Wheatstone Project
LNG Plant
Works Approval Application
LNG and Domgas Plants

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1.0 INTRODUCTION

The Wheatstone Project LNG Plant (Wheatstone Project) will be one of Australia's largest resource projects, consisting of offshore facilities and onshore domestic gas (Domgas) and Liquefied Natural Gas (LNG) processing plants (Figure 1.0-1).

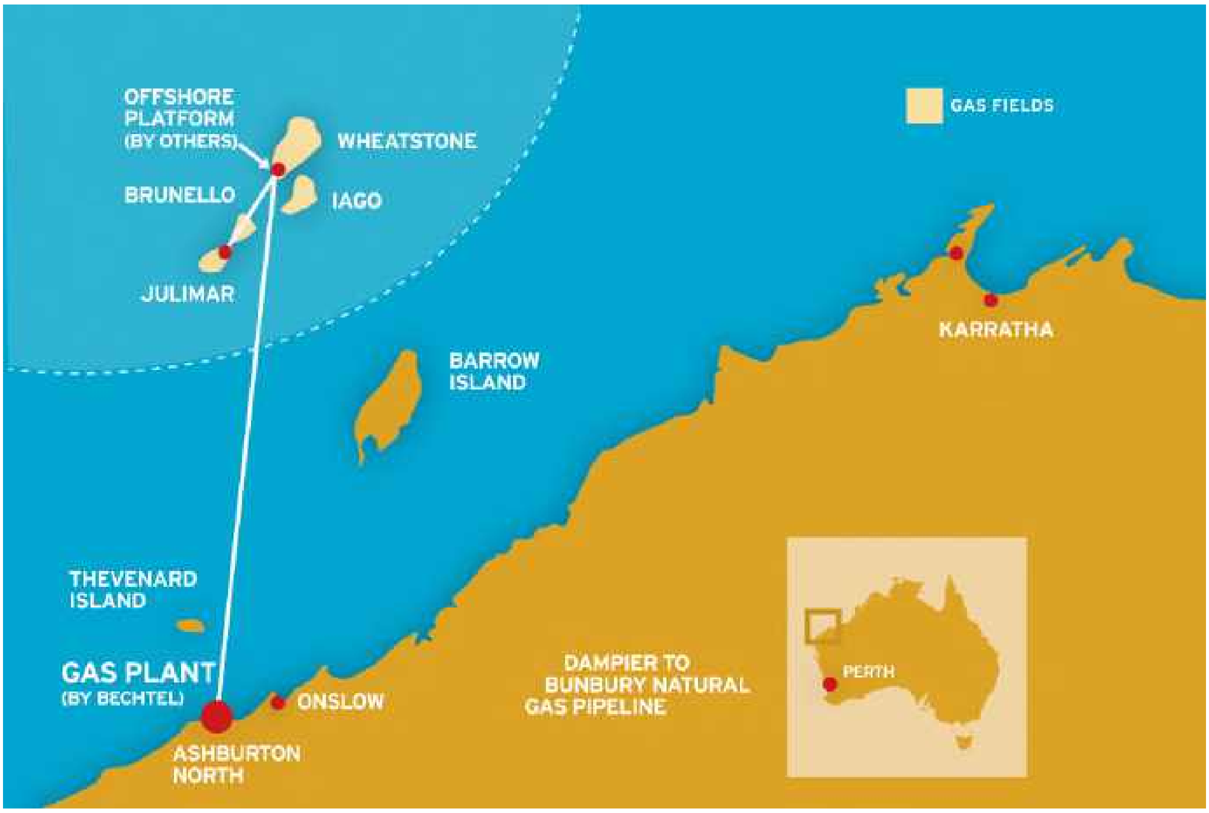

Figure 1.0-1: Wheatstone Project Offshore and Onshore Facilities

Offshore facilities for the Wheatstone Project will be for gas gathering and processing. An offshore platform will initially treat gas and condensate (a low-density mixture of hydrocarbon liquids) which will then be transported via a subsea pipeline to the onshore LNG processing facility.

The onshore facilities of the Wheatstone Project are located on the northwest coast of Western Australia approximately 12 kilometres (km) south-west of Onslow (Figure 1.0-1). The foundation project will consist of two LNG trains, LNG and Condensate Storage Tanks, pipelines, Domgas Plant, accommodation and support facilities. The Wheatstone Project has environmental approval to develop an LNG facility consisting of up to five LNG processing trains. First LNG export is expected in 2016, which will be loaded onto ships via jetty and shipped to international markets.

The onshore Project Area is shown on Figure 1.0-2 and comprises:

- Accommodation Area (Ashburton North Village);
- Project Access Roads;
- Borrow Pits; and
- Plant Site (see Figure 1.0-3)

For more information about the Wheatstone Project please refer to the Draft Environmental Impact Statement / Environmental Review and Management Programme (EIS / ERMP) for the Proposed Wheatstone Project (Chevron Australia Pty Ltd 2010a).

