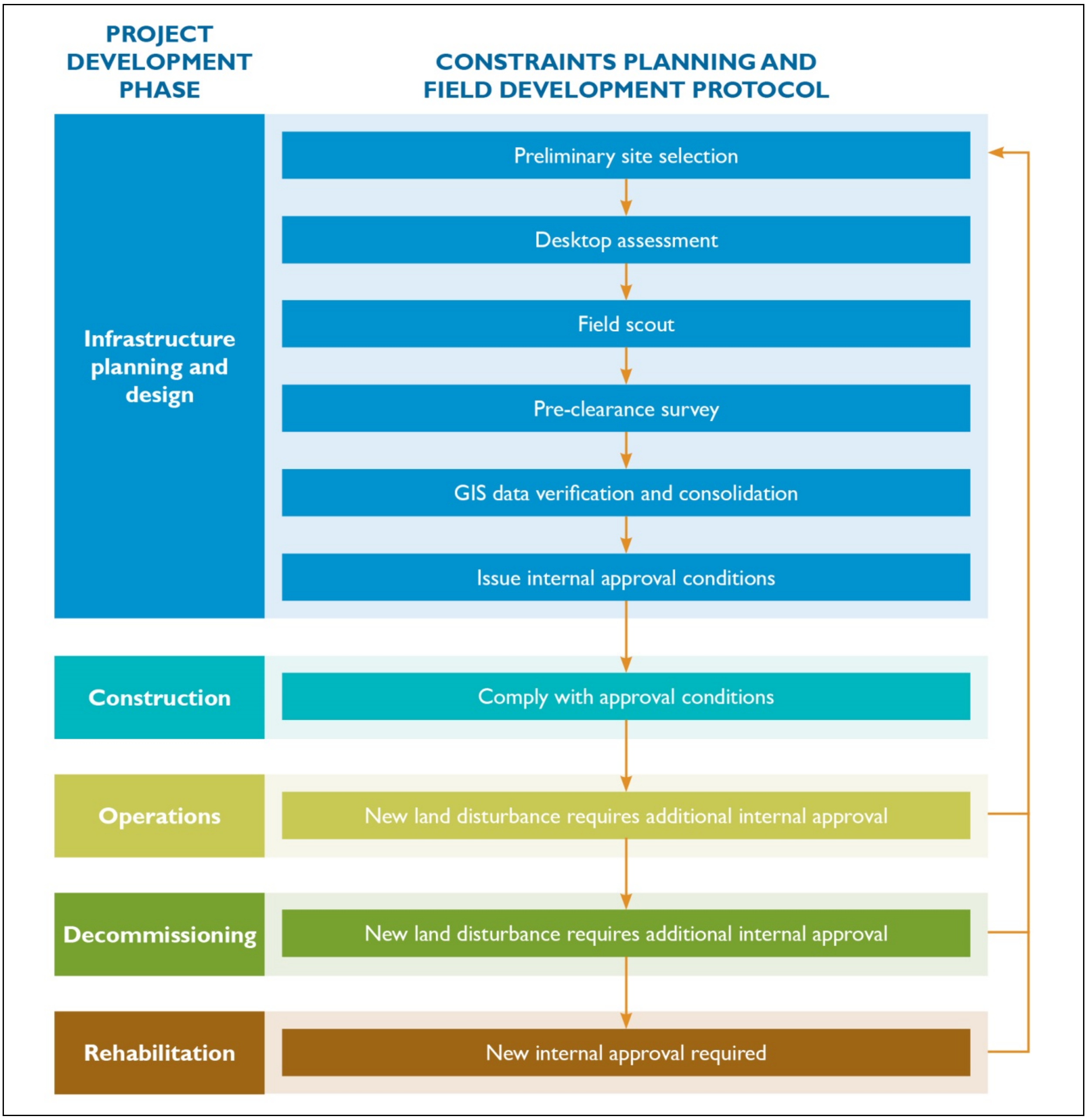
Consistent with Santos GLNG's environmental management hierarchy, the Constraints protocol prioritises avoidance of environmental impact during field planning by identifying those areas that are not amenable to development. This includes areas of high environmental value as identified in regulatory frameworks and Santos GLNG's baseline surveys. For areas that are considered appropriate to develop, Santos GLNG will identify impacts to environmental values that could potentially occur due to the construction, operations and decommissioning activities of the GFD Project, and determine pre-mitigated impacts (i.e. those that would occur without mitigation).

Relevant mitigation and management measures based on the approved environmental management framework already implemented for the GLNG Project are then applied to the pre-mitigated impacts to identify the mitigated (residual) impacts. This process increases certainty about potential impacts by identifying those areas that are not amenable to development, and for those areas where development could occur, how development should proceed.

The post-EIS field development process is a continuation of the field planning process and will be ongoing throughout the life of the GFD Project. The field development process will inform the GFD Project's design, together with a range of other factors including technical feasibility, cost and risk as required by standards applicable to the design, construction, operations, decommissioning and rehabilitation of gas developments. This information will be used to support the subsequent approvals process such as environmental approval application and the plan of operations.

The tasks involved in the field development process are summarised in **Figure 3.**

Figure 3 Field development process



4 EXISTING ENVIRONMENT

4.1 Climate

The GFD Project area is defined by the tenures and possible supporting infrastructure area illustrated in **Figure 1.** In describing regional climate, the region is defined as the area including and surrounding the GFD Project area. To describe local climate, data was used from several meteorological observation stations operated by the Bureau of Meteorology (BoM) in the region (refer to **Figure 4)**.

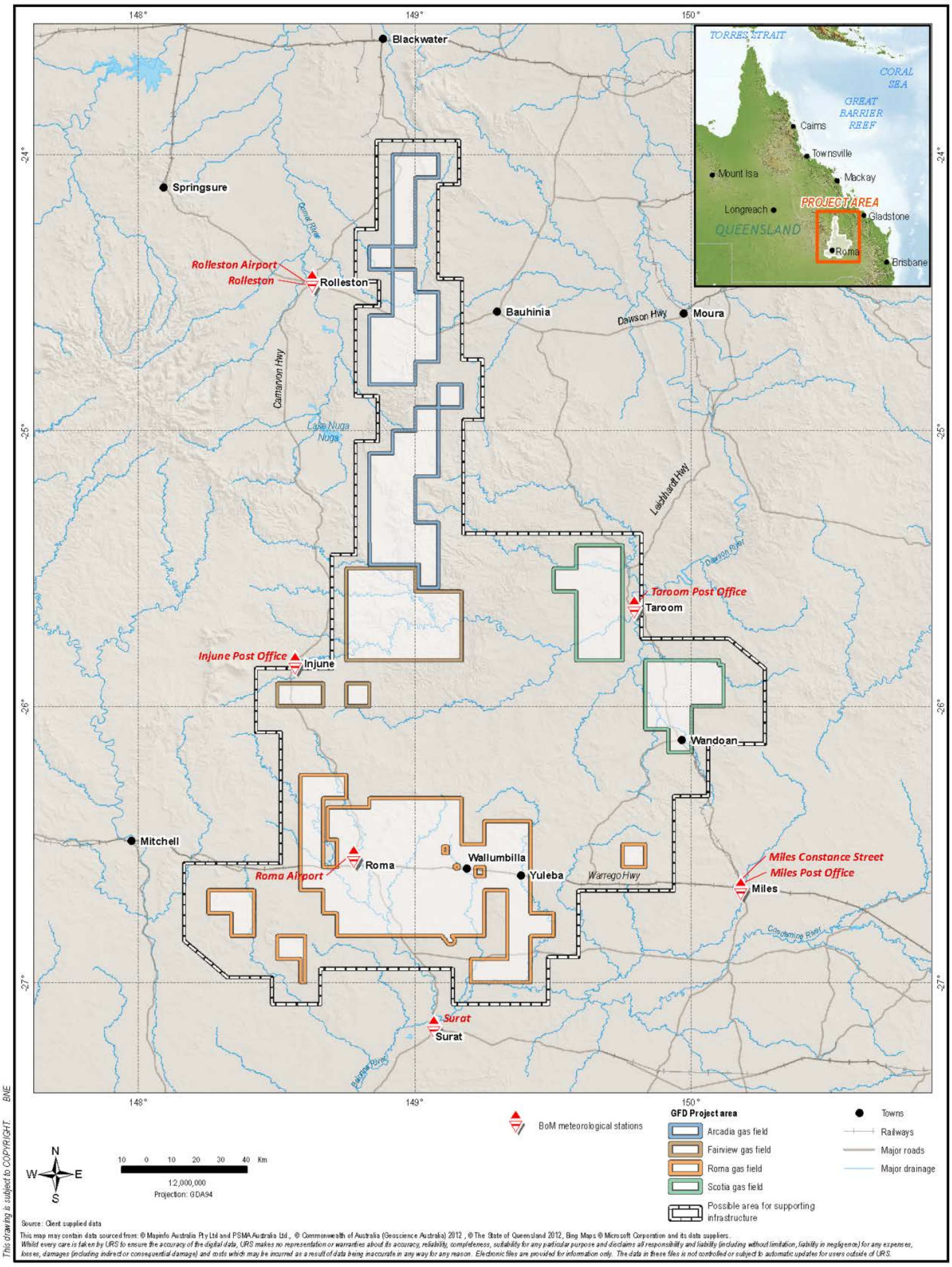
The climate of the region and GFD Project area is predominately sub-tropical. Late spring and summer is characterised by rainfall with an annual median of 540 to 675 millimetres (mm). Rainfall generally decreases from northwest to southeast and the majority of precipitation falls in the warmer months of the year (November to February). Mean maximum temperature ranges from 34.8 degrees Celsius (°C) in January to 19.3°C in July, and mean minimum temperatures range from 22.2°C in January to below 3.1°C in July. The highest annual mean temperatures (approximately 24°C) can be found in the north of the region. Heatwave conditions can be expected between November and February and frosts between June and August.

Annual wind roses for the meteorological stations located in Miles, Roma and Rolleston are presented in **Figure 5**. The wind roses show the frequency of occurrence of winds by direction (degrees from north) and wind speed in metres per second (m/s). The bars correspond to the 16 compass points – north (at 0°), NNE (at 22.5°), NE (at 45°), etc. The bar at the top of each wind rose diagram represents winds blowing from the north (i.e., northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds. Thus it is possible to visualise how often winds of a certain direction and strength occur over a long period, either for all hours of the day, or for particular periods during the day.

The annual windroses presented in **Figure 5** show that wind patterns vary across the GFD Project area, with the winds in the southern areas (Miles and Roma) predominantly blowing from the north and northeast quadrant, and winds in the northern area (Rolleston) predominantly blowing from the south and south-southeast. Wind speeds are noticeably higher at Roma compared to Miles and Rolleston.

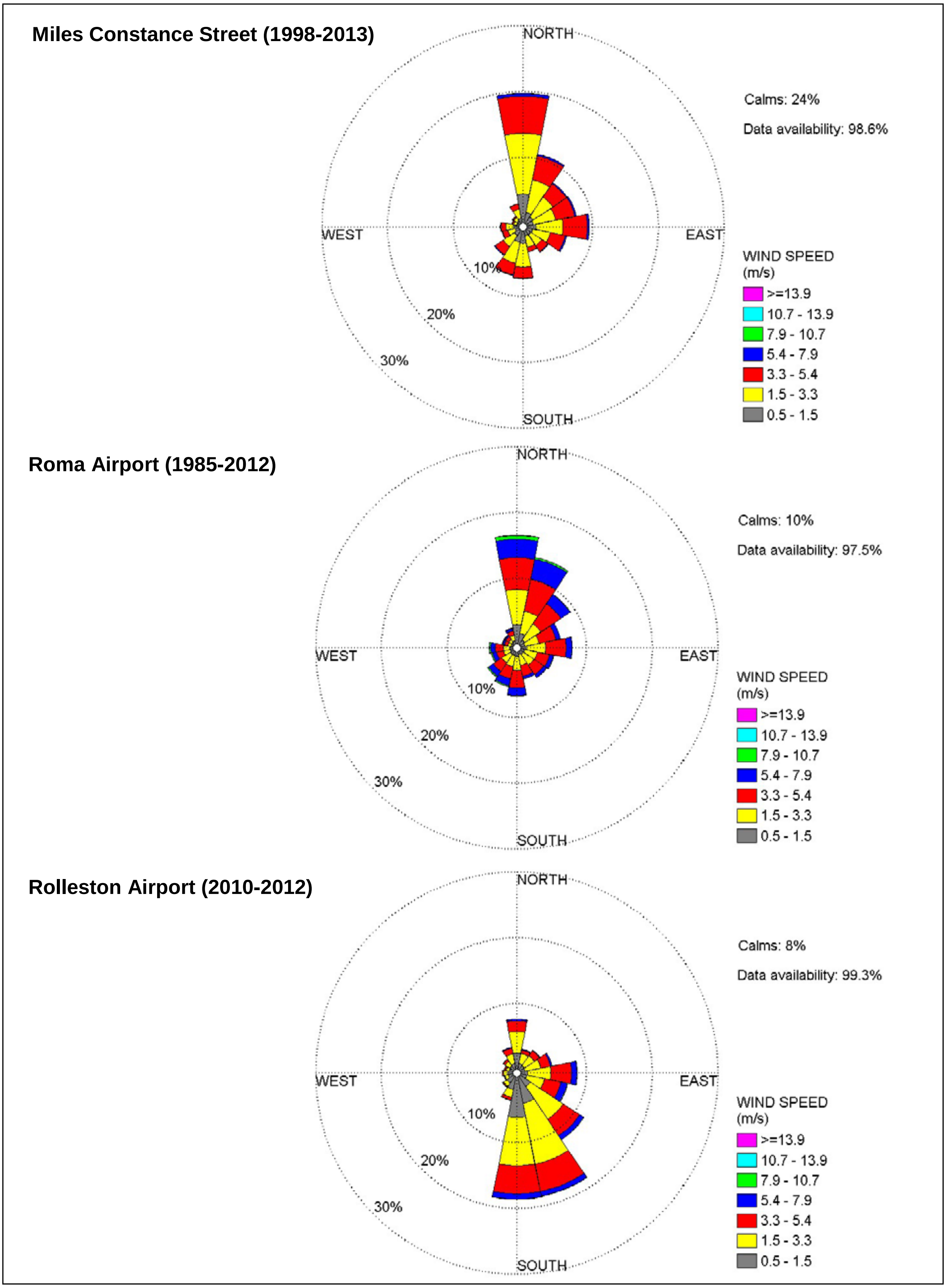
A detailed discussion of the meteorological data used in the air dispersion modelling study performed as part of this assessment is provided in **Section 5.1**.

Figure 4 Meteorological station locations



SOURCE: URS, 2014; File No. 42627064-g-2019.mxd

Figure 5 Long term wind data recorded by meteorological stations in the region



SOURCE: Bureau of Meteorology, 2012. *Climate and past weather*. http://www.bom.gov.au/climate/. Accessed 28 June 2013

4.2 Background air quality

To predict potential cumulative air quality impacts, it is necessary to quantify and characterise the existing ambient air quality environment.

4.2.1 Fairview and Roma ambient air quality monitoring program

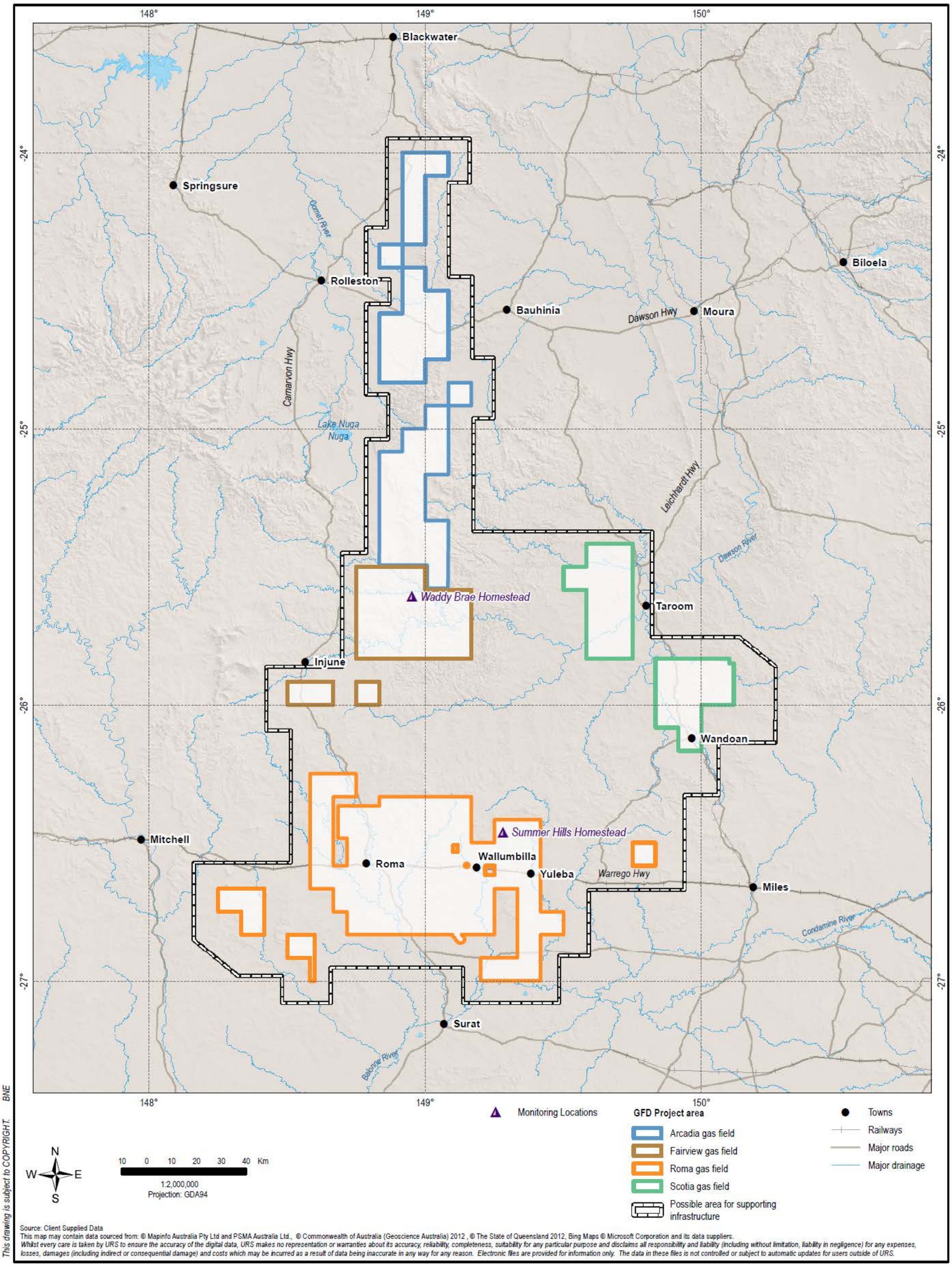
Santos GLNG has recently installed two ambient air quality monitoring stations to collect representative ambient air quality data for their upstream gas extraction and processing activities in these areas. The approximate locations of the proposed monitoring locations are shown in **Figure 6**.

The monitoring stations will operate for a period of at least six months, and will measure and record:

- Ambient concentrations of oxides of nitrogen (NO_X) using a continuous Thermo 42i NO-NO_2-NOx chemiluminescent analyser
- Ambient concentrations of carbon monoxide (CO) using a continuous non-dispersive infra-red (NDIR) analyser
- Monthly average VOC concentrations using passive diffuse samplers
- Wind speed and wind direction at three metres above ground level.

As they have only recently been commissioned, no data are currently available from these monitoring stations. Hence the assessment of background air quality has been performed based on a review of regional air quality monitoring data and a background dispersion modelling study as described below.

Figure 6   Locations of air quality stations installed in Fairview and Roma



SOURCE: URS, 2014; File No. 42627064-g-2044.mxd

4.2.2 Regional ambient air quality monitoring network

The EHP operates a number of ambient air quality monitoring locations around Queensland to monitor air quality and ensure compliance with air quality goals. The nearest EHP air quality monitoring location to the GFD Project was the Toowoomba air quality monitoring station which was located approximately 330 km east-southeast of Roma. This station collected data from July 2003 until December 2010 when it was damaged in a major flooding event. The monitoring location was surrounded by light industry and residential areas, and has been used to provide a conservative estimate of background air quality in previous air quality assessments for upstream gas extraction and processing projects in the Surat Basin.

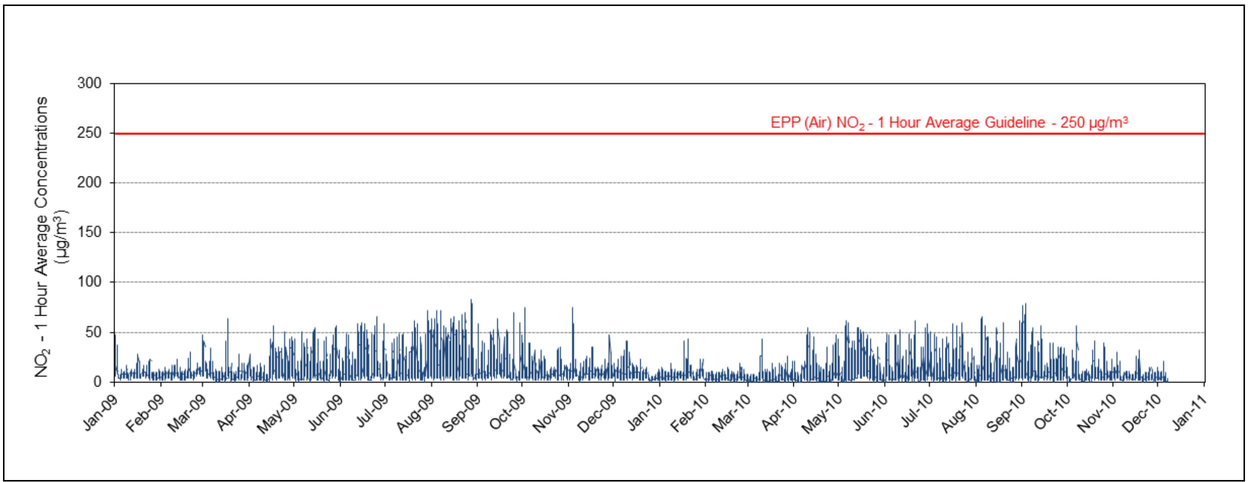
The air pollutants measured at Toowoomba included O_3, NO, NO_2, NO_X, CO and PM_{10}. Data collected by the Toowoomba air quality monitoring station in 2009 and 2010 are summarised in **Figure 7**, **Figure 8** and **Figure 9**.

The 1-hour average NO_2 concentrations recorded at Toowoomba (refer **Figure 7**) generally vary between 0-75 µg/m^3, which is well below the EPP Air guideline of 250 µg/m^3. The 2009 and 2010 annual average concentrations were 11.4 µg/m^3 and 9.2 µg/m^3 respectively.

The maximum CO 8-hour average concentration recorded at Toowoomba in 2009 and 2010 (refer **Figure 8**) was 2,100 µg/m^3 recorded on 27 August 2009. This is significantly less than the EPP Air guideline of 11,000 µg/m^3.

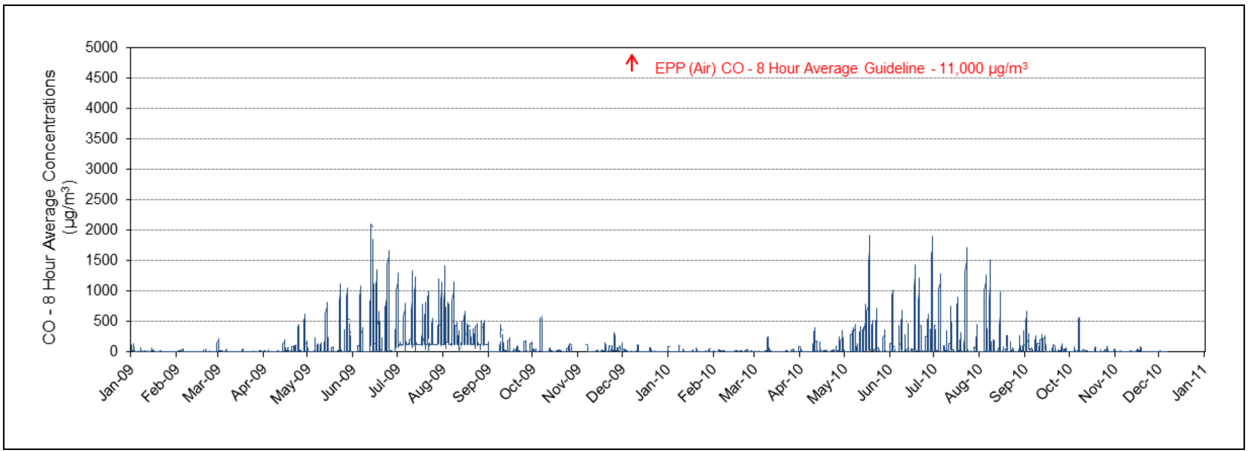
The 24-hour average PM_{10} concentrations recorded at Toowoomba in 2009 and 2010 (refer **Figure 9**) generally vary between 0-25 µg/m^3, which is below the EPP Air guideline of 50 µg/m^3. A dust storm swept across the Australian states of New South Wales and Queensland from 22 to 24 September 2009, with a maximum 24-hour average concentration of 1,131 µg/m^3 recorded at Toowoomba on 23rd September.

Figure 7 Toowoomba – NO_2 1-Hour average concentrations (2009-2010)



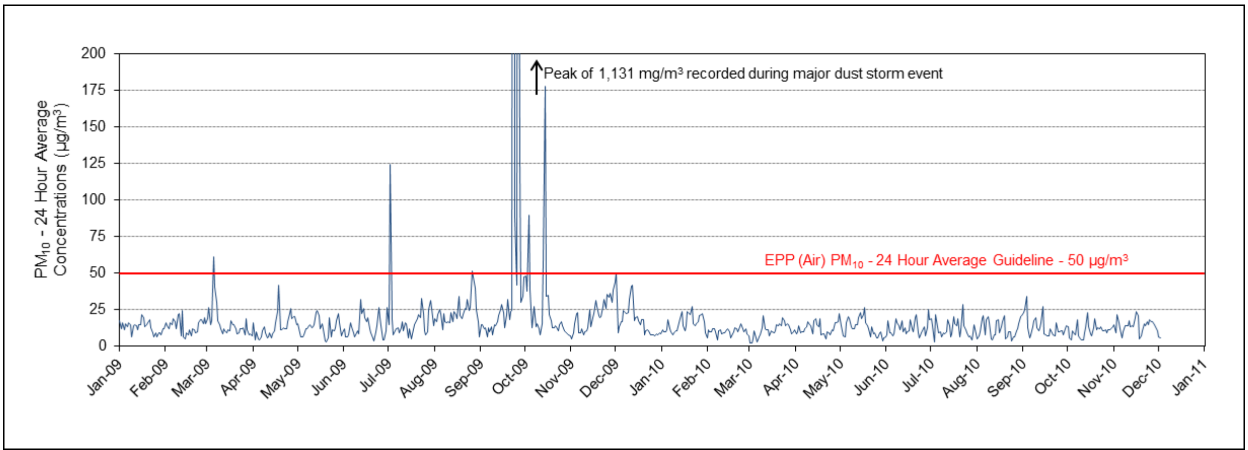
Note: In December 2010, the Toowoomba monitoring station was damaged in a major flooding event, and no data is available after this time

Figure 8 Toowoomba – CO 8-Hour average concentrations (2009-2010)



Note: In December 2010, the Toowoomba monitoring station was damaged in a major flooding event, and no data is available after this time

Figure 9 Toowoomba – PM_{10} 24-Hour average concentrations (2009-2010)



Note: In December 2010, the Toowoomba monitoring station was damaged in a major flooding event, and no data is available after this time

4.2.3 Modelling of background sources in the GFD Project area

As the Toowoomba monitoring station was located some distance from the GFD Project area, in a much more urbanised area (with significantly different source emissions), and data is no longer being collected from this station, modelling has been performed to provide a more representative estimate of background NO_X and CO concentrations within the GFD Project area. This modelling included NO_X and CO emissions from existing and approved power stations, gas extraction activities, coal mines and other major industry in the region. The modelling was performed using CALPUFF as described in **Section 5**.

Background particulate emissions were not modelled for the following reasons:

- The dominant source of regional background particulate levels will be wind erosion of bare soils agricultural activities, vehicle traffic on unpaved roads and mines. These fugitive sources are difficult to characterise or quantify and are highly variable and seasonally dependant.
- As discussed in **Section 2**, particulate emissions associated with the GFD Project primarily relate to fugitive emissions during construction and rehabilitation activities, with negligible emissions of particulate matter anticipated to occur as a result of operational activities. The potential impacts associated with these emissions have been assessed qualitatively and a detailed modelling assessment has not been performed.

The emission data used in the background NO_X and CO modelling was collated using data from the NPI for the 2011/12 reporting year and publicly available air quality impact assessments for industrial developments, including other gas-related projects, in the region.

A summary of the model inputs is provided in **Appendix A** while charts showing the relative contribution of each major source type to air emissions within the modelling domain are presented in **Figure 10.** As shown in **Figure 10**, coal power stations were the main source of NO_X emissions during 2010/2011, while mines and quarries were the main source of CO emissions. The source group “Santos Facilities” includes emissions from two reporting facilities; ‘Scotia’ and ‘Fairview Coal Seam Methane Field’.

Figure 11, **Figure 12** and **Figure 13** present contour plots of the peak 1-hour and annual average NO_2 concentrations and maximum 8-hour average CO concentrations predicted across the GFD Project area, which is further divided into gas field domains for the purpose of modelling. These plots also show the locations of the emission sources considered in the modelling. As indicated by these plots, the annual average NO_2 concentrations and 8-hour average CO concentrations are predicted to be well below guideline levels across the modelling domain. The peak 1-hour average NO_2 concentrations vary significantly across the modelling domain and elevated concentrations are predicted in localised areas surrounding some of the more significant sources.

Figure 10 Contributors to background NO_2 and CO emissions in the modelling domain

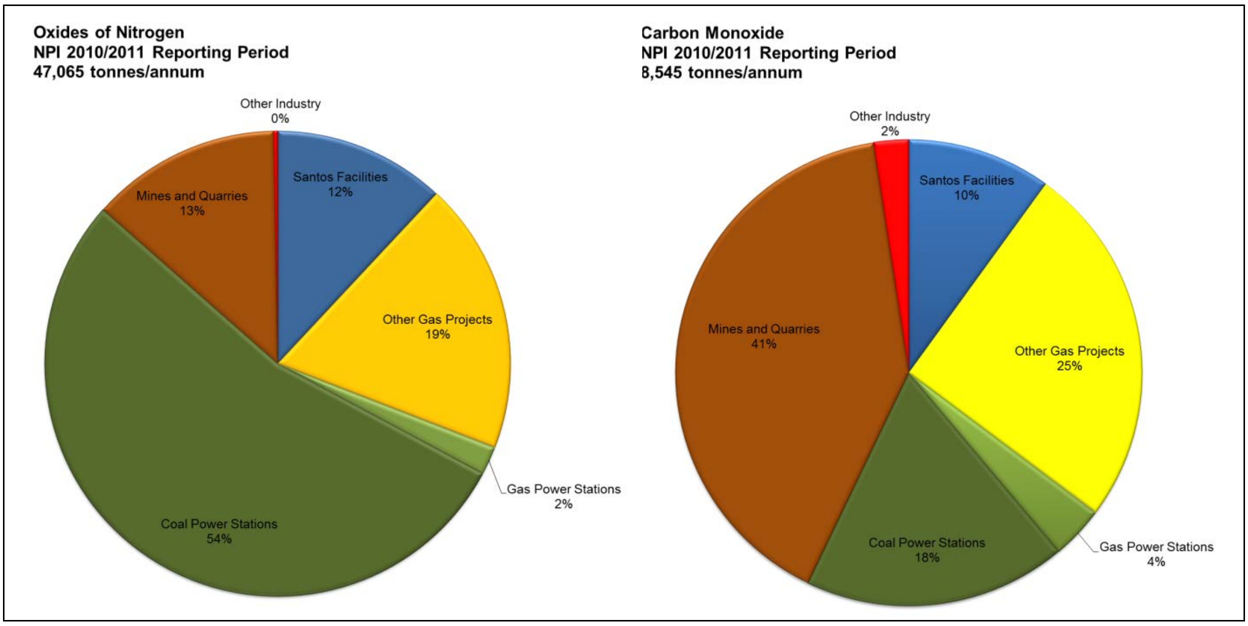


Figure 11 Peak 1-hour average NO_2 concentrations predicted for background sources