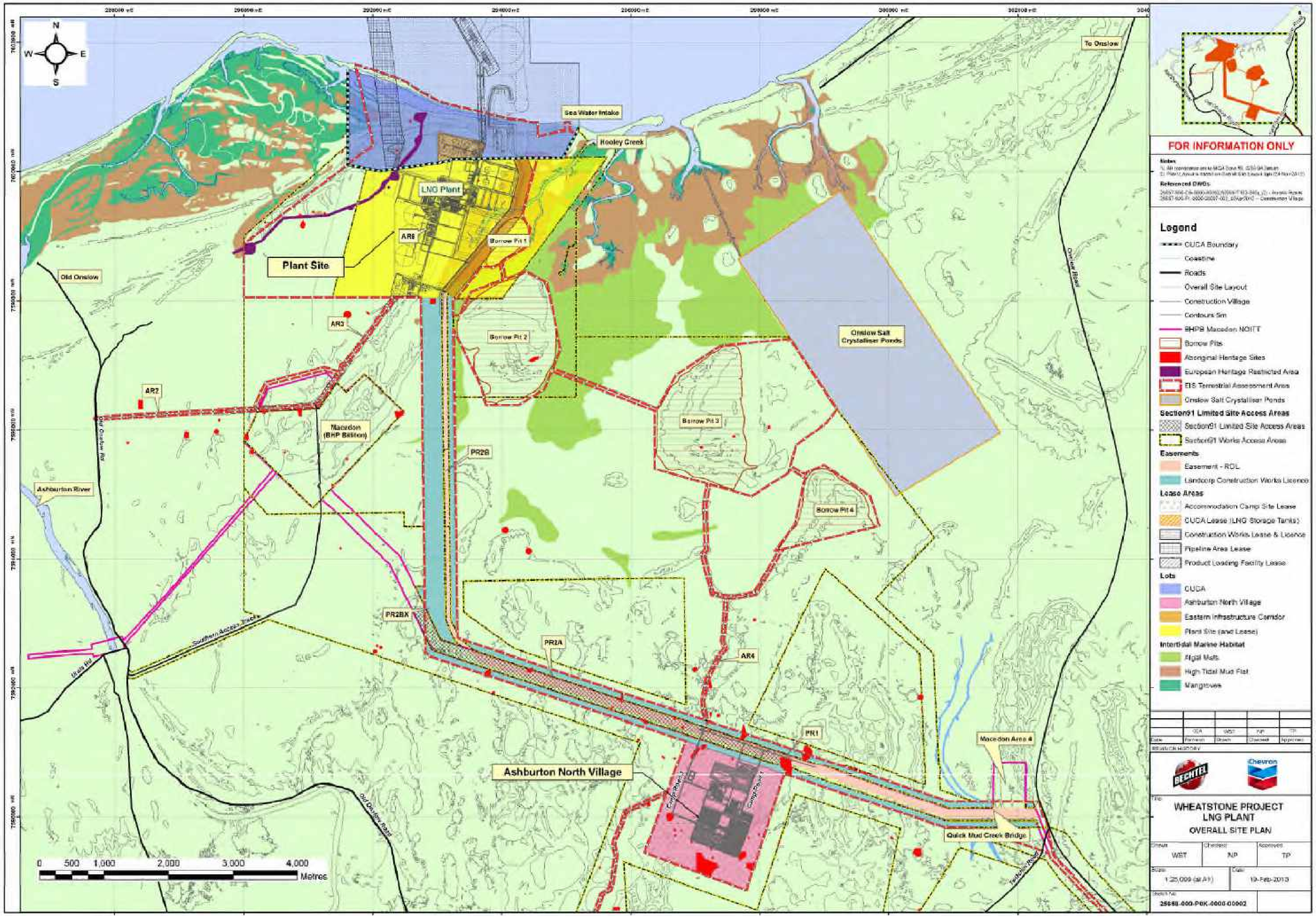

Figure 1.0-2: Layout of the Onshore Wheatstone Project Area Including Plant Site and Ashburton North Village