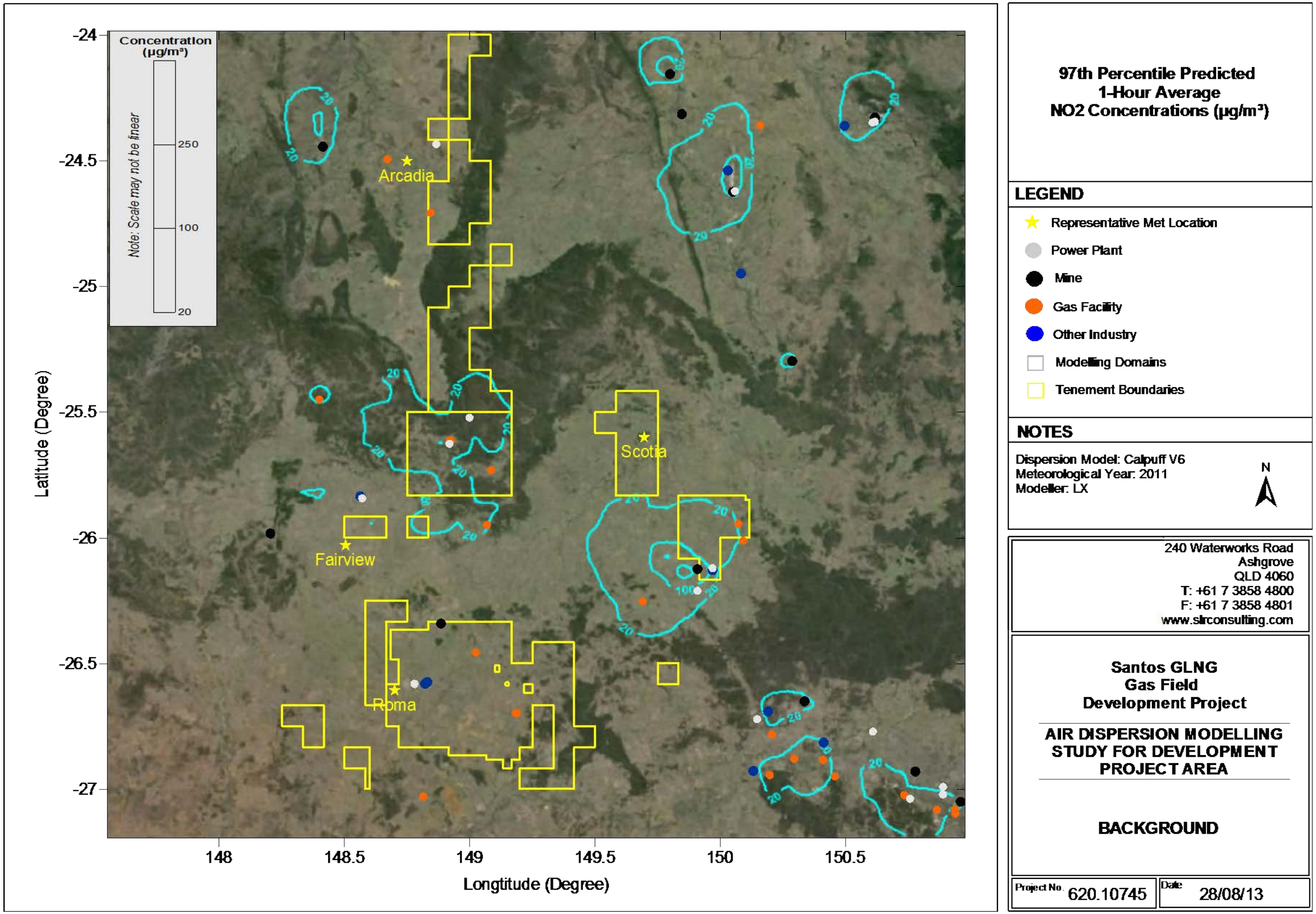


Figure 12 Annual average NO_2 concentrations predicted for background sources

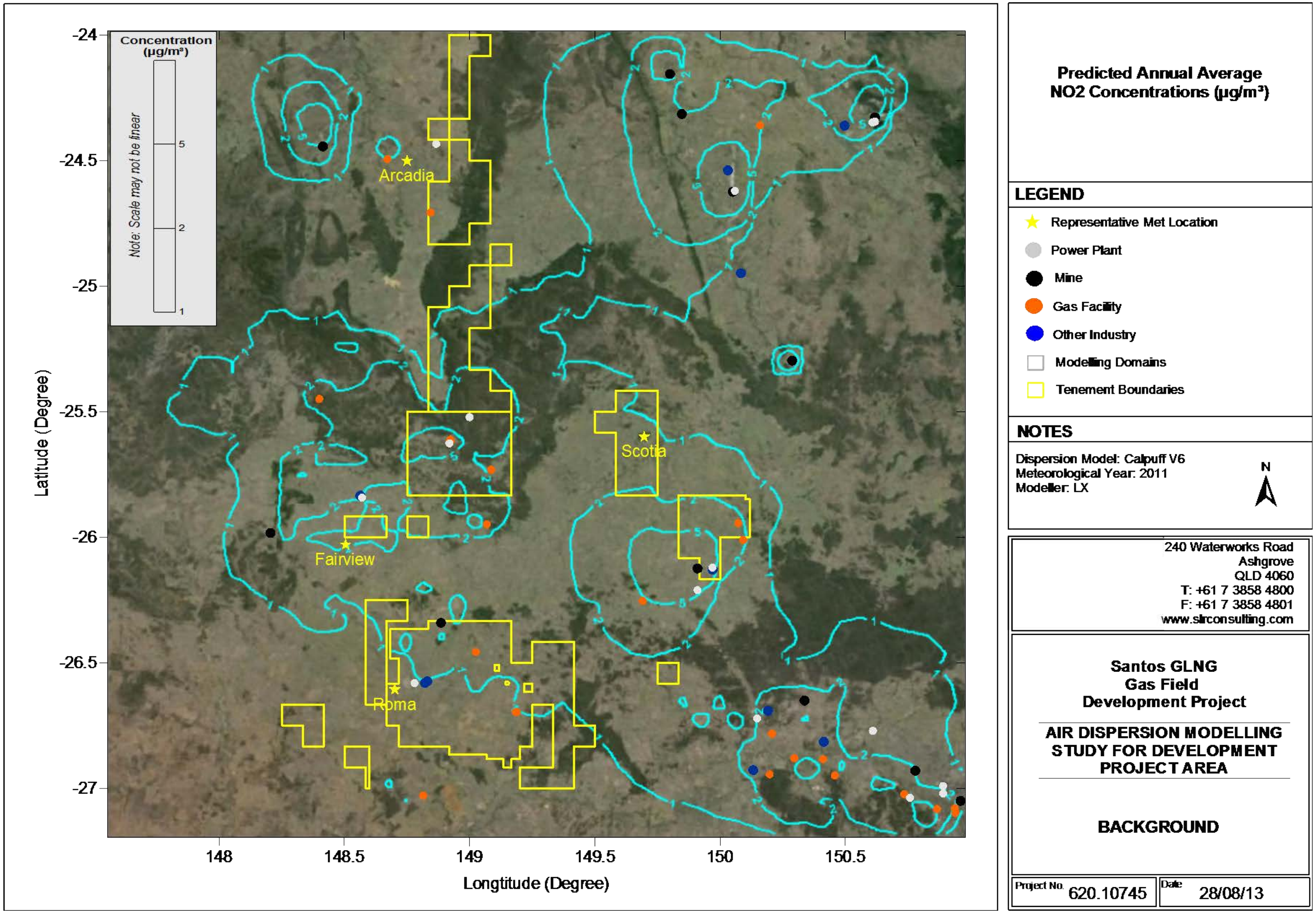
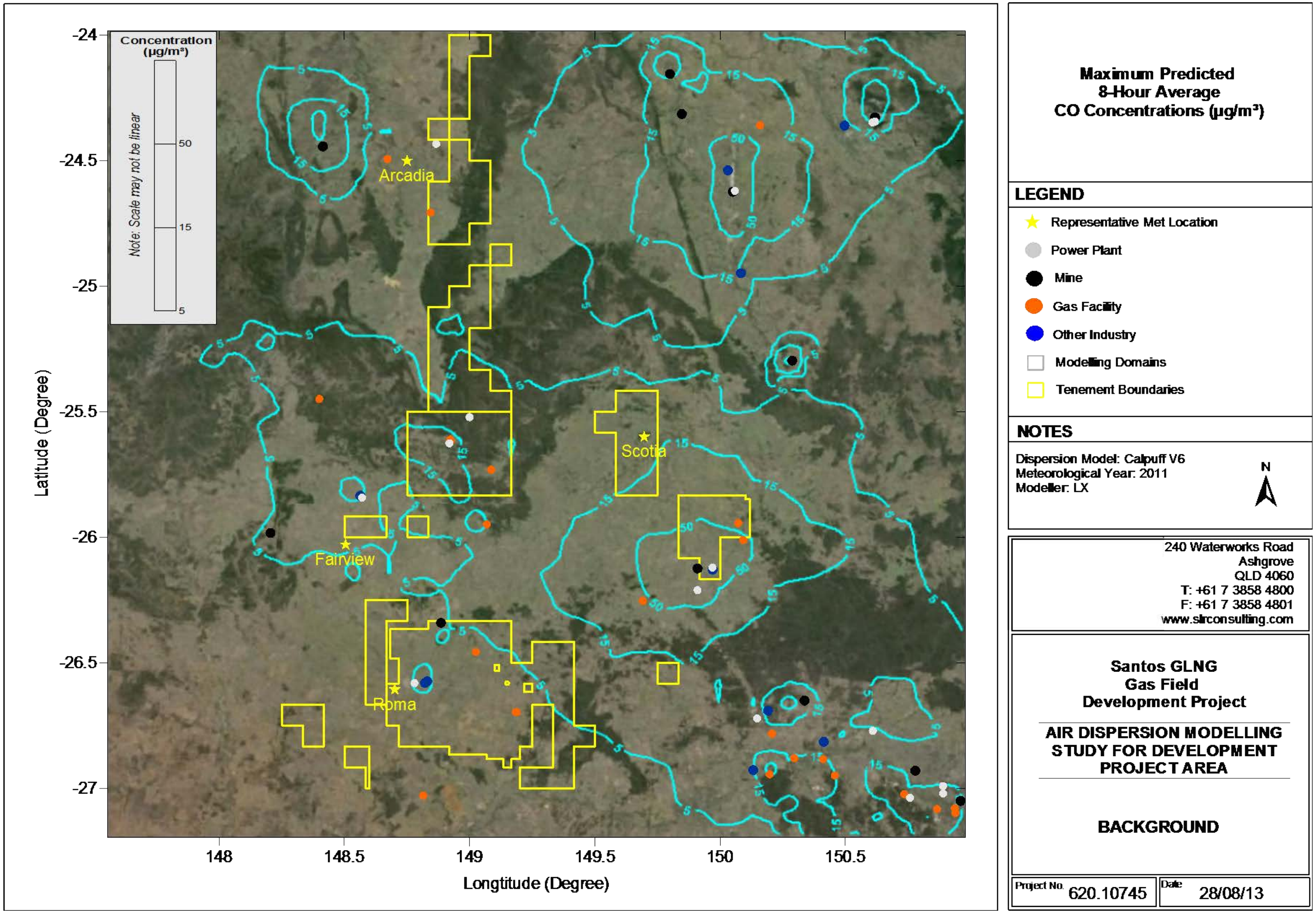


Figure 13 Maximum predicted 8-hour average CO concentrations from background sources



4.2.4 Background concentrations used in this assessment

In order to provide estimates of background NO_2 and CO concentrations for use in this assessment that are conservative, yet more representative of the study area than the historic Toowoomba data, the worst case ground level NO_2 and CO concentrations predicted by the modelling within the proposed areas for future gas compression facilities (i.e. within the blue and pink shaded areas in **Figure 1**) have been identified. These predictions are shown in **Table 5**.

This table shows that the background 8-hour average CO concentrations predicted across the gas field domains are far below the relevant guideline. The peak 1-hour NO_2 concentrations and annual average NO_2 concentrations in Fairview, Arcadia and Roma gas field are also low compared to the relevant guidelines. There are areas in the Scotia gas field, near Wandoan, that are predicted by the background modelling to experience more elevated NO_2 concentrations. These areas are close to existing sources, and in particular mines which have been modelled as low-level emission sources, and it is considered likely that the model predictions close to these sources are conservatively high. however they have been used as a worst case estimate of potential background concentrations.

Table 5 Estimated background NO_2 and CO concentrations in the GFD Project areas

Gas Field Domain	NO_2 Concentration ($\mu g/m^3$, assuming 100% NO_X in the form of NO_2)		CO Concentration ($\mu g/m^3$)
	1-Hour Average	Annual Average	8-Hour Average
Fairview	40	3	10
Arcadia	15	1	5
Scotia	120	10	200
Roma	17	5	8
Guideline	**246**	**33**	**11,000**

* Background 1-hour average NO_2 concentration conservatively estimated based on the maximum 97th percentile prediction within each gas field domain and assuming 100% conversion of NO to NO_2.

The maximum NO_2 concentrations predicted by the modelling close to existing emission sources is also expected to overestimate actual levels as the modelling assumes 100% of the background NO_X is in the form of NO_2. This conservative approach has been used because at a given location within the study area, the background NO_X concentrations will be a result of a mix of plumes from different sources. NO_X emitted by combustion sources typically comprises around 5-10% NO_2 with the majority of the gases being in the form of NO. Close to the source therefore, the NO_2/NO_X ratio is likely to be in the region of 30%. However, as the plume travels downwind, the NO reacts in the atmosphere to form additional NO_2, with this reaction occurring over a number of hours. To be conservative, the assumed background levels in the table are based on all NO_X being NO_2, or 100% conversion.

A comparison of the modelled background datasets with the levels measured at Toowoomba shows that the background modelling study predicts lower long-term average NO_2 concentrations in the project area than the levels measured at Toowoomba; however short-term concentrations in some areas can on occasion be elevated. The predicted CO concentrations are also lower than the levels measured at Toowoomba.

4.3 Sensitive receptors

The EPP Air is designed to protect human health and biodiversity of ecosystems and preserve amenity of land use. For the purpose of assessing potential air quality impacts, air quality sensitive receptors may include:

- dwellings
- library or educational institutions
- childcare centres or kindergartens

- schools or playgrounds
- hospitals, surgeries or other medical institution
- commercial and retail activities
- protected areas, or an area identified under a conservation plan under the *Nature Conservation Act 1992* as a critical habitat or an area of major interest
- parks or gardens that are open to the public
- agricultural land.

The approach used in this assessment has been to perform preliminary modelling of representative worst case and typical surface facilities to provide information on indicative maximum required separation distances from sensitive receptors for such facilities. When preferred locations for individual facilities are identified, and details of the required size and number of engines and other fuel-burning equipment are known, more detailed modelling will be performed to enable an assessment of the potential impacts at sensitive receptors (if relevant).

5 MODELLING METHODOLOGY

As noted previously, the locations of the future major facilities within the GFD Project will be identified as the GFD Project develops, hence detailed site-specific modelling cannot be performed at this stage. The approach used in this assessment has therefore been designed to provide a conservative assessment of downwind impacts from:

- a nominal large (non-electrified) hub gas compression facility (240 TJ/day) – normal operations
- a nominal large (non-electrified) hub gas compression facility (240 TJ/day) – major flaring event
- a typical (non-electrified) nodal gas compression facility (80 TJ/day) – normal operations.

The results of this modelling can be used to assess the potential for exceedances of the compliance criteria and, if applicable, identify mitigation measures that may be required such as minimum separation distances from sensitive receptors that would potentially be required for such facilities. As preferred locations for individual facilities are identified, and details of the required size and number of engines and other fuel-burning equipment are known, more detailed modelling would be performed to enable site-specific factors such as the surrounding topography and land use to be accounted for in the modelling to quantify the impacts of these factors of the predicted downwind concentrations.

Details of the methodology used in the modelling study are provided in the following sections.

5.1 Meteorological modelling

5.1.1 TAPM

The dispersion model AUSPLUME requires a meteorological input data file containing information on wind speed, wind direction, fluctuation of the wind direction (sigma theta), air temperature, atmospheric stability class and mixing layer heights.

The TAPM Version 4.0 prognostic model, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to generate the upper air data required for CALMET modelling.

TAPM model predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program 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 1 full year of 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. Five BoM stations observational data were assimilated into the TAPM model run. **Table 6** details the parameters used in the TAPM meteorological modelling for this assessment.

Table 6 Meteorological Parameters used for this Study - TAPM

TAPM (v 4.0)	Parameters Used
Number of grids (spacing)	4 (30 km, 10 km, 3 km and 1 km)
Number of grid points	30 x 30 x 35
Year of analysis	2011
Centre of analysis	746,096 m E 7,168,185 m S
Data assimilation	BoM Stations: Roma Airport, Rolleston Airport, Miles Constance Street, Gayndah Airport, Gladstone Airport

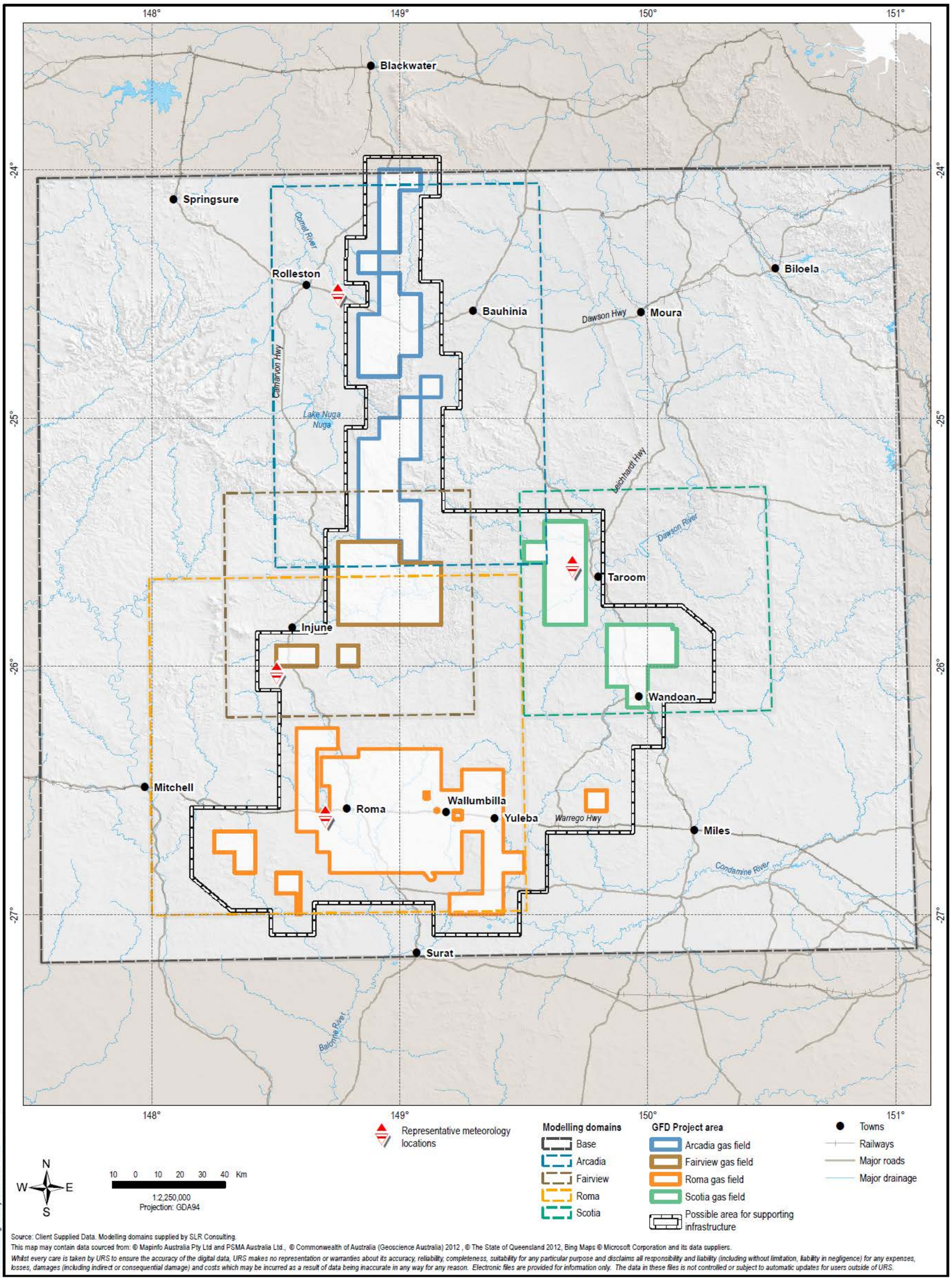
5.1.2 Meteorological modelling - CALMET

Five separate CALMET model runs were configured for one outer coarse domain and four refined domains for each of the four adopted meteorological zones (Acacia, Fairview, Roma and Scotia gas fields) as shown in **Figure 14**. Refined meteorological modelling was performed using a grid spacing of 1 km. Representative locations (shown in **Figure 14**) within each modelling domain were then selected and an AUSPLUME meteorological data file was extracted from CALMET at each point. The coordinates of each meteorological dataset are as shown in **Table 7**.