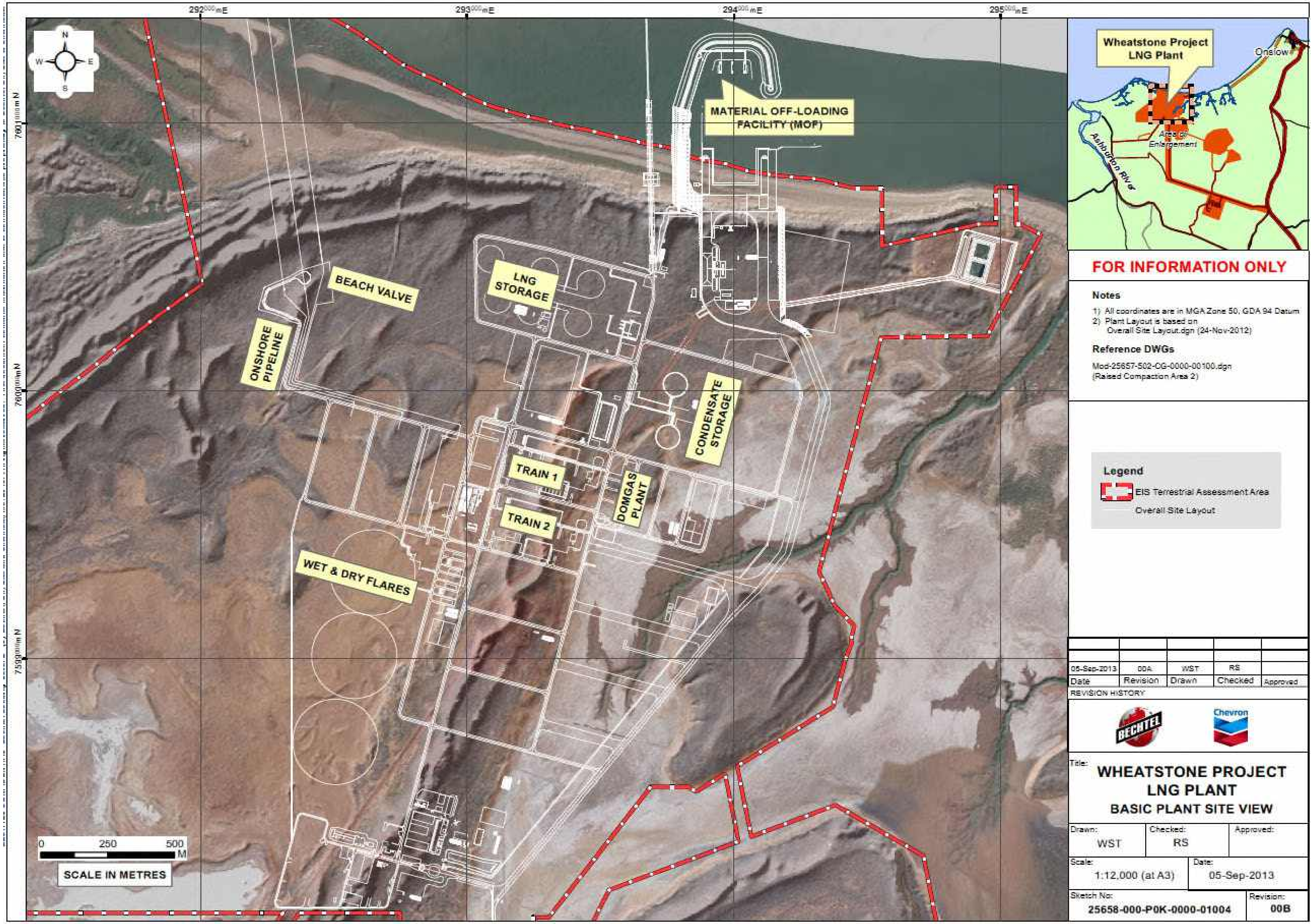

Figure 1.0-3: Layout of the Wheatstone Project LNG Plant Site

1.1 Proponent

Chevron Australia Pty Ltd (Chevron) has engaged Bechtel (Western Australia) Pty Ltd (Bechtel) as the engineering, procurement and construction (EPC) contractor to deliver the LNG Plant and associated facilities of the Wheatstone Project.

Bechtel is a subsidiary of Bechtel Oil, Gas and Chemicals Inc., a world leader in the construction of chemical, petrochemical and LNG plants. Bechtel has designed and / or constructed LNG facilities in Algeria, Indonesia, United Arab Emirates, Libya, Egypt, Trinidad, Angola, Equatorial Guinea and Australia.

Contact details of the proponent are as follows:

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1.2 Document Purpose and Scope

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Domgas Plant

- One Domgas processing train including acid gas removal, dehydration and mercury removal, hydrocarbon dew point control and nitrogen rejection and compression and metering.

Common Utilities and General Facilities

- Utilities including fuel gas and recycle gas systems, power generation, heating media system, flares and vents, diesel storage and distribution and Refrigerant storage.
- Stormwater drainage
- Sewerage and effluent treatment systems (subject to a future WAA)
- Fire and gas protection, air and water systems

- Turbine inlet air humidification (TIAH)
- Nitrogen system

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1.3 Proposed Prescribed Premises Categories

Schedule 1 of the Environmental Protection Regulations 1987 (the Regulations) categorises different activities, which produce significant emissions and discharges that have the potential to cause significant risk to the environment. These activities are divided into a series of numbered prescribed premises categories based upon the significance of emissions and discharges. A works approval is required for the construction of facilities relevant to these activities.

The LNG and Domgas Plants are prescribed by category 10, 34, 52, and 73 of the Regulations (Table 1.3-1). Category 10: Oil and Gas Production from Wells and category 34: Oil or gas refining are triggered by the LNG and Domgas process trains. The onshore LNG plant will produce 8.9 million tonnes (t) per annum of LNG from natural gas extracted from below the seabed, separated and treated to produce purified natural gas. The Domgas Plant will produce 200 terajoule per day of natural gas which will be exported to the Dampier to Bunbury Natural Gas Pipeline for domestic gas supply.

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Table 1.3-1: Applicable Categories of the Regulations

Category No	Category Description	Production / Design Capacity		Premises Fee Component[2]
		Category[1]	Premises	
10	Oil and gas production from wells: premises, whether on land or offshore, on which crude oil, natural gas or condensate is extracted from below the surface of the land or the seabed, as the case requires, and is treated or separated to produce stabilized crude oil, purified natural gas or liquefied hydrogen gases.	5,000 tonnes or more per year	8.9 million tonnes per annum[3]	More than 2,000,000 tonnes per year
34	Oil or gas refining: premises on which crude oil, condensate or gas is refined or processed.	Not applicable	8.9 million tonnes per annum[3]	Not applicable
52	Electric power generation: premises (other than premises within category 53 or an emergency or standby power generating plant) on which electrical power is generated using a fuel.	20 megawatts or more in aggregate (using natural gas). 10 megawatts or more in aggregate (using fuel other than natural gas)	184 MW	More than 100 but not more than 200 megawatts
73	Bulks Storage of Chemicals, etc: premises on which acids, alkalis or chemicals that – Contain at least one carbon to carbon bond; and Are liquid at STP (standard temperature and pressure) are stored.	1,000 cubic metres in aggregate	7, 000 cubic metres	Not applicable

1 From Schedule 1 (Prescribed premises) of the Regulations
2 From Schedule 4 (Licence Fee) of the Regulations
3 Calculated on 'in ship' capacity based on current engineering design

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2.0 PHYSICAL ENVIRONMENT AND LOCATION

The section below provides environmental details of the Wheatstone Project area. The 'project area' is within this section defined as the area within and immediately surrounding the Terrestrial Assessment Area (TAA) (Figure 1.0-2), which includes the proposed prescribed premises.