Table 7 Coordinates of meteorological files used in modelling

Meteorological File	Latitude	Longitude	Easting (m)	Northing (m)
Arcadia	-24.5005738	148.7505298	677,371	7,289,227
Scotia	-25.5994002	149.6967507	770,856	7,165,923
Fairview	-26.0288089	148.5052042	650,611	7,120,257
Roma	-26.6056854	148.7011692	669,381	7,056,111

Figure 14 Model domains used for meteorological modelling



SOURCE: URS, 2014; File No. 42627064-g-2045b.mxd

Note: Modelling is performed in Cartesian units (i.e. UTM). Due to the curvature of the earth, when converted into geographic map projection GDA, the modelling domain appears slightly distorted.

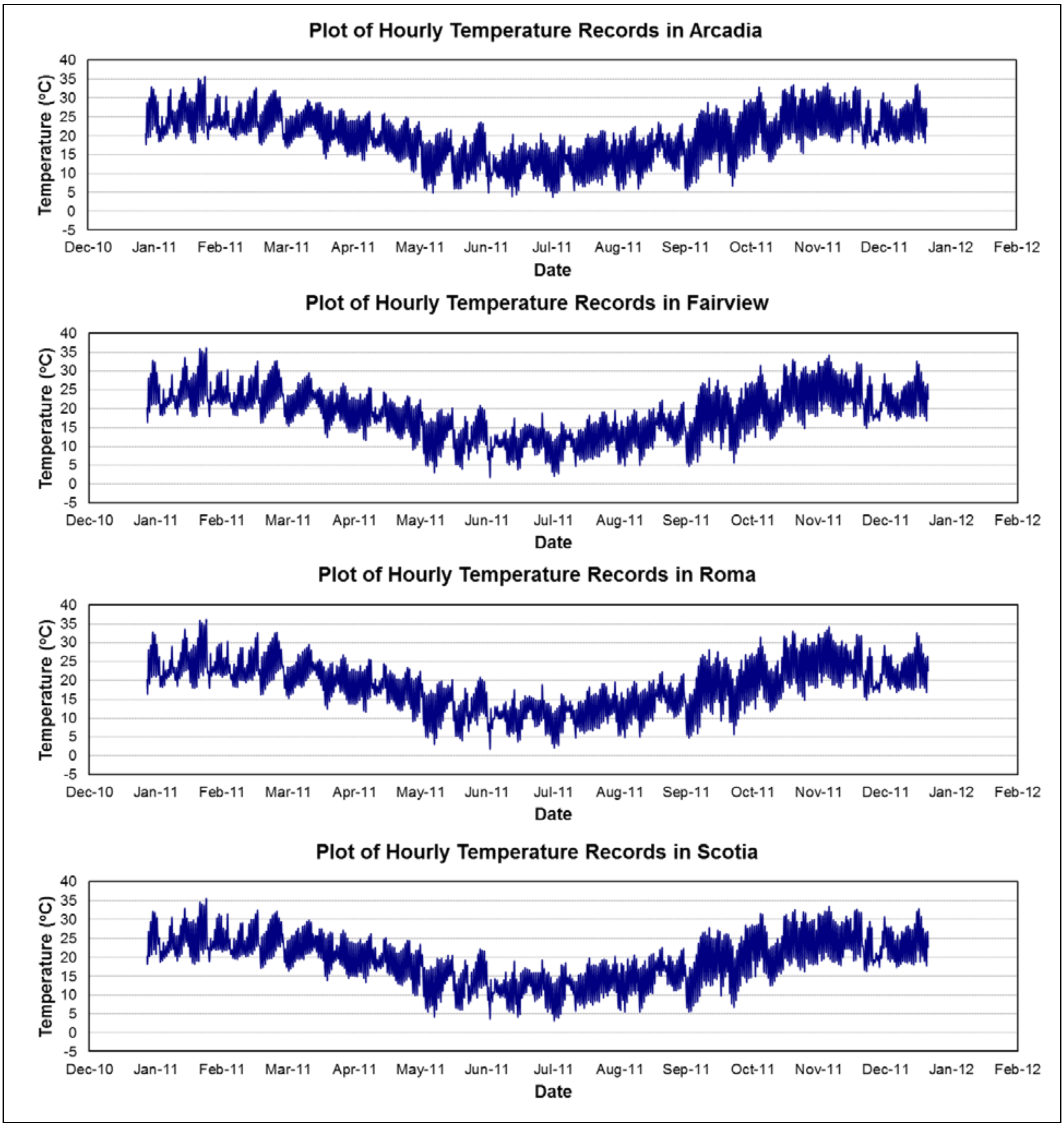
5.2 Meteorological data used in modelling

A summary of the key meteorological parameters contained within the four meteorological data files used in the modelling is provided in the following sections.

5.2.1 Temperature

A summary of the temperature profiles predicted for the four representative locations selected for meteorological modelling is shown in **Figure 15**. This plot shows that the temperature data given by the modelling for the four sites follow a similar pattern, ranging from just above 0°C in the winter to a maximum of approximately 37 °C in the summer.

Figure 15 Temperature profiles for the meteorological datasets used in AUSPLUME modelling



5.2.2 Wind speed and direction

A summary of the wind speed frequency distributions predicted by CALMET for the four representative locations selected for meteorological modelling is shown in **Figure 16**. The annual wind behaviour predicted for each location is presented as a wind rose in **Figure 17**.

Figure 16 indicates that in 2011 these four locations experienced predominantly light to moderate winds (between 1.5 m/s and 6 m/s). Calm wind conditions (wind speed less than 0.5 m/s) were predicted to occur less than 4% of the time at all locations during 2011.

The annual wind roses indicate that:

- In Arcadia, the wind predominantly blows from the southwestern quadrant (approximately 44% of the time).
- In Fairview, the wind predominantly blows from the eastern quadrant (approximately 28% of the time).
- In Roma, winds mainly blow from a north-northeasterly direction, with a frequency of approximately 32% of the time.
- In Scotia, winds predominantly blow from the east-southeastern quadrant, occurring approximately 33% of the time.

Figure 16 Wind speed frequency distribution plots for the meteorological datasets used in AUSPLUME modelling

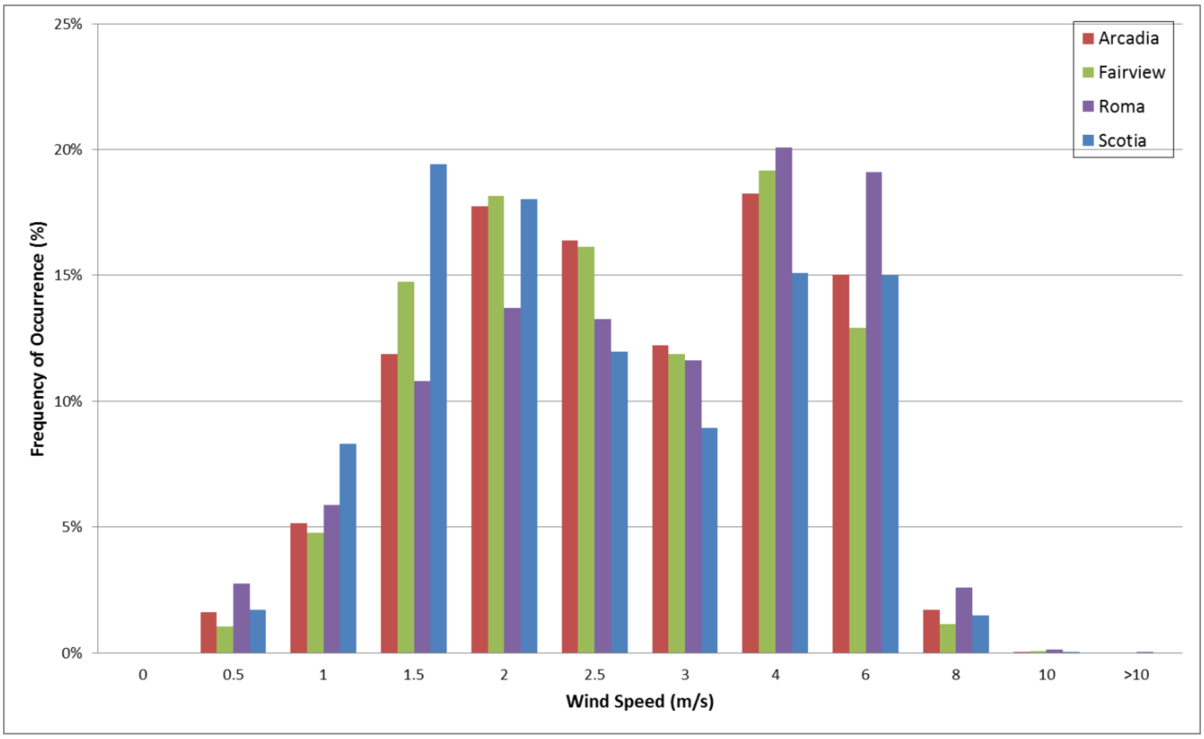
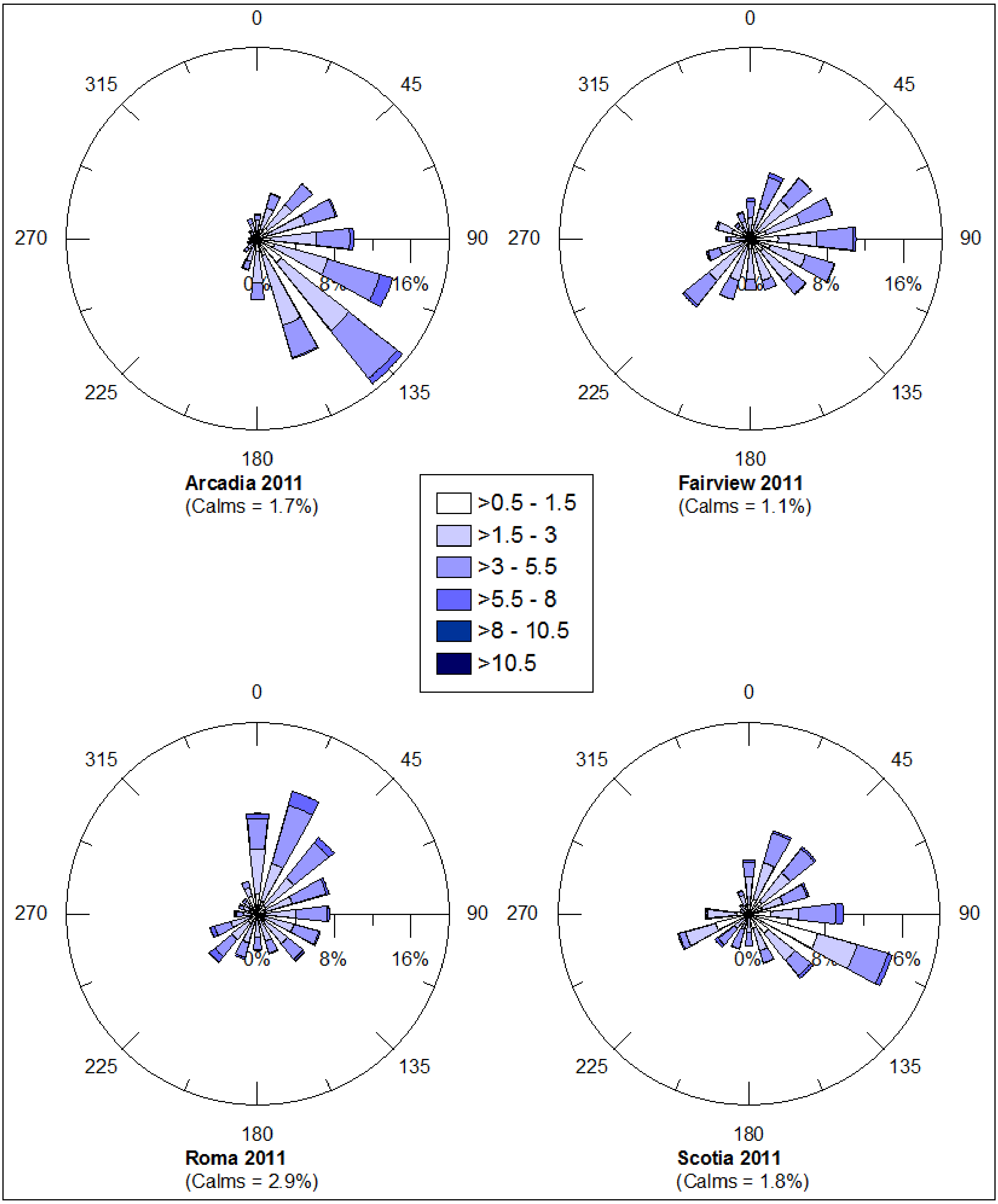


Figure 17 Annual wind roses for the meteorological datasets used in AUSPLUME modelling



5.2.3 Atmospheric stability

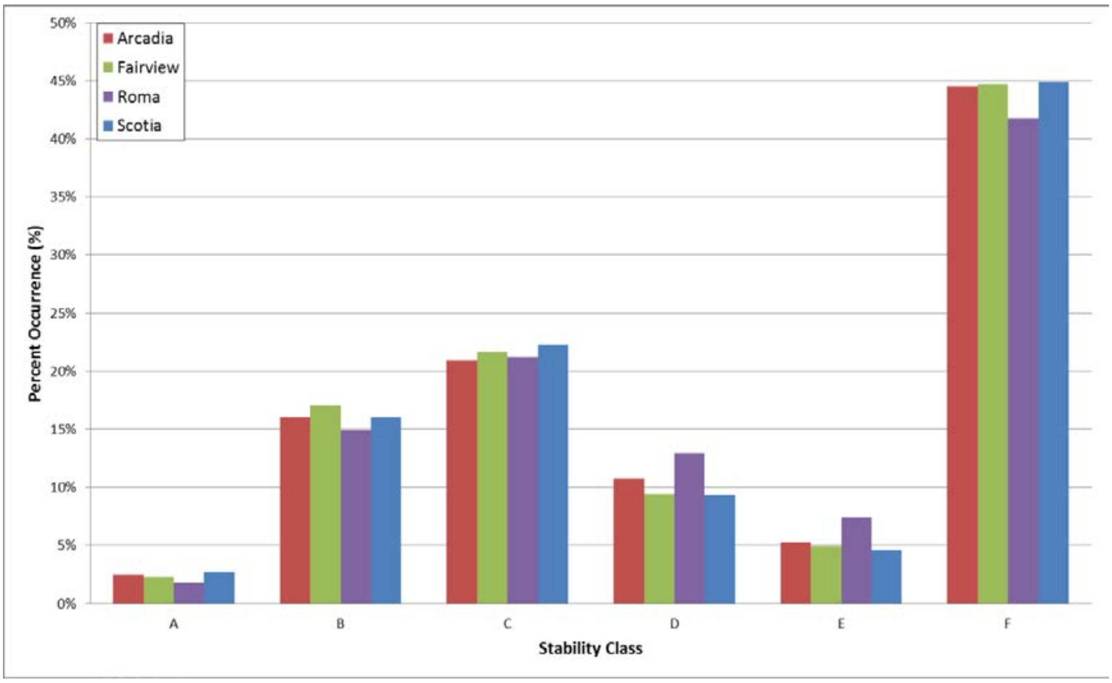
Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Turner assignment scheme identifies six Stability Classes, A to F, to categorise the degree of atmospheric stability (see **Table 8**). These classes indicate the characteristics of the prevailing meteorological conditions and are used as input into various air dispersion models.

The frequency of each stability class predicted by CALMET for the four meteorological datasets used in the modelling is presented in **Figure 18**. The results indicate a high frequency of conditions typical to Stability Class F at all four locations. Stability Class F is indicative of very stable night time conditions, conducive to a low level of pollutant dispersion due to mechanical mixing.

Table 8 Description of atmospheric stability classes

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

Figure 18 Stability class distributions for the meteorological datasets used in AUSPLUME modelling



5.3 Plume dispersion modelling - AUSPLUME

The AUSPLUME (v6.0) dispersion modelling computer package was used for the emissions modelling for the GFD Project. AUSPLUME is a Gaussian plume dispersion model, designed to predict ground level concentrations or the deposition of pollutants emitted from one or more sources.

The mathematical basis of AUSPLUME is the Victorian EPA's Plume Calculation Procedure (Victoria EPA 1986) which itself is an extension of the Industrial Source Complex (ISC) model.

To configure AUSPLUME a range of information is required, including source locations, pollutant emission rates, emission source characteristics (source release heights, diameters, velocities, ambient temperatures and source dimensions), terrain of the GFD Project area, dimensions of buildings that may cause building downwash, and meteorological information.

5.3.1 Stack and emission data

Large hub gas compression facility (240 TJ/day) – normal operations

Dispersion modelling has been performed for a nominal large hub gas compression facility, including:

- gas-fired compressors
- gas-fired power alternators
- gas-fired TEG reboilers
- flare (pilot and maximum emergency flaring scenarios both assessed).

Emissions from back-up diesel-fired power generators have not been assessed as they would operate intermittently and only when one or more of the gas-fired power alternators are not operating, and would only be used to maintain power to emergency systems and maintain communication to the facility. Emissions from these smaller back-up diesel-fired power generators would be lower than those from the gas-fired power generators; hence the operational scenarios modelled represent a worst-case scenario.

The NO_X and CO source emission rates and source characteristics used in the modelling are shown in **Table 8**. This information is based on supplier information provided for the new Fairview hub gas compression facilities (HCS-04 and HCS-05), and information provided by Santos GLNG on the numbers of each unit that would be required for a large integrated hub. Source locations within the footprint of the hub gas compression facility were modelled based on a nominal facility layout provided by Santos GLNG.

Table 9 Stack and emission data representative of a typical large integrated hub (240 TJ/day)

Process Unit	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (ºC)	NO_X Emission (g/s)	CO Emission (g/s)
Hub Compressor 1	10	1.8	36.3	565	1.56	0.3611
Hub Compressor 2	10	1.8	36.3	565	1.56	0.3611
Hub Compressor 3	10	1.8	36.3	565	1.56	0.3611
Hub Compressor 4	10	1.8	36.3	565	1.56	0.3611
TEG Reboiler 1	10	0.5	26.0	400	0.56	0.0014
TEG Reboiler 2	10	0.5	26.0	400	0.56	0.0014
TEG Reboiler 3	10	0.5	26.0	400	0.56	0.0014
Gas Turbine 1	12	1.8	36.3	565	1.56	0.3611
Gas Turbine 2	12	1.8	36.3	565	1.56	0.3611
Gas Turbine 3	12	1.8	36.3	565	1.56	0.3611
Gas Turbine 4	12	1.8	36.3	565	1.56	0.3611
TOTAL					**14.2**	**2.9**

m/s: metres per second; g/s: grams per second.

Large hub gas compression facility (240 TJ/day) – flaring

Operation of a flare at a gas compression facility would occur either in an emergency release situation or when a phased shutdown of the plant occurs such as for maintenance. During operation of the flare, the gas supply to the facility is shut down. This is done through a number of means, including throttling of gas supply into the facility or complete shutdown through closure of entry and exit valves at the gas compression facility.

Peak flaring only occurs for a period of 5-15 minutes with other compression and electricity generation plant effectively shut down. The flaring rate is regulated for a controlled depressurisation. However, based on the size of the plant, there is only a finite amount of gas in the plant. Some prolonged flaring may occur on start-up and commissioning but this is short-term and infrequent. Further, this would not occur with the other plant operating and the flows would be minimised as much as practical to limit lost revenue.

For the purposes of assessing potential worst case impacts associated with a maximum flaring scenario, a flaring rate 270 MMSCFD (million standard cubic feet per day) was used, which is consistent with a 240 TJ/day station capacity. Mass emissions of NO_X and CO were estimated based on this flaring rate and using emission factors of 1.5 grams per kilogram (g/kg) for NO_X and 8.7 g/kg for CO published in the National Pollutant Inventory (NPI) *Emission Estimation Technique Manual (EETM) for Oil and Gas Extraction and Production*, Version 2.0 (SEWPaC, 2013). A gas density of 0.729 kilograms per cubic metre (kg/m^3) was assumed based on data provided for other air quality assessments performed by SLR for Santos GLNG upstream facilities.

Emissions from flares are not assessed as a typical emission stack source, as flares operate with an exposed flame beyond the stack tip. To provide more representative emission release characteristics, an ‘equivalent’ stack height and stack diameter were calculated as follows (OEPA, 2003).

Equivalent stack height (H_{equiv}) is computed as a function of heat release:

$$H_{equiv} = H_{actual} + 0.944(Q)^{0.478}$$

Equivalent diameter (d_{equiv}) is calculated using:

$$d_{equiv} = 0.1755(Q)^{0.5}$$

where: Q = heat release value in million British thermal unit per hour (MMBTU/hr)
H_{actual} = 60 m

The flaring rate of 270 MMSFCD was converted to MMBTU using a lower heating value of 864 British thermal unit per cubic foot (BTU/ft^3) based on data provided for other air quality assessments performed by SLR for Santos GLNG upstream facilities.

In accordance with Ohio Environmental Protection Agency (OEPA, 2003) modelling was performed assuming temperature of 1,000ºC and a gas exit velocity of 20 m/s.

The data used to model flaring emissions is summarised in **Table 10.**

Table 10 Stack and emission data representative of an emergency flaring event (270 MSCFD)

Site	Equivalent Stack Height (m)	Equivalent Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (ºC)	NO_X Emission (g/s)	CO Emission (g/s)
Flare	136	17.5	20	1000	96.8	561.2

Note: data for flare represent the equivalent stack height and diameter for this source accounting for additional plume rise from heat generated in the flame. Calculation of equivalent stack height and stack diameter is explained above.

Field nodal gas compression facility (80 TJ/day)

While the worst-case scenario described above provides an assessment of maximum potential impacts on local air quality, this scenario is representative of a more typical facility. The NO_X and CO source emission rates and source characteristics used in the modelling for this facility are shown in **Table 11**. This information is based on stack and emission data for existing satellite nodal gas compression facilities within the Fairview project Area and information provided by Santos GLNG. Source locations within the footprint of the field nodal gas compression facility was modelled based on a nominal site layout provided by Santos GLNG.

Table 11 Stack and emission data representative of a satellite nodal compression facility (80 TJ/day)

Site	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (ºC)	NO_X Emission (g/s)	CO Emission (g/s)
Nodal Compressor 1	10	0.33	30.4	470	0.46	0.3611
Nodal Compressor 2	10	0.33	30.4	470	0.46	0.3611
Nodal Compressor 3	10	0.33	30.4	470	0.46	0.3611
Reciprocating Engine 1 [1]	10	0.20	9.7	573	0.53	0.3611
Reciprocating Engine 2 [1]	10	0.20	9.7	573	0.53	0.3611
TEG Reboiler 1	10	0.50	26.0	400	0.56	0.0014
TEG Reboiler 2	10	0.50	26.0	400	0.56	0.0014
TOTAL					**3.6**	**1.8**

1 Assumed 75 kW

5.3.2 Receptor locations

Ground level pollutant concentrations were estimated at receptors located along 22.5˚ vectors at a spacing of 100 m up to a distance of 5 km from the source. This receptor grid was used to assess the extent of dispersion and to provide estimates of predicted ground level impacts at increasing distances downwind.

5.3.3 Terrain effects

At this stage, the precise location of infrastructure associated with the GFD Project is unknown and therefore potential terrain influences cannot be included in the dispersion model. The windroses shown in **Figure 17** show that the four meteorological datasets used in the modelling have different predominant wind directions, reflecting the impact of local terrain features and katabatic drainage flows and these variations will be reflected in the results of the AUSPLUME modelling. The meteorological datasets were compiled for a range of locations spread across the gas fields and, given the generally uncomplicated topographical nature of the region, are expected to adequately represent the types of wind profiles that may occur across the project area.

Detailed asset-specific modelling would be performed as part of the siting and design phases for a gas compression facility or other infrastructure with the potential to burn more than 500 kg/hour of fuel.

5.3.4 Building wake effects

The BPIP (Building Profile Input Program) included in the AUSPLUME model was used to compile building height and width data so that building wake effects could be accounted for in the model. The dimensions of engine housings and the surrounding buildings for large hub and typical nodal compression facility operation scenarios were entered into model correspondently as shown in **Table 12**.

Table 12 Dimensions of engine housing

Status	Engine	Width (m)	Length (m)	Height (m)
Large hub gas compression facility	Compressors	4	18	5
	Warehouse	20	50	5
	Workshop/Control Room	20	30	5
Field nodal gas compression facility	Compressors	4	6	5
	Workshop/Control Room	20	30	5

5.3.5 Hours of operation

For modelled scenarios, the emissions have been assumed to occur 24 hours per day, 365 days per year.

As the maximum flaring event scenario for the large integrated hub gas compressor facility would only occur for a short period of time per event, ground level concentrations were only predicted for comparison against the 1-hour average air quality criteria (i.e. annual average impacts have not been assessed). The modelling for emergency flare events also assumed that other sources would not be operational during the event.

5.3.6 Conversion of NO_X to NO_2

At the point of discharge, the NO_2:NO_X ratio for combustion gas emissions is normally in the range of around 5 to 10%, with the majority of the NO_X being in the form of NO. NO emitted into the air, however, reacts in the atmosphere to form additional NO_2, which means that the NO_2:NO_X ratio in the plume increases as it travels downwind.

For this assessment, it has been conservatively assumed that 40% of the NO_X emitted from the compressor stations has been converted to NO_2. The *Clean and Healthy Air for Gladstone – Final Ambient Air Quality Monitoring Plan* (DERM, 2009) reported that monitoring results from the three existing Gladstone monitoring sites indicates that only between 20 - 40% of the NO_x is present as NO_2 when high levels are recorded. Hence, a ratio of 0.4 has been used as a conservative approach for the impact assessment.

As noted in **Section 4.2.4**, for the modelling of regional background emission sources, it was assumed that NO_X was in the form of NO_2, given the significantly larger travel distances.

6 ASSESSMENT OF AIR QUALITY IMPACTS

6.1 Construction and decommissioning phases

A qualitative assessment of potential impacts from dust emissions during construction, decommissioning and rehabilitation activities has been performed based on the following:

- The construction, decommissioning and rehabilitation works are temporary in nature and the duration of these activities means that fugitive particulate matter emissions would be released for a relatively short period of time.
- Fugitive particulate matter emissions from these activities will be highly variable depending upon what activities are being performed.
- In most instances the area exposed for each component is small (~1.5 ha for a typical well lease), although large facilities can have earthworks areas as large as 10 ha.
- The emissions would primarily be sourced from earthworks activities that typically consist of larger particle size fractions (i.e. TSP and to a lesser extent PM_{10} and $PM_{2.5}$). Larger dust particles typically settle out near the source and are therefore localised in dispersion.
- Ready and effective control of potential particulate matter emissions is available through management and mitigation measures.

The locations of surface facilities such as well leases, access roads, gas compression facilities, water storage and management facilities and other infrastructure will be selected in accordance with the *Environmental Protocol for Constraints Planning and Field Development* (Santos GLNG, 2014) or other similar field planning document. This Constraints protocol has been developed to enable Santos GLNG to systematically identify, assess and manage potential impacts to environmentally sensitive areas and receptors in accordance with the environmental approvals for the Santos GLNG gas fields. Through this process, appropriate separation distances will be maintained between surface infrastructure and identified sensitive receptors to protect against impacts relating to a range of environmental issues including noise and vibration, land clearing, flora and fauna, soils, as well as dust emissions during construction activities. Dust control measures, as discussed in **Section 7**, will also be implemented to avoid potential nuisance impacts during construction and rehabilitation works.

Given the above, and based on SLR's experience, it is considered that there is potential for construction, decommissioning and rehabilitation activities undertaken within approximately 500 m of sensitive receptors, to give rise to air quality impacts as a result of fugitive particulate matter emissions. Impacts would be temporary and highly localised in nature, and would cease once the major earthworks are completed and disturbed areas have been stabilised. A range of mitigation and management measures will be incorporated into the GFD Project to minimise such impacts. Where construction, decommissioning or rehabilitation activities are undertaken greater than 500 m from receptors, the risk of impacts from air emissions are considered to be very low.

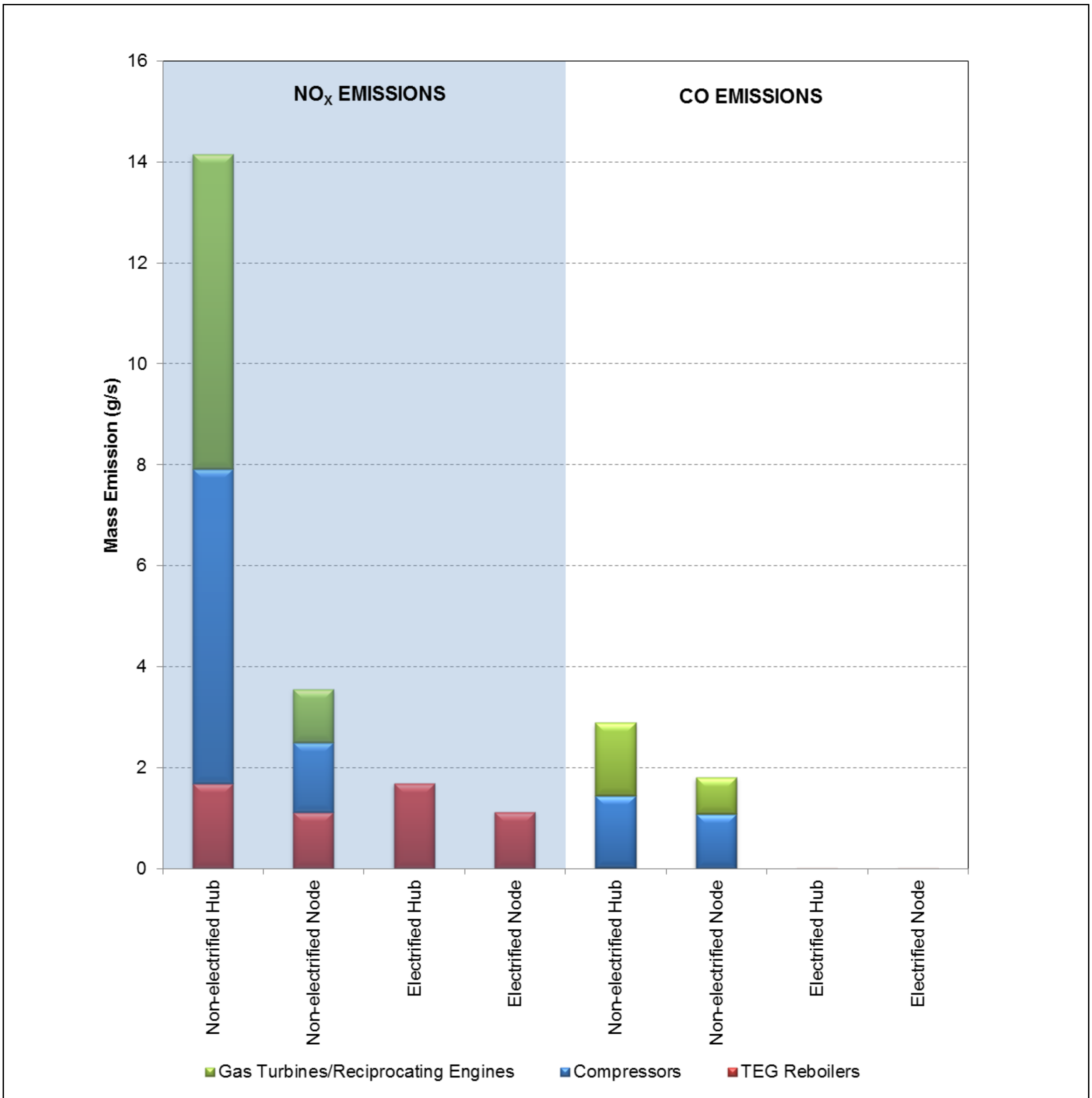
6.2 Operational emissions

The results of the AUSPLUME modelling study are presented and discussed in the following sections. It is noted that these modelling results are based on the stack and emission data presented in **Section 5.3.1** and are for representative non-electrified hub and nodal gas compression facilities. As discussed in **Section 2.2.1**, the gas turbine alternators and gas turbine compressors are potentially only required during commissioning and early operations until the facilities are connected to the electric transmission grid. Once electrified, there would be no requirement for power from the combustion of gas and consequently no further air emissions from gas turbine alternators and gas turbine compressors. The only remaining sources of emissions would be the TEG re-boilers and emergency flaring events.

A comparison of the total emissions for non-electrified and electrified gas compression facilities (normal operating conditions) is presented in **Figure 19** to illustrate the reduction in emissions that will occur when a facility is connected to the grid (based on the representative equipment numbers and emission data provided for this assessment).

Figure 19 also illustrates the difference in the total non-electrified emissions from a typical hub gas compression facility compared to a nodal gas compression facility. It is noted that the 240 TJ/day hub gas compression facility used in this assessment is considered a representative example of the largest facility that would be constructed as part of the GFD Project, while the 80 TJ/day nodal gas compression facility is representative of a more 'typical' field gas compression facility configuration to facilitate transmission of gas to a hub gas compression facility for further compression and export from the gas field.

Figure 19 Indicative reductions in air emissions due to electrification of gas compression facilities



6.2.1 Hub gas compression facility – normal operations

The maximum predicted downwind 1-hour average NO_2 concentrations for a nominal large hub gas compression facility (240 TJ/day) are shown in **Figure 20.** The top graph shows the incremental impacts predicted for the hub operating in isolation (the same across the four gas fields), while the bottom graph shows the cumulative impact, including the maximum background levels predicted in each gas field (see **Table 5**) to provide a worst case cumulative assessment. Similar plots are presented in **Figure 21** for the annual average NO_2 predictions.

It is noted that the incremental NO_2 concentrations predicted as a result of emissions from the hub have been conservatively estimated from the AUSPLUME modelling results based on an assumption that 40% of the NO_X in the plumes is in the form of NO_2. This approach is likely to overestimate NO_2 concentrations in areas close to the hub as the conversion of NO to NO_2 occurs over a number of hours and will have had little time to occur this close to the hub.

The plots show that the incremental 1-hour and annual average concentrations predicted are well below the relevant ambient air quality guidelines downwind of the facility and that the variations in meteorological concentrations across the study area (as represented by the four meteorological datasets used in the modelling) do not have a significant impact on the maximum incremental ground level concentrations predicted. The maximum downwind NO_2 concentrations are predicted to return to background levels within approximately 500 m of the hub gas compression facility.

In addition, even if the peak background concentrations (estimated by modelling the major anthropogenic sources in the region) are assumed for each gas field, the cumulative concentrations are still below the relevant guideline levels. It is noted that the actual background concentrations that would be relevant for a proposed new facility will depend on location and proximity to other existing emission sources. However the modelling indicates that the incremental impacts are low, and that there does not appear to be a significant constraint with respect to the capacity of the local airshed to assimilate these emissions.

The maximum predicted downwind 8-hour average CO concentrations (including and excluding maximum estimated background levels) for a nominal large hub gas compression facility are shown in **Figure 22**. The plots show that the 8-hour CO concentrations predicted are far below the ambient air quality guideline downwind of the facility and would not result in a significant increase above existing background levels. There do not appear to be significant constraints with respect to the capacity of the local airshed to assimilate these emissions.