2.1 Location

The Wheatstone Project area is situated in the Shire of Ashburton, in the Pilbara region, approximately 12 kilometres (km) south west of the Onslow town site (Figure 1.0-2). The Shire of Ashburton covers an area of 105,647 km^2 and accommodates land uses including mining, grazing and fishing. Ashburton North Village is located approximately 8 km away from the prescribed premises. The LNG plant is connected to the Ashburton North Village (Construction Village) by a recently constructed or largely completed road network (see access roads PR1, PR2A, PR2BX and PR2B in Figure 1.0-2).

The terrestrial portion of the Wheatstone Project is located within the Ashburton North Strategic Industrial Area (ANSIA), a new strategic industry precinct currently under development. Two pastoral leases surround ANSIA (i.e. Urala and Minderoo Stations). The Onslow Solar Salt Project, operated by Onslow Salt Pty Ltd, holds a mining lease approximately 3 km east of the LNG Plant site and 6 km north-east of the Ashburton North Village. In addition several exploration and other mining permits / leases are in the area.

2.2 Climate

The Pilbara region has an arid to tropical climate influenced by two air masses - the Indian Tropical Maritime air moving in from the west or north-west during summer and the tropical continental air from inland during winter (Australian Natural Resource Atlas (ANRA) 2009). Average annual rainfall in the Onslow area is approximately 276 millimetres (mm), with most falling in the first half of the year. A pronounced dry period occurs between September and November (Bureau of Meteorology 2012).

Onslow experiences an average maximum summer temperature of 35.7°C and an average minimum winter temperature of 11.7°C (Figure 2.2-1). Evaporation rates in the Pilbara region are highly variable between seasons averaging 135 mm in June and 370 mm in December (Chevron 2011). The average yearly evaporation (about 3,100 mm) exceeds average yearly rainfall consistently throughout the year (Bureau of Meteorology 2012).

The Pilbara region is subject to occasional tropical cyclones, usually between January and April, with a frequency of approximately seven cyclones every decade (ANRA 2009).

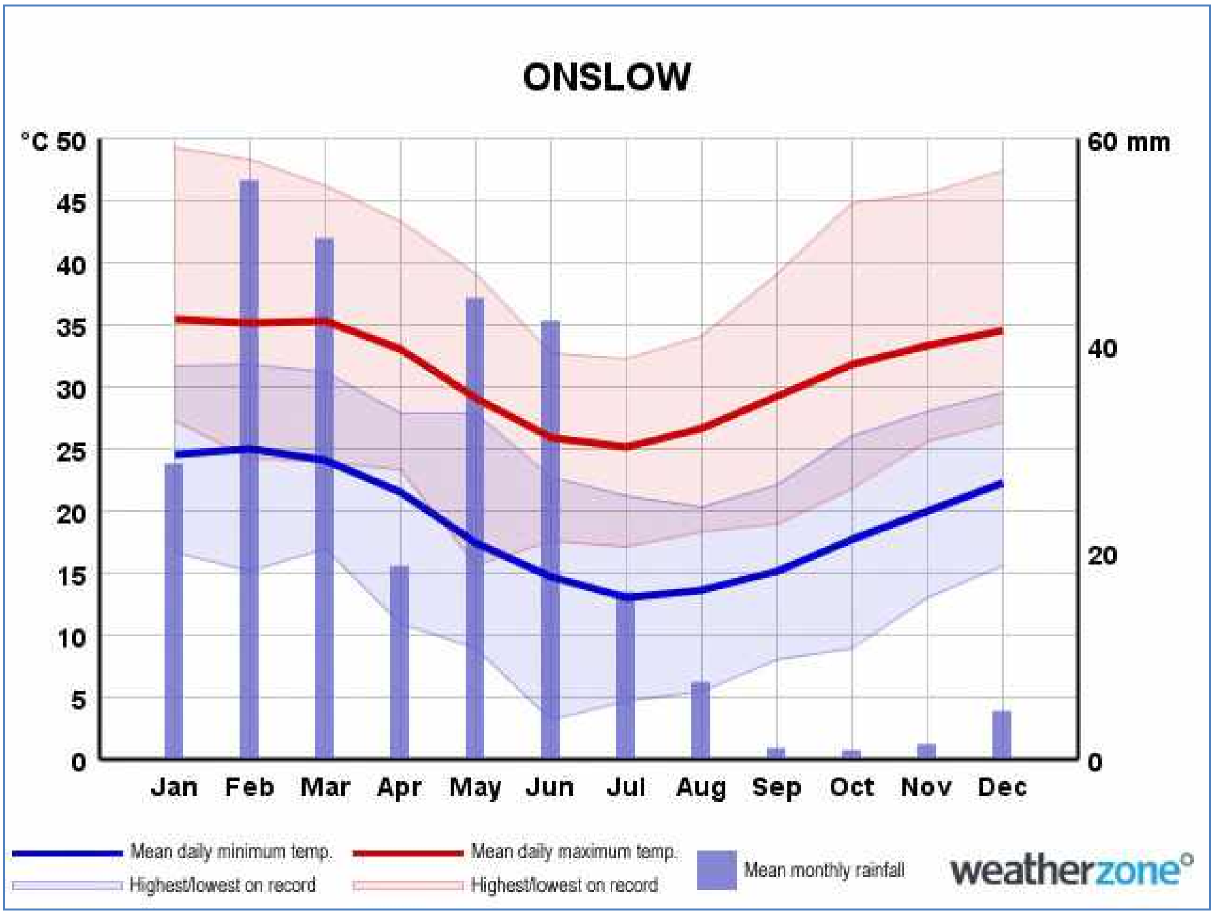

Figure 2.2-1: Climatic Averages for Onslow (Weatherzone 2012)

2.3 Landforms

The topography of the Wheastone Project area is predominately undulating dunal systems, alluvial / colluvial plains and low-lying coastal systems (Chevron 2011). The Wheatstone Project area ranges between 5 to 21 metres (m) Australian Height Datum (AHD) (Landgate 2011). Seven land systems mapped by Payne et al. (1988) were identified in the area surrounding the Wheatstone Project area, two of which are located within the project area:

- RGEONS: Onslow Land System

  Depositional surfaces include sandy plains, with non-saline clay plains subject to sheet flow, narrow drainage zones and minor depressions. Coastal fringes of low sand plains interspersed with slightly less saline samphire flats and minor claypans, coastal dunes and beaches with a relief of up to 20 m in height.