Figure 20 Maximum predicted 1-hour average NO_2 concentrations – hub compression facility

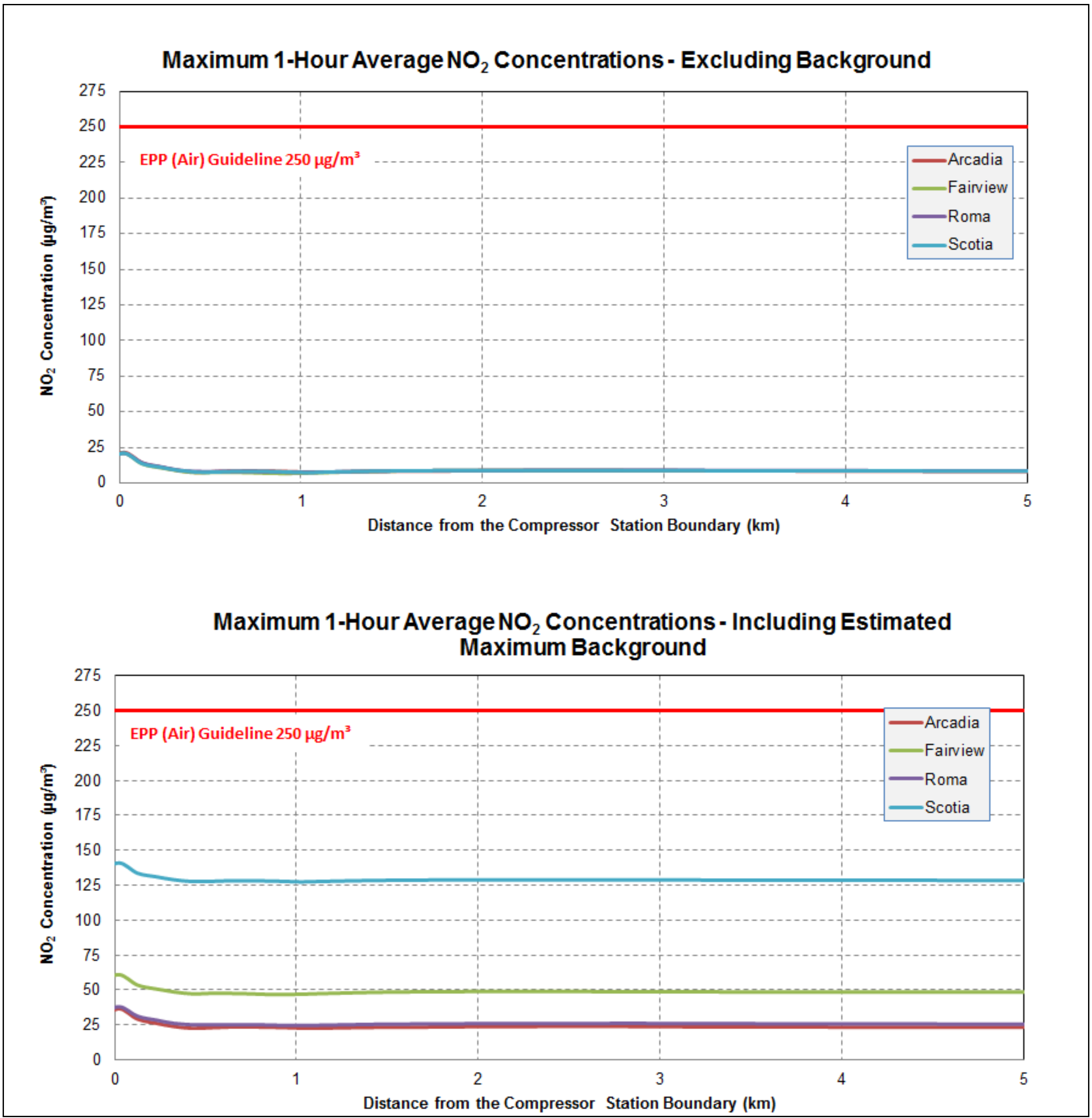


Figure 21 Maximum predicted annual average NO_2 concentrations – hub compression facility

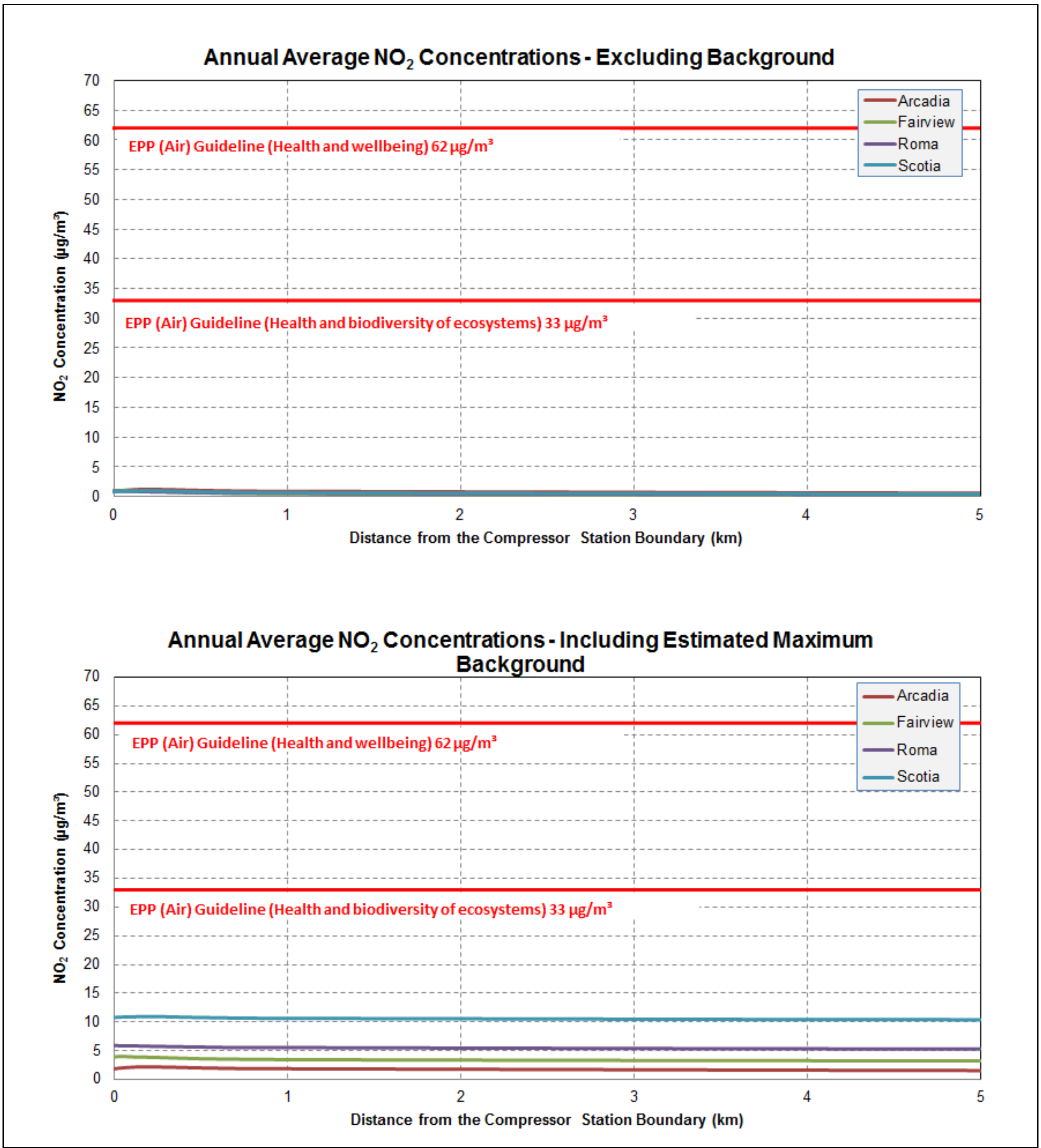
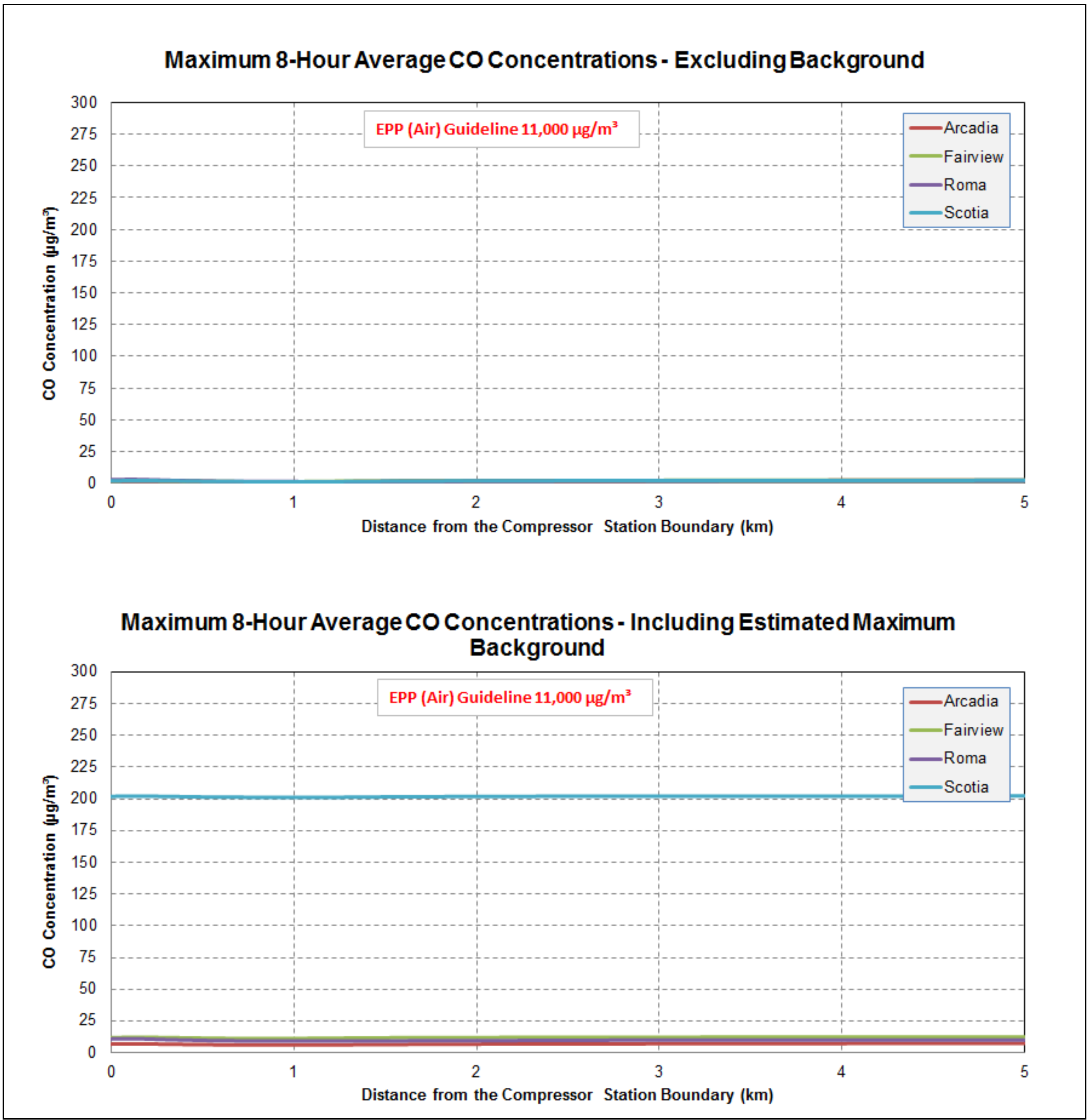


Figure 22 Maximum predicted 8-hour average CO concentrations – hub gas compression facility

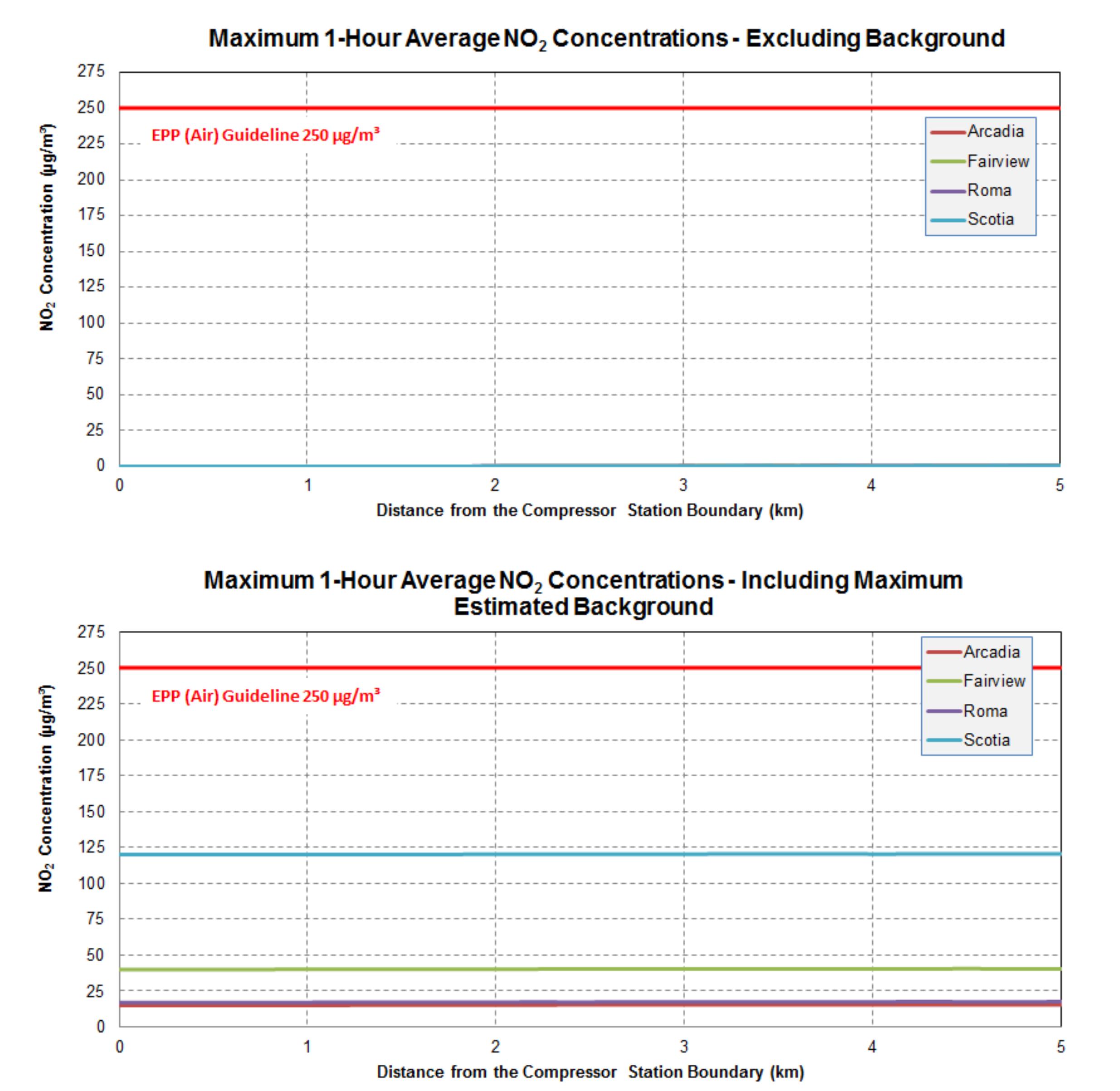


6.2.2 Hub gas compression facility – maximum flaring scenario

The maximum predicted incremental and cumulative 1-hour average NO_2 concentrations for a maximum flaring scenario at a nominal large hub gas compression facility are shown in **Figure 23**. As above, these predictions have been conservatively estimated from the NO_X emission modelling based on the assumption that 40% of the NO_X in the plumes is in the form of NO_2. This approach is likely to overestimate NO_2 concentrations in areas close to the hub as the conversion of NO to NO_2 occurs over a number of hours and will have had little time to occur. Annual average NO_2 predictions and 8-hour average CO concentrations are not presented as flaring would only occur very infrequently and for short durations.

The plots show that the incremental 1-hour average concentrations predicted (the same across the four gas fields) are negligible and far below the relevant ambient air quality guideline downwind of the facility. The high buoyancy of the plume due to high temperature of the flare means that the emissions are well dispersed and do not have a significant impact on the background ground level concentrations. There does not appear to be a significant constraint with respect to the capacity of the local airshed to assimilate these emissions.

Figure 23 Maximum predicted 1-hour average NO_2 concentrations – maximum flaring



6.2.3 Nodal gas compression facility

The maximum predicted downwind 1-hour average NO_2 concentrations (including and excluding maximum estimated background levels) for a field nodal compression facility (80 TJ/day) are shown in **Figure 24** (the same across the four gas fields), while the annual average NO_2 predictions are shown in **Figure 25**. As for the hub gas compression facility, these predictions have been conservatively estimated from the NO_X emission modelling based on the assumption that 40% of the NO_X in the plumes is in the form of NO_2.

The plots show that the incremental and cumulative 1-hour NO_2 concentrations predicted are below the ambient air quality guidelines downwind of the facility and that the variations in meteorological concentrations across the GFD Project area (as represented by the four meteorological datasets used in the modelling) do not have a significant impact on the maximum incremental ground level concentrations predicted. Based on these results, it is concluded that the local airshed would have sufficient capacity to assimilate these emissions.

The maximum predicted downwind incremental and cumulative annual average NO_2 concentrations are also below the ambient air quality guideline downwind of the facility and there do not appear to be significant constraints with respect to the capacity of the local airshed to assimilate these emissions on an annual average basis.

The maximum predicted downwind 8-hour average CO concentrations (including and excluding maximum estimated background levels) for a nominal field nodal compression facility are shown in **Figure 26**. The plots show that the incremental 8-hour CO concentrations predicted are far below the ambient air quality guideline downwind of the facility and there does not appear to be a significant constraint with respect to the capacity of the local airshed to assimilate these emissions.

It is noted that the maximum ground level concentrations predicted for the field nodal compression facility are higher than those predicted for the large hub gas compression facility, despite the total compression facility emissions being lower. This is due to the lower exit velocity used for the reciprocating engines.