- RGEDUN: Dune Land System

  Depositional surfaces include dune fields, which comprise sand dunes with a relief of up to 15 m in height, and swales with no organised drainage. Minor claypans, swamps and depressions are also identified.

2.4 Hydrology

Below is a description of surface and ground water of the Wheatstone Project area.

2.4.1 Surface Water

The surface water environment of the Wheatstone Project area is influenced by variable seasonal climatic conditions (Chevron 2011). The presence of surface water is predominantly the result of runoff from local sub-catchments during periods of high precipitation. Flood waters from the Ashburton River spill onto the flood plain and may significantly add to the stream flow in the drainage lines of the project area (Chevron 2011). The Ashburton River Delta consists of the Ashburton River Mouth, Southwest, Hooley Creek and northeast sub-catchments. The Wheatstone Project area is located in the Hooley Creek sub-catchment (Figure 2.4.1-1).

A surface water study was undertaken to determine the location of watercourses within the vicinity of the project area was commissioned for the Wheatstone Project (Figure 2.4.1-1). Salinity measured in surface water samples taken from clay pans in the vicinity of the Wheatstone Project area in Mar-2009 was low (200 milligrams per litre [mg/L]), indicating freshwater inundation (URS 2010a). It should be noted that some clay pans in the vicinity of the project area are hyper-saline.

2.4.2 Ground Water

A groundwater study of the project area was undertaken by URS (2010b) to understand the local groundwater parameters. The study identified that the stabilised groundwater levels for the project area was approximately 0.5 m below the Australian Height Datum (AHD), noting that depth to groundwater varies above and below 0.5 m across the project area. The project area is generally a groundwater discharge zone i.e. groundwater is generally pressurized and rises to the surface.

URS (2010b) concluded that local groundwater is brackish to hypersaline, near neutral to slightly alkaline and a sodium–chloride type. Dissolved metal concentration in the groundwater exceeded the Australian and New Zealand Environment and Conservation Council (ANZECC 1997) guidelines in many of the monitoring bores, which is commensurate with local groundwater salt concentrations and high groundwater salinity. The premises is not located within a Public Drinking Water Source Area (Department of Water (DoW) 2010).

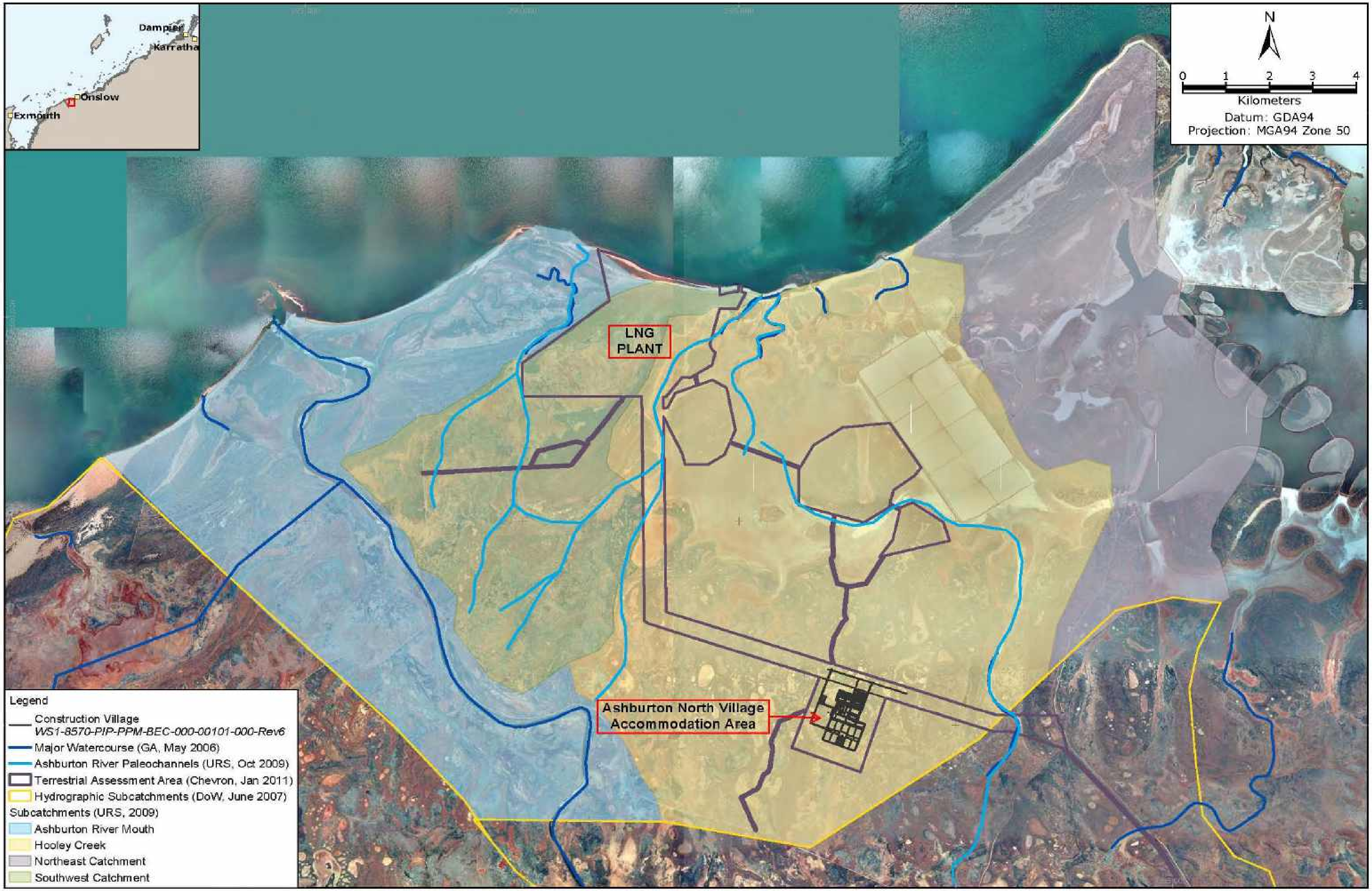

Figure 2.4.2-1: Major Watercourses and Sub-catchments in Close Proximity to the Prescribed Premises

2.5 Flora and Vegetation

The Wheatstone Project area is located within the Carnarvon (CAR) bioregion (Department of the Environment, Water, Heritage and the Arts (DEWHA) 2006). The CAR bioregion has a low and gently undulating landscape with open drainage. Vegetation is mainly acacia and saltbush / bluebush shrubland, with areas of tussock grassland in the north.

The Wheatstone Project area lies within the Carnarvon Botanical District of the Eremaean Botanical Province, as defined by Beard (1975). The vegetation of this province is typically open and frequently dominated by spinifex, acacia and occasional eucalypts.

Numerous baseline flora and vegetation surveys have been undertaken for the greater Wheatstone Project. Of these, the LNG Plant study area (a portion of the greater Wheatstone study area, which encompasses the TAA and surrounds) was surveyed in April 2009 (Biota Environmental Sciences Pty Ltd (Biota) 2010). Three priority listed species were identified within the LNG Plant study area:

- *Triumfetta echinata*; a Priority 3 listed species was identified within the central part of the precinct. This species is only restricted to red sand dunes however it is widespread throughout the local area (Biota 2009).
- *Eremophila forrestii* subsp. viridis; a Priority 3 listed species was identified in the northern portion of the precinct. This particular sub-species is thought to be restricted to the Onslow area, though has been identified in multiple locations outside the study area (Biota 2010; Chevron 2010a).
- *Atriplex flabelliformis*; a Priority 3 listed species was identified in the southern section of the precinct. This species has been recorded from a small number of sites, however, it has a wide distribution through the Pilbara to the Great Sandy Desert and Tanami bioregions.

Eleven non-native species were identified within the LNG Plant study area. Three of these; *Prosopis pallida, Prosopis glandulosa, and Parkinsonia aculeata* are classified as declared weeds under the *Agriculture and Related Resources Protection Act 1976* (Biota 2010). *Prosopis pallida and Prosopis glandulosa* are widespread within the LNG Plant study area (Biota 2010). No occurrences of threatened flora nor threatened or priority ecological communities (meaning communities that are at risk of becoming a Threatened Ecological Community), were recorded in the Wheatstone Project area during the field surveys (Biota 2010).

2.6 Fauna

Terrestrial fauna and habitats were surveyed within the Wheatstone study area (Biota 2010). Six fauna habitats were considered to be present within the entire LNG Plant study area. These include:

1. Primary Dune: *Spinifex* and *Triodia* grassland and buffel tussock on primary dune;
2. Sand / Loam plains: *Acacia sp*. over *Triodia epactia* hummock grassland on sand / loam plain;
3. Samphire: Samphire on claypan;
4. Inland Dune: *Trioda epactia* dominated hummock grassland on inland dune system;
5. Tussock on Clay: Tussock grassland on clay pan; and
6. Drainage: *Eucalyptus* sp. And buffel tussock dominated drainage line.

The terrestrial fauna survey identified that there were 25 species of conservation significance that occurred or had the potential to occur within the TAA. However, the habitat types associated with these species was considered to be well represented within the locality and in the wider region. Twelve species were listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and were not associated with or dependent upon the terrestrial habitats considered in the Wheatstone study area (Biota 2010).

2.7 Existing Air Quality

Ambient air quality around the town of Onslow is likely to be influenced by ocean sources, biogenic emissions, particulate matter less than 10 micrometres in diameter (PM_{10}) and regional smoke (SKM 2010). The main sources of volatile organic compounds (VOC), nitric oxide and nitrogen dioxide (NO_X) emissions is likely to be sourced from biogenic and burning / wildfire sources (SKM 2003).

Existing dust at Ashburton North is predominantly windblown with some minor anthropogenic sources including dust produced by vehicles on unsealed roads in the area. Dust levels are seasonally variable due to distinct wet and dry seasons. Dust levels within the TAA were on average 13.8 micrograms (μg)/m^3 (Chevron 2010a).

3.0 REGULATORY APPROVALS AND LICENCES

Below is a summary of significant legislation and guidelines that the Wheatstone Project will operate under.

3.1 *National Greenhouse and Energy Reporting Act 2007*

The *National Greenhouse and Energy Reporting Act 2007* (the NGER Act) includes a legal requirement for the reporting and distribution of information about greenhouse gas (GHG) emission, GHG projects and energy use and production of corporations. The Wheatstone Project is required to report GHG on an annual basis.