Figure 24 Maximum predicted 1-hour average NO_2 concentrations – nodal gas compression facility

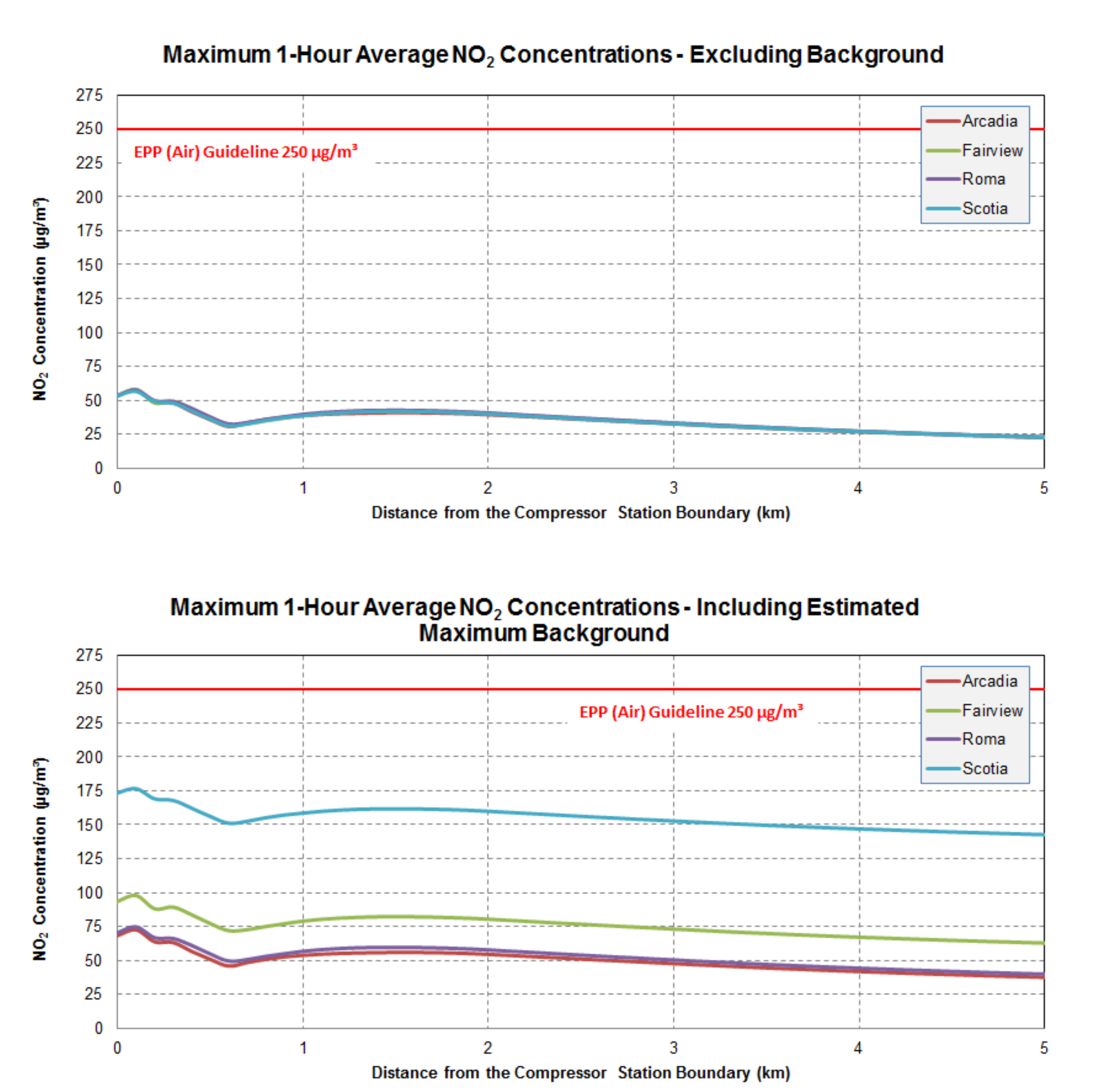


Figure 25 Maximum predicted annual average NO_2 concentrations – nodal gas compression facility

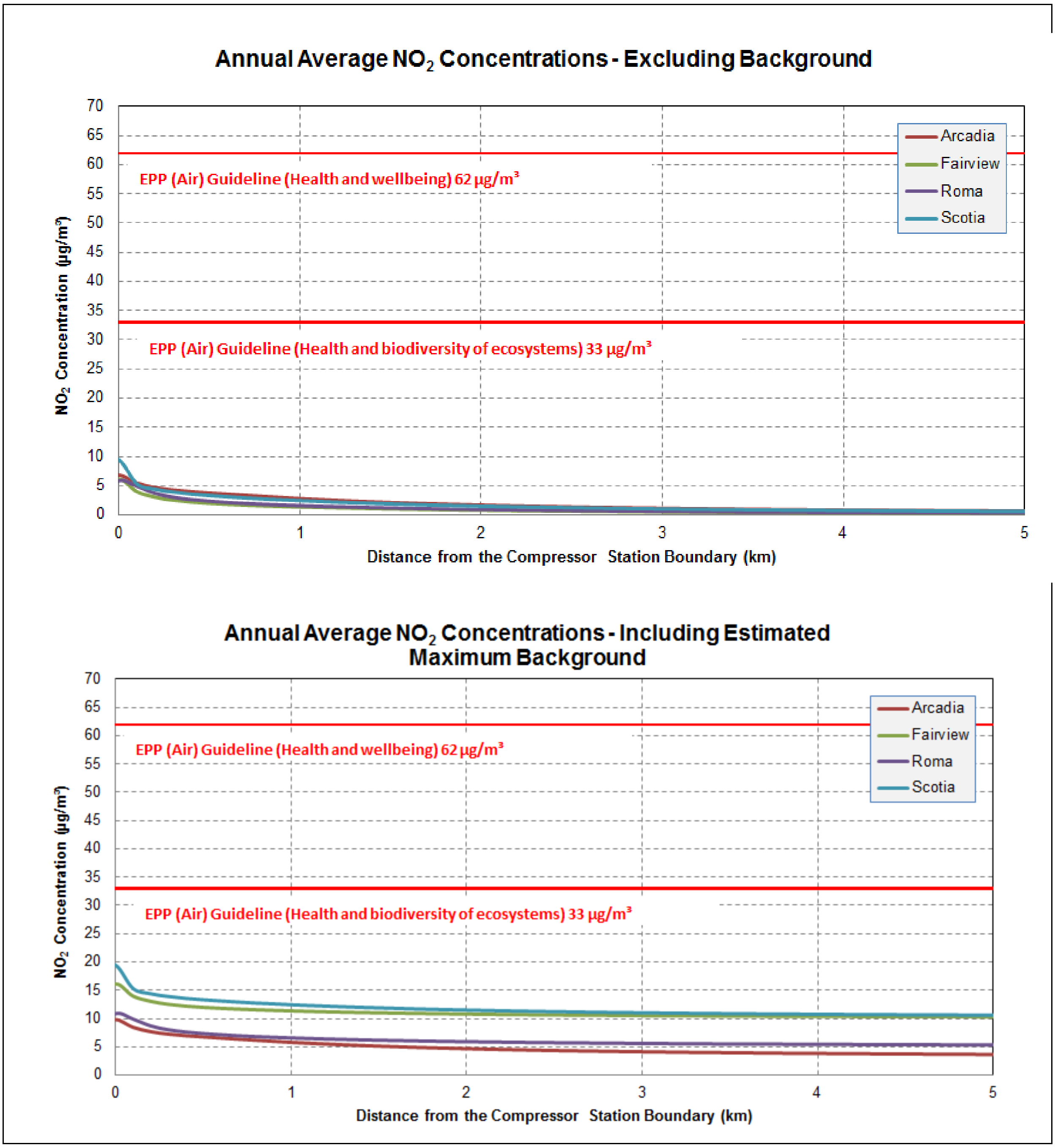
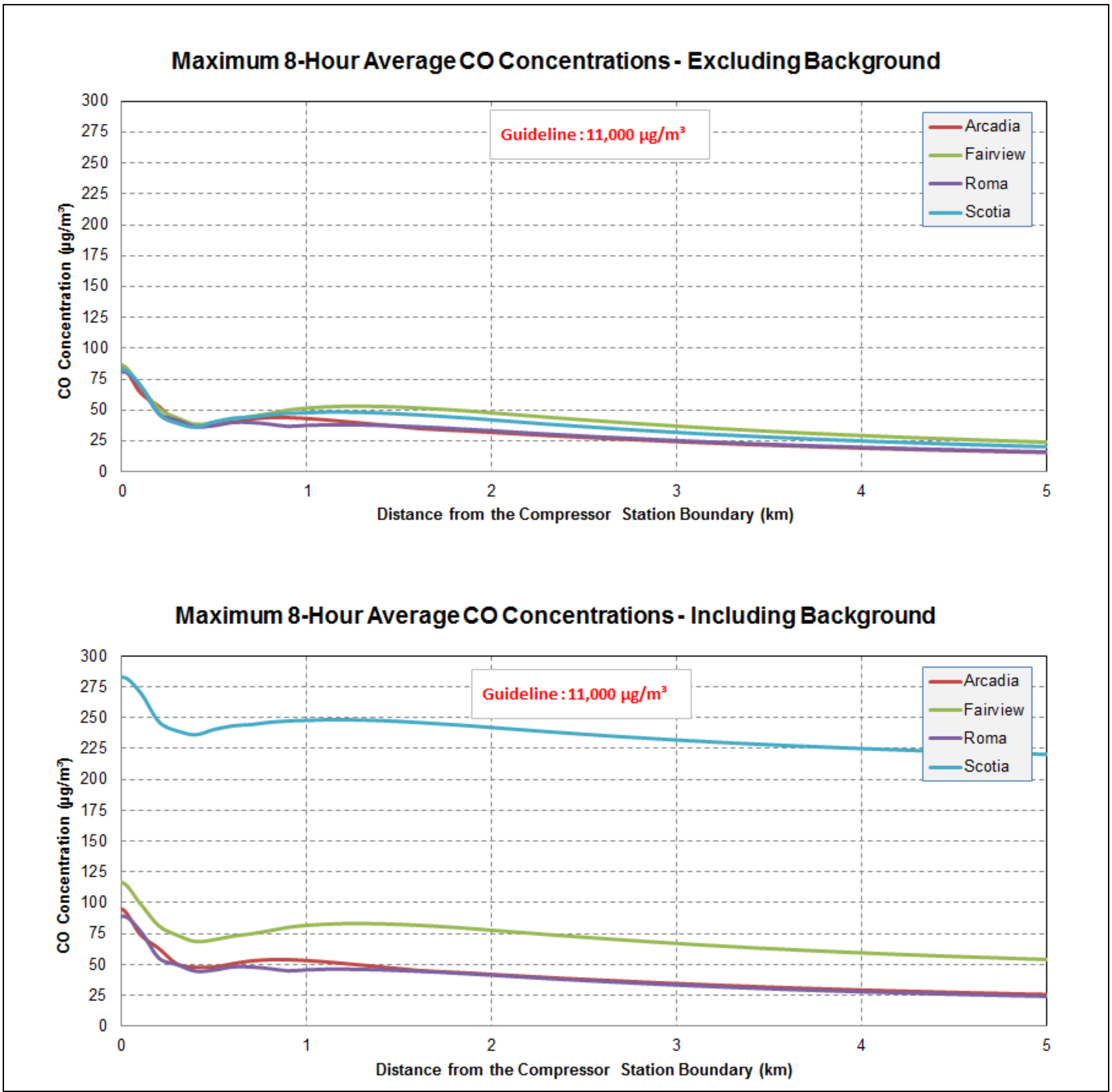


Figure 26 Maximum predicted 8-hour average CO concentrations – nodal gas compression facility



6.2.4 Traffic emissions

The GFD Project will extend from the area around Roma to north of Rolleston. The road network providing access to the gas fields are a combination of sealed State-controlled roads and both sealed and unsealed (gravel) local government roads. The State-controlled road network predominantly has a large volume of traffic travelling at high speeds ranging from 80 to 110 km/h, whereas the gravel roads providing access to the gas fields have lower traffic volumes and speeds.

To provide context on the expected increases in traffic volumes on existing levels associated with the GFD Project, a summary of the background (i.e. non GFD Project-related) and the peak annual GFD Project-related traffic volumes shown in **Table 13** as provided in a traffic and transport impact assessment for this EIS undertaken by Cardno (2013). These data show that the projected maximum increase in vehicle numbers relative to existing traffic levels varies significantly depending on the section of road. In most cases the peak daily GFD Project-related traffic volumes are well within the range of the background traffic volumes estimated for each road.

Given the diffuse nature of this emission source, which will be spread over a wide area, the incremental traffic volumes shown in **Table 13** would not be expected to result in exhaust emissions that would contribute significantly to regional NO_X, CO or SO_2 levels. In addition, studies of vehicle exhaust pollutants near major highways and motorways have shown that the ambient concentrations of NOx and CO reduce to background levels within 50 m or 100 m of a major road (HEI, 2010), hence localised impacts would be negligible.

There is potential, however, for vehicles travelling on unpaved roads passing close to residential dwellings and other sensitive receptors to give rise to nuisance dust impacts. The estimation of particulate emissions associated with vehicles travelling on unpaved roads is subject to an extremely high level of uncertainty and therefore a quantitative assessment of impacts associated with these emissions is not appropriate. These impacts are most appropriately managed through the constraints planning process (e.g. Project infrastructure to be located with landholder agreement on acceptable impacts), logistics planning to minimise traffic volumes on these roads, appropriate maintenance of road surfaces and ongoing driver training, as discussed in **Section 7.1**.

Table 13 Background and GFD Project-Related Traffic Volumes on State Controlled Roads

Road	Background Traffic Volumes[1] (AADT) / % Heavy Vehicles	Peak Daily GFD Project Traffic Volumes[2] / % Heavy Vehicles	Year of Estimated Peak GFD Project Traffic Volumes
Warrego Highway	1,193 – 16,419 / 14% - 32%	115 - 688 / 81% - 86%	2022
Carnarvon Highway	564 - 3,838 / 28% - 50%	196 - 1,530 / 70% - 86%	2024
Leichhardt Highway	941 - 1,617 / 36% - 50%	227 - 1,082 / 89% - 98%	2024
Dawson Highway	390 - 3,184 / 14% - 43%	184 - 283 / 72% - 98%	2027
Fitzroy Development Road	51 - 158 / 18% - 40%	149 / 93%	2024
Roma Condamine Road	118 - 347 / 25% - 27%	140 / 87%	2030
Blackwater Rolleston Road	182 - 189 / 29% - 63%	154 - 301 / 65% - 68%	2036
Wallumbilla South Road	44 - 326 / 21% - 28%	78 - 286 / 94% - 95%	2022
Roma Southern Road	158 - 627 / 17% - 32%	121 / 78%	2023
Jackson-Wandoan Road	359 - 360 / 27% - 28%	442 / 65%	2024
Roma Taroom Road	187 - 659 / 22% - 47%	11 - 168 / 2% - 90%	2026

Source: Cardno, 2013

Note 1: The background Annual Average Daily Traffic (AADT) numbers above are based on existing (Year 2011) traffic volumes and % heavy vehicle data sourced from DTMR and predicted future traffic volumes based on 3% annual traffic growth. Traffic for both directions.

Note 2: Traffic for both directions.

6.3 Regional air quality impacts

Regional air pollution can be broadly considered as having the potential to adversely affect an airshed. The airshed has been defined in this assessment as 50 km north of Rolleston to Surat in the South, Miles in the East and Mitchell to the west; encompassing an area of approximately 250 km by 350 km.

The regional air quality assessment has been based on the GLNG Project's upstream activities as a whole, the conceptual nature of the proposed GFD Project activities and the predicted air quality impacts discussed in **Section 6.1** and **Section 6.2.** A qualitative assessment has been undertaken and, as detailed in **Section 6.3.1** and **Section 6.3.2**, the GFD Project is expected to be a minor contributor to the more common forms of regional air pollution of acid deposition and the formation of photochemical smog. Given this, the GFD Project is not expected to require management or mitigation of air emissions to control regional impacts, with the airshed having sufficient capacity for the assimilation and dispersion of emissions associated with the Project.

6.3.1 Acid deposition

Acid deposition, also commonly known as acid rain, is the deposition of acidifying compounds either dissolved in precipitation or in 'dry' form. Sulphur dioxide (SO_2) and oxides of nitrogen (NO_X) are the most common contributors to acid rain. As detailed in **Section 2.3**, the absence of detectable concentrations of sulfur in the gas will limit SO_2 emissions from the project to very low levels and therefore the GFD project is not expected to significantly contribute to acid deposition.

Oxides of nitrogen would be emitted during the lifetime of the GFD Project. Based on the predicted compliance with the NO_2 concentrations stipulated in the EPP Air, and the large regional area; the potential acid deposition is likely to be minimal and a low impact at potential receptors.

6.3.2 Photochemical smog

Photochemical smog occurs as a result of a complex series of chemical reactions involving oxides of nitrogen and reactive organic species including VOCs and non-methane hydrocarbons. These reactions can occur on timescales ranging from hours to several days producing compounds which result in the formation of smog and secondary pollutants such as O_3.

Typical conditions for the formation of photochemical smog include long periods of low winds, high temperatures, sunlight and sufficient concentrations of man-made chemicals that lead to smog production. In addition to the climatic conditions, the regional terrain features and meteorological patterns can also enhance smog production by promoting the trapping or recirculation of pollutants, for example during temperature inversion conditions.

Land use in the region is primarily rural and includes agricultural practices such as cattle grazing and rural landholdings. The primary road corridors in the project are not heavily commuted and the traffic volumes shown in **Table 13** are not likely to result in NO_X emissions that would contribute significantly to NO_X loadings on the regional airshed. The dispersion modelling results presented in **Section 6.2** indicate that potential NO_X and CO emissions would be well dispersed within 1-2 km of the GFD Project hub and nodal gas compression facilities and would approach background levels at this distance. Given this and the absence of large non-methane VOC emissions, it is concluded that the GFD Project would not contribute to regional photochemical smog levels.

6.4 Cumulative impacts

When numerous projects occur in a region they result in cumulative impacts, which differ from those of an individual project when considered in isolation. Cumulative impacts may be positive or negative, and their severity and duration will depend on the project size, location and timing overlap.

The ToR for the GFD Project EIS requires an assessment of the GFD Project's cumulative impacts.

Projects for inclusion in the cumulative impact assessment have been designated as those within the GFD Project's tenures and within a 50 km buffer around the tenures that:

a Are currently being assessed under Part 1 of the Chapter 3 of the *Environmental Protection Act 1994* (Qld) (EP Act) and as a minimum, an Initial Advice Statement (IAS) is available on the EHP website

b Have been declared a 'significant project' or 'coordinated project' by the Coordinator-General under the *Sustainable Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) and an EIS is currently being prepared or is complete and as a minimum, an IAS is available on the Queensland Department of State Development, Infrastructure and Planning (DSDIP) website

c Will, or may, utilise resources located within the region (including materials, groundwater, road networks or workforces) that are the same as those to be used by the GFD Project

d Could potentially compound residual impacts that the GFD Project may have on environmental or social values.