3.2 *Planning and Development Act 2005*

The prescribed premises is located within Ashburton North Strategic Industrial Area (ANSIA) estate. The State Government created ANSIA estate under the Planning and Development Act 2005 to cater for heavy industry for multiple proponents and related downstream opportunities (Department of State Development (DSD), 2010). ANSIA estate will include a multi-user port facility, land areas for proponents and infrastructure to accommodate LNG and other hydrocarbon-based processing and natural gas processing for Domgas supply (DSD 2010).

In Oct-2011, the Shire of Ashburton adopted the ANSIA Structure Plan and submitted the plan to the Western Australian Planning Commission (WAPC) for endorsement. The structure plan was endorsed and subsequently Town Planning Scheme No. 7 was amended under the *Planning and Development Act 2005* to include the ANSIA Structure Plan.

The Pilbara Joint Development Approval Panel (JDAP) granted Planning Approval for the LNG and Domgas Plants on 10-Jul-2013.

3.3 *Environmental Protection Act 1986* Part IV and EPBC Act

The environmental impact assessment (EIA) process for the Wheatstone Project commenced in Sep-2008 when the Wheatstone Project proposal was formally referred to the Environmental Protection Authority (EPA) and the Department of the Environment (DOTE). The EIA process is administrated by the EPA and DOTE under the *Environmental Protection Act 1986* (EP Act) and EPBC Act respectively.

Both agencies agreed to a coordinated environmental assessment process, under which, a single Draft EIS) / ERMP document was developed to satisfy the requirements of each agency The Wheatstone Project was given final environmental approval under the EP Act via Ministerial Statement (MS) No. 873 (MS 873), which was published on 30-Aug-2011, and as amended by MS 903, 922 and 931and EPBC Act via Referral Approval EPBC 2008/4469, published on 22-Sep-2011.

Condition 18 of MS 873 regulates emissions to air and is activated by the LNG and Domgas Plants.

<u>18 Emissions to Air</u>

18-1 The Proponent shall install equipment in the LNG Plants and Domgas Plants and manage ongoing operations such that best practice for a liquefied natural gas / domestic gas facility is achieved in respect of:

i. minimising emissions of volatile organic compounds and oxides of nitrogen emissions;
ii. optimising the smokeless capacity of flares so as to minimise the frequency and duration of visible smoke; and
iii. minimising non emergency flaring of gas.

18-2 As part of its Works Approval application under Part V of the EP Act for the Wheatstone Project and also for Works Approval applications for subsequent LNG trains, the Proponent shall provide reports to DER showing:

i. specific design features that have been used to minimise and monitor emissions to air, pursuant to condition 18-1;
ii. how the design features compare with current lowest emissions for similar operations and proposals internationally and within Australia; and
iii. a peer review report as required by condition 18-3.

18-3 The Proponent shall commission peer reviewer(s), approved by the CEO to undertake the following, in accordance with terms of reference also approved by the CEO:

i. a review of the reports referred to in condition 18-2(i) and (ii);
ii. provide comment on the basis and validity of the conclusions in the reports; and
iii. provide comment on the relevance of the described Australian and international standards for this Proposal.

The report and peer review required by Conditions 18-1 and 18-2 have been attached to this report (Appendices A & B, respectively).

3.4 *Environmental Protection Act 1986* Part V

Clearing of native vegetation is typically regulated by Part V of the EP Act. Clearing of flora and vegetation within the TAA has been addressed and approved under Part IV of the EP Act via MS 873 and therefore a permit is not required under Part V of the EP Act.

Environmental Regulation by works approvals and licences is dealt with by Part V of the EP Act. A works approval and licence is required to construct or operate a prescribed premises respectively. Bechtel is the applicant for this works approval application, as Bechtel will have operational control of the Wheatstone Project during construction and commissioning after which Chevron will assume operational control.

Table 3.4-1 is a record of other regulatory works approvals and licences obtained by Bechtel for the Wheatstone Project to date. Other work approvals and licences for the Wheatstone Project will be obtained by Chevron and Bechtel subcontractors and are not included here.

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Noise at the LNG and Domgas Plants is regulated by subsidiary regulations of the EP Act the Environmental Protection (Noise) Regulations 1987 (Noise Regulations). Construction works including sandblasting and metal coating is to be managed in accordance with the Environmental Protection (Abrasive Blasting) Regulations 1998 and the Environmental Protection (Metal Coating) Regulations 2001 accordingly.

3.5 *Rights in Water and Irrigation Act 1914*

The *Rights in Water and Irrigation Act 1914* prescribes the extraction of ground and surface water. No ground and surface water use is expected from the proposed prescribed premises during construction or operation of the LNG and Domgas Plants.

3.6 *Dangerous Goods Safety Act 2004*

Storage of hydrocarbons is governed under the *Dangerous Goods Safety Act 2004* (DG Act) and subsidiary regulations Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007 (DG Regulations) and Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007, administered by the WA Department of Mines and Petroleum (DMP).

During construction diesel and other chemical storage within the prescribed premises will be above or below DG Regulation licence quantities. Bechtel will obtain a DG licence for individual facilities during the construction period of the Wheatstone Project.

LNG and Domgas Plants will require a Major Hazard Facility (MHF) Licence prior to commissioning of the LNG and Domgas Plants. Bechtel is currently assembling the safety report for the Wheatstone Project. The safety report forms the basis for obtaining a MHF licence for all relevant permanent infrastructure including those licences under the DG Regulations.

DMP have released a Code of Practice for the Storage and handling of dangerous goods (DMP Code of Practice). Storage of environmentally hazardous materials will be compliant with the DMP Code of Practice.