Projects that are excluded from the GFD Project's cumulative impact assessment are:

- Existing or historic projects within the project area and surrounding buffers that are considered to constitute part of the baseline environment
- Projects that have not been developed to the point that their environmental assessment process has been made public.

Future projects with the potential to contribute to NO_X and CO emissions within the airshed have been included in the cumulative air quality impact assessment for the GFD Project by including them in the modelling of representative background NO_2 and CO concentrations across the GFD Project (refer **Appendix A**). As noted above, the dispersion modelling results (presented in **Section 6.2)** indicate that potential NO_X and CO emissions from the GFD Project would be dispersed within 1 to 5 km of the gas compression facilities. At this distance, levels would approach background levels. The potential for cumulative impacts is therefore very low and can be managed through appropriate siting of such facilities.

7 MITIGATION AND MANAGEMENT OF AIR QUALITY IMPACTS

The potential unmitigated air quality impacts have been assessed against air quality assessment criteria adopted for the GFD Project which comply with the NEPM and EPP Air.

Where construction, decommissioning and rehabilitation activities associated with the GFD Project are undertaken within 500 m of sensitive receptors, the potential exists for air quality impacts to occur as a result of fugitive particulate matter emissions. Impacts would be temporary and highly localised in nature, and would cease once the major earthworks are completed and disturbed areas have been stabilised. The following sections outline mitigation and management measures to be incorporated into the GFD Project to minimise such impacts. Where construction, decommissioning or rehabilitation activities are undertaken greater than 500 m from receptors, the risk of impacts from air emissions would be very low.

Modelling of operational emissions from large hub gas compression facilities and nodal compression facilities has indicated the magnitude of air quality impacts to be low with worst case impacts due to potential emission levels predicted to comply with the EPP Air objectives to preserve health and wellbeing and biodiversity of ecosystems.

The measures discussed in this section will be used to manage potential air quality impacts and will be considered during the planning and scheduling of GFD Project activities to achieve a low magnitude of impact for air quality at potential receptors.

7.1 Air quality mitigation and management commitments

The following mitigation and management measures have been identified to be adopted as part of the GFD Project to protect human health and wellbeing as well as the health and biodiversity of ecosystems.

Management Framework	Description and Mitigation Measures
GFD Project environmental protocol for constraints planning and Field Development (the Constraints protocol)	The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to: • Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation • Support Santos GLNG's environmental policies and the General Environmental Duty (GED) as outlined in the EP Act • Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances • Minimise cumulative impacts on environmental values. The Constraints protocol will be implemented to guide placement of infrastructure, which adopts the following management principles: • Avoidance - avoid direct and indirect impacts • Minimisation - minimise potential impact • Mitigation - implement mitigation and management measures to minimise cumulative adverse impacts • Remediation and rehabilitation - actively remediate and rehabilitate impacted areas • Offset – offset residual adverse impacts in accordance with regulatory requirements.
Draft environmental management plan	Air quality controls detailed in the plan will be implemented including measures such as: • Monitoring of pollutant concentrations will be undertaken for registered discharge points in accordance with the environmental authority. Production rate and plant status will be recorded during the test period. • Site-specific air dispersion modelling studies will be performed to identify

Management Framework	Description and Mitigation Measures
	potential impacts to air quality from proposed fuel burning equipment capable of burning at least 500 kg of fuel in an hour. • Contaminants emitted from fuel burning equipment point sources will be emitted via appropriately designed stacks (i.e. at a suitable release height) for maximum dispersion. • The compressor engines and other fuel burning equipment for new surface facilities will have the manufacturer's specifications for pollutant emission levels taken into account, in order to comply with environmental authority emission limits. • Fuel burning equipment will be maintained and operated in accordance with the manufacturer's specifications to ensure pollutant emissions are minimised. • If blasting is required as part of demolition activities, Santos GLNG will develop and implement a Blast management plan in accordance with the EA. • A strict no-burning of waste policy will be implemented to prevent smoke generation and fire control procedures will be implemented during operations.
Erosion and sediment control management plan	The plan will be implemented which includes measures such as: • Construction activities will aim to reduce exposure of disturbed areas to the minimum time period required, with progressive revegetation or rehabilitation as soon as practicable after the completion of construction. • Stabilisation of disturbed areas, including stockpiles, through the use of measures such as mulch, erosion blankets and establishment of ground cover.
Chemical and fuel management plan	The plan will be implemented for the safe handling and storage of chemicals and fuels including minimising fugitive emissions as per appropriate regulations and guidelines.
Decommissioning and abandonment management plan	Dust minimisation measures detailed in the plan will be implemented, including measures to mitigate and manage the potential for nuisance dust and other air quality impacts such as: • Dust suppression (water, mulching or alternative measures) will be applied to exposed surfaces that are generating dust. Dust suppression will be maintained and effort increased during periods of high risk (e.g. high winds). • Landholders with the potential to be impacted by dust emissions will be consulted with prior to the commencement of activities.
Rehabilitation management plan	Disturbed areas will be rehabilitated to a safe, stable and non-polluting environment suitable for the intended land use in accordance with the strategies contained within the Rehabilitation management plan.
Road-use management plan	Dust control measures will be implemented to ensure road-user safety and the safe operation of project vehicles in line with TMR's standards.

7.2 Review of management hierarchy for air emissions in the EPP Air

As noted in **Section 3.1**, Section 9 of the EPP Air states that, to the extent that it is reasonable to do so, air emissions must be dealt with in the following order of preference:

1. Avoid
2. Recycle
3. Minimise
4. Manage

Table 14 summarises the mechanisms though which the proposed GFD Project would avoid, recycle, minimise and manage air emissions.

Table 14 Summary of proposed air quality controls with reference to the management hierarchy for air emissions in the EPP Air

Avoid	Recycle	Minimise	Manage
No-burning of waste Fire control procedures Linking surface infrastructure to the national grid, avoiding need for fossil fuel combustion.	The emissions to air associated with the GFD Project have no residual value and there is no viable option for recycling of these emissions.	Minimisation of fugitive dust emissions as detailed in the Erosion and sediment control management plan, Rehabilitation management plan, Decommissioning and abandonment management plan and Road-use management plan. Consideration of supplier specification in equipment selection process. Appropriate maintenance and operation of equipment.	Landholder consultation processes. Monitoring of emissions in accordance with environmental authority requirements. Site-specific air impact assessments for proposed new fuel burning equipment capable of burning at least 500 kg of fuel in an hour. Register of combustion equipment. Appropriate stack design.

7.3 Verification of predicted impacts

The air quality impacts predicted in this assessment will be verified during the detailed design phase to confirm the air emission impacts of the final design and location of GFD Project infrastructure. The verification will include prediction air pollutant concentrations adopting the following:

- Site-specific meteorological modelling based on known locations for those gas compression facilities which undertake major fuel burning activities.
- Dispersion modelling incorporating representative background air quality levels, localised terrain and land use data and locations of sensitive receptors.

Where the verification of potential impacts identifies the need for further impact controls, additional mitigation measures to minimise emissions to the atmosphere could include:

- Increasing the stack heights for key sources, or
- Investigating alternative sites located further from sensitive receptors or with improved local dispersion characteristics, or
- Use of low NO_x technology, such as staged combustion systems.

Monitoring of air emissions will be performed in accordance with the Environmental Monitoring and Reporting appendix of the GFD Project Draft EM Plan. This will include the routine measurement of stack exit velocities and NO_X emission rates from compressor engines and gas turbines as required by the relevant environmental authorities.

In addition, as discussed in **Section 4.2.1**, Santos GLNG have recently installed two ambient monitoring stations, one in the Fairview area and one in the Roma area, to monitor ambient concentrations of NO_X, CO and VOCs over at least a six month period. The results of this monitoring will provide information on current air quality, which can be used as a baseline for future development as well as providing specific background data for future air quality impact assessments. Analysing the continuous monitoring data based on concurrent wind direction data and the locations of emission sources in the surrounding area can also be performed to provide a measure of the incremental impact of existing developments.

Verification of the effectiveness of dust management measures will be achieved through ongoing consultation with landholders and monitoring of complaints records.

The activities proposed as part of the GFD Project are not anticipated to have the potential to give rise to odour nuisance impacts. However, should Santos GLNG receive complaints related to odour, an odour impact assessment would be performed for the activity/facility of concern in accordance with the EHP guideline *Odour Impact Assessment from Developments* (EHP, 2013).

8 CONCLUSIONS

8.1 Construction

The assessment has concluded that potential particulate matter (dust) and vehicle emissions arising from unmitigated construction works within 500 m of receptors have the potential to result in nuisance impacts requiring mitigation and management. Where construction activities are undertaken greater than 500 m from receptors, potential particulate matter and vehicle emissions are expected to have a low magnitude impact with concentrations at the receptors being compliant with the adopted air quality assessment objectives.

Through the implementation of existing management and mitigation controls from the Santos GLNG management framework, such as minimising the duration of exposed surfaces, watering access tracks, soil stockpiles and spoil, and a no burning policy, it is expected potential impacts from particulate emissions for construction activities can be mitigated to comply with relevant air quality objectives resulting in a low magnitude impact at receptors.

8.2 Operation

Based on the key air emission sources, the assessment of air pollutant emissions during operation focused on NO_2 and CO from gas compression facilities as these are the key emission sources. Other potential pollutants would be emitted at very low and trace levels that would comply with the air quality assessment objectives.

Dispersion modelling for NO_2 and CO determined that predicted concentrations from gas compression activities under normal operations and during flaring (commissioning and emergency) would comply with objectives for the preservation of health and wellbeing and biodiversity of ecosystems. More detailed site-specific assessments will be performed once preferred locations and detailed design data are available to confirm these results.

Air pollutant emissions have been determined to be a low impact and based on this assessment would not require specific mitigation measures to control or reduce potential source emissions or air quality impacts at receptors.

Potential impacts on regional air quality are expected to be minimal with potential GFD Project operations not a dominant source contribution to regional NO_2 levels.

8.3 Decommissioning and rehabilitation

Consistent with the assessment for construction, through the implementation of dust and vehicle emission controls, emissions can be mitigated through the Santos GLNG management framework to comply with relevant air quality objectives and be a low magnitude impact at receptors.

9 REFERENCES

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Santos GLNG (2014). *Environmental Protocol for Constraints Planning and Field Development*.

Source Data - Modelling of Background NO_X and CO Emissions

Table A1 Model input data used for regional background sources of NO_X and CO

Emission Source	Latitude (degrees)	Longitude (degrees)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (ºC)	NO_X Emission (g/s)	CO Emission (g/s)	Source of Data and Notes
Power Stations									
Condamine Power Station	-26.721	150.148	34	3.7	13.7	127	25.37	6.35	AQIA for upstream and pipeline gas field infrastructure for the QCLNG project. Emission data from NPI 2011/2012
Kogan Creek Power Station	-27.020	150.890	160	7.0	24.0	125	164.66	16.81	
Roma Power Station	-26.580	148.780	34	3.7	13.7	127	1.05	0.26	Stack parameters estimated. Emission data from NPI 2011/2012
Daandine Power Station	-27.100	151.033	34	3.7	13.7	127	6.66	4.44	Stack parameters estimated. Emission data from NPI 2011/2012
Callide A&B Power Station	-24.347	150.609	160	7	24	125	570.78	17.44	Stack parameters estimated. Emission data from NPI 2011/2012
Callide C Power Station	-24.344	150.618	160	7	24	125	174.40	20.61	Stack parameters estimated. Emission data from NPI 2011/2012
Oil and Gas Extraction									
Wallumbilla LPG Plant	-26.696	149.188	9	0.5	30	350	4.33	0.79	Emissions from NPI 2011/12. Nominal stack parameters used
Kogan CS	-27.022	150.735	9	0.5	30	350	0.83	0.22	
Condamine CS	-26.944	150.198	9	0.5	30	350	0.12	0.03	
Kogan North	-27.081	150.866	9	0.5	30	350	1.65	0.43	
Daandine Gas Field	-27.097	150.940	9	0.5	30	350	6.82	4.47	
Kogan Gas Field	-27.078	150.937	9	0.5	30	350	1.21	0.79	
South Denison	-25.449	148.400	9	0.5	30	350	16.37	4.14	
Spring Gully	-25.948	149.069	9	0.5	30	350	104.70	15.30	
Condabri	-26.782	150.207	9	0.5	30	350	0.34	0.27	
North Denison	-24.493	148.672	9	0.5	30	350	5.08	0.64	
Talinga	-26.883	150.411	9	0.5	30	350	95.16	12.72	
Peat	-26.011	150.092	9	0.5	30	350	7.61	0.95	
Wallumbilla Terminal	-26.696	149.184	9	0.5	30	350	5.82	0.71	
Rolleston Comp & Meter Stn	-24.707	148.845	9	0.5	30	350	2.69	0.22	
Banana CS	-24.359	150.160	9	0.5	30	350	2.90	0.22	

Source Data - Modelling of Background NO_X and CO Emissions

Emission Source	Latitude (degrees)	Longitude (degrees)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (ºC)	NO_X Emission (g/s)	CO Emission (g/s)	Source of Data and Notes
Surat	-27.028	148.815	9	0.5	30	350	10.16	1.44	
Kenya CPP and FCSs	-26.948	150.458	9	0.5	30	350	26.65	16.56	
Kenya CPP	-26.253	149.691	9	0.5	30	350	1.33	0.35	
Windibri CPP & FCSs	-26.879	150.296	9	0.5	30	350	26.95	15.73	
Scotia	-25.943	150.072	9	0.5	30	350	21.23	2.69	
Fairview CSM Field	-25.616	148.924	9	0.5	30	350	181.44	27.32	
Mining/Quarrying									
The Dawson Mines	-24.623	150.051	5	0.5	5	30	107.47	63.90	Emissions from NPI 2011/12. Each site modelled as a number of short stacks spread across site
Callide Mine	-24.327	150.618	5	0.5	5	30	42.87	24.68	
Baralaba Coal Mine	-24.155	149.800	5	0.5	5	30	14.57	6.48	
Baralaba Load Out	-24.314	149.847	5	0.5	5	30	0.08	0.05	
Kogan Creek Mine	-26.929	150.779	5	0.5	5	30	9.68	3.60	
Wilkie Creek Coal Mine	-27.049	150.960	5	0.5	5	30	18.50	6.97	
Rolleston Coal Mine	-24.443	148.415	5	0.5	5	30	21.36	8.89	
Cameby Downs Coal Mine	-26.649	150.337	5	0.5	5	30	6.56	3.76	
Boral Quarries Amby	-25.982	148.205	5	0.5	5	30	0.33	0.10	
Boral Quarries Warrians	-26.340	148.886	5	0.5	5	30	0.26	0.11	
Evolution Cracow	-25.296	150.288	5	0.5	5	30	2.23	3.23	
Miscellaneous Industry									
Cypress Supplies - Roma	-26.5795	148.8224	8	0.5	10	150	0.20	0.52	Emissions from NPI 2011/12. Nominal stack parameters used
Yuleba Cypress Sawmills	-26.6903	150.1914	8	0.5	10	150	0.05	0.13	
Hornick Cypress	-26.5729	148.8310	8	0.5	10	150	0.07	0.20	
QNP Ammonium Nitrate Plant	-24.5379	150.0310	8	0.5	10	150	2.35	1.27	
Wandoan Green Mill	-26.1281	149.9703	8	0.5	10	150	0.66	1.77	
Theodore Green Mill	-24.9478	150.0831	8	0.5	10	150	0.46	1.23	

Source Data - Modelling of Background NO_X and CO Emissions

Emission Source	Latitude (degrees)	Longitude (degrees)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (ºC)	NO_X Emission (g/s)	CO Emission (g/s)	Source of Data and Notes
Stanbroke Feedlot	-26.8136	150.4136	8	0.5	10	150	0.16	0.08	
Biloela	-24.3605	150.4967	8	0.5	10	150	0.32	0.74	
Miamba Feedlot	-26.9265	150.1323	8	0.5	10	150	0.15	0.09	
Injune Cypress	-25.8341	148.5641	8	0.5	10	150	0.35	0.97	
Womblebank Sawmilling Co	-25.8344	148.5639	8	0.5	10	150	0.12	0.32	
Approved Future Projects									
Chinchilla Power Station	-26.770	150.610	34	3.7	13.7	127	40.59	10.15	Scaled from Condamine PS (125MW) based on 200MW plant
Kogan Creek B Power Station	-26.990	150.890	160	7.0	24.0	125	164.66	16.81	Scaled from Kogan Creek PS (750MW) based on 750MW plant
Kogan-SEQ2 Power Station	-27.037	150.758	34	3.7	13.7	127	71.04	17.77	Scaled from Condamine PS (125MW) based on 350MW plant
Wandoan Power Station	-26.120	149.970	160	7.0	24.0	125	153.68	15.69	Scaled from Kogan Creek PS (750MW) based on 700MW plant
Wandoan GE Power Station	-26.210	149.910	160	7.0	24.0	125	87.82	8.96	Scaled from Kogan Creek PS (750MW) based on 400MW plant
Moura Power Station	-24.620	150.059	34	3.7	13.7	127	12.18	3.05	Scaled from Condamine PS (125MW) based on 60MW plant
Mungi Power Station	-24.433	148.867	34	3.7	13.7	127	8.73	2.18	Scaled from Condamine PS (125MW) based on 43MW plant
Fairview 2 Power Station	-25.625	148.920	34	3.7	13.7	127	20.30	5.08	Scaled from Condamine PS (125MW) based on 100MW plant
Injune Power Station	-25.842	148.571	34	3.7	13.7	127	20.30	5.08	Scaled from Condamine PS (125MW) based on 100MW plant
Spring Gully Power Station	-25.521	149.000	34	3.7	13.7	127	202.96	50.77	Sourced from PAEHolmes (2011), represented by a single stack
Wandoan Coal Project	-26.124	149.910	5	0.5	5	30	98.36	56.34	Scaled from Cameby Downs Coal Mine