3.7 Relevant Standards and Environmental Guidelines

Industry standards and guidelines developed for the safe and effective construction and operation of LNG and Domgas Plants that have been used and considered include:

- American Society of Mechanical Engineers (ASME) 2012. B31.3-2000 Process Piping
- ASME PD442 - BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels
- American Petroleum Institute (API) 650: Welded Steel Tanks for Oil Storage
- API 1104: Standard for Welding Pipelines and Related Facilities
- WA Department of Consumer and Employee Protection. 2008. Storage and Handling of Dangerous Goods – Code of Practice
- *NSW Government Gazette, Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010*

- Standards Australia. 2004. AS 1940:2004 The Storage and Handling of Flammable and Combustible Liquids
- Standards Australia. 2005. AS 3961:2005 Storage and Handling of Liquefied Natural Gas
- Standards Australia. 2007. AS 2885.2:2007 Pipelines-Gas and liquid petroleum, Part 2: Welding
- Standards Australia. 2007. AS 3580.1.1:2007 Methods for Sampling and Analysis of Ambient Air - Part 1.1: Guide to Siting Air Monitoring Equipment

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Figure 4.1.6-1: LNG Plant Block Flow Diagrams

4.2 Domgas Plant Units

The Domgas plant units consist of:

- Acid gas removal
- Hydrocarbon dew point control and nitrogen rejection
- Compression and metering
- Dehydration and mercury removal

4.2.1 Physical Description

A physical description of Domgas Plant units is provided below.

4.2.2 Acid Gas Removal Unit

The AGRU system is designed to remove acid gas components such as CO_2 and H_2S from the feed gas using an aMDEA system. The removed acid gas will be routed to a thermal oxidiser for destruction.

4.2.3 Hydrocarbon Dew Point Control and NRU

The HC dew point requires control to prevent the formation of liquids during pipeline gas transportation. The treated feed gas is cooled and then flashed (allowed to expand by reducing pressure) through a Joule-Thompson Valve (or equivalent process) to condense HC liquid and meet the product dew-point specification. The HC liquid is routed back to the inlet facilities for re-processing.

To meet the Domgas' inert gas content specification, N_2 must be removed from the gas. A slip stream of treated gas is taken from the dew point control unit and sent to a NRU where N_2 is cryogenically separated from methane and then vented to the atmosphere. The N_2 free gas stream is blended with the rest of the treated gas stream from the dewpoint control unit.

4.2.4 Compression and Metering

Once treated to meet sales specifications, the domestic supply gas is compressed, metered and sent to the distribution pipeline.

4.2.5 LNG Revapourisation

Domgas availability and continued delivery of domestic gas during extended outages such as planned Domgas Plant or Wheatstone Project platform turnarounds requires the use of a LNG revapourisation unit. The LNG revapourisation unit takes LNG from either of the LNG storage tanks to produce natural gas. A submerged combustion vapouriser is used to regasify the LNG. This will be operated only when there is no feed gas available from the offshore facilities.

4.2.6 Process Description

A simplified process description of the Domgas Plant is shown in Figure below.

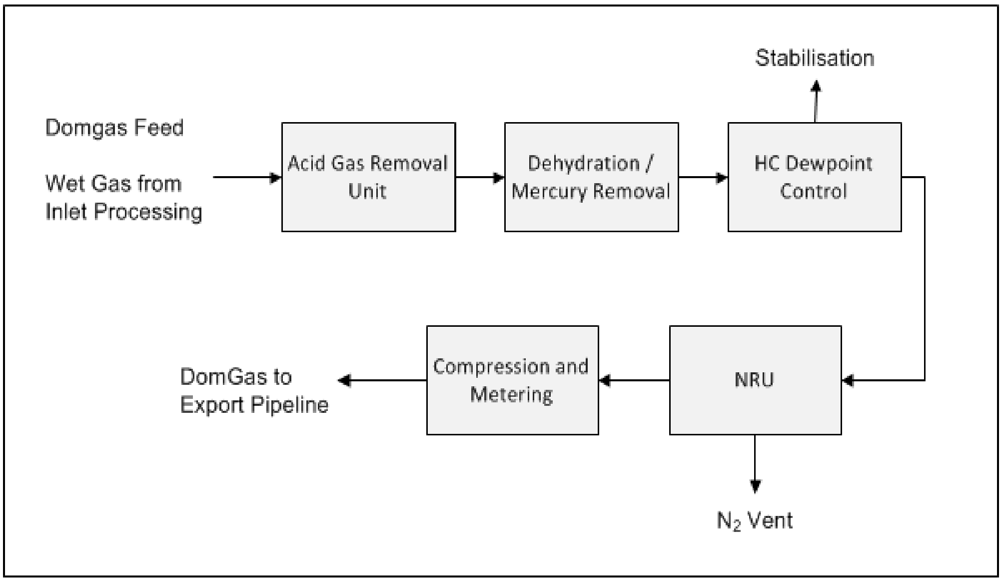

Figure 4.2.6-1: Domgas Plant Block Flow Diagram

4.3 Utilities and General Facilities

The following utilities and general facilities will be required to support the LNG and Domgas Plants.

- Fuel gas and recycle gas system
- Power generation system
- Heating medium system
- Pressure relief / liquids disposal
- Flare and vent systems
- Diesel storage and distribution
- LNG and condensate products storage (W5480/2013/1) and export facilities

- Refrigerant storage unit
- Stormwater drainage
- Sewerage and effluent treatment systems (subsequent WAA)
- Fire and gas protection systems
- Plant and instrument air system
- Water system
- Turbine inlet air humidification
- Nitrogen system

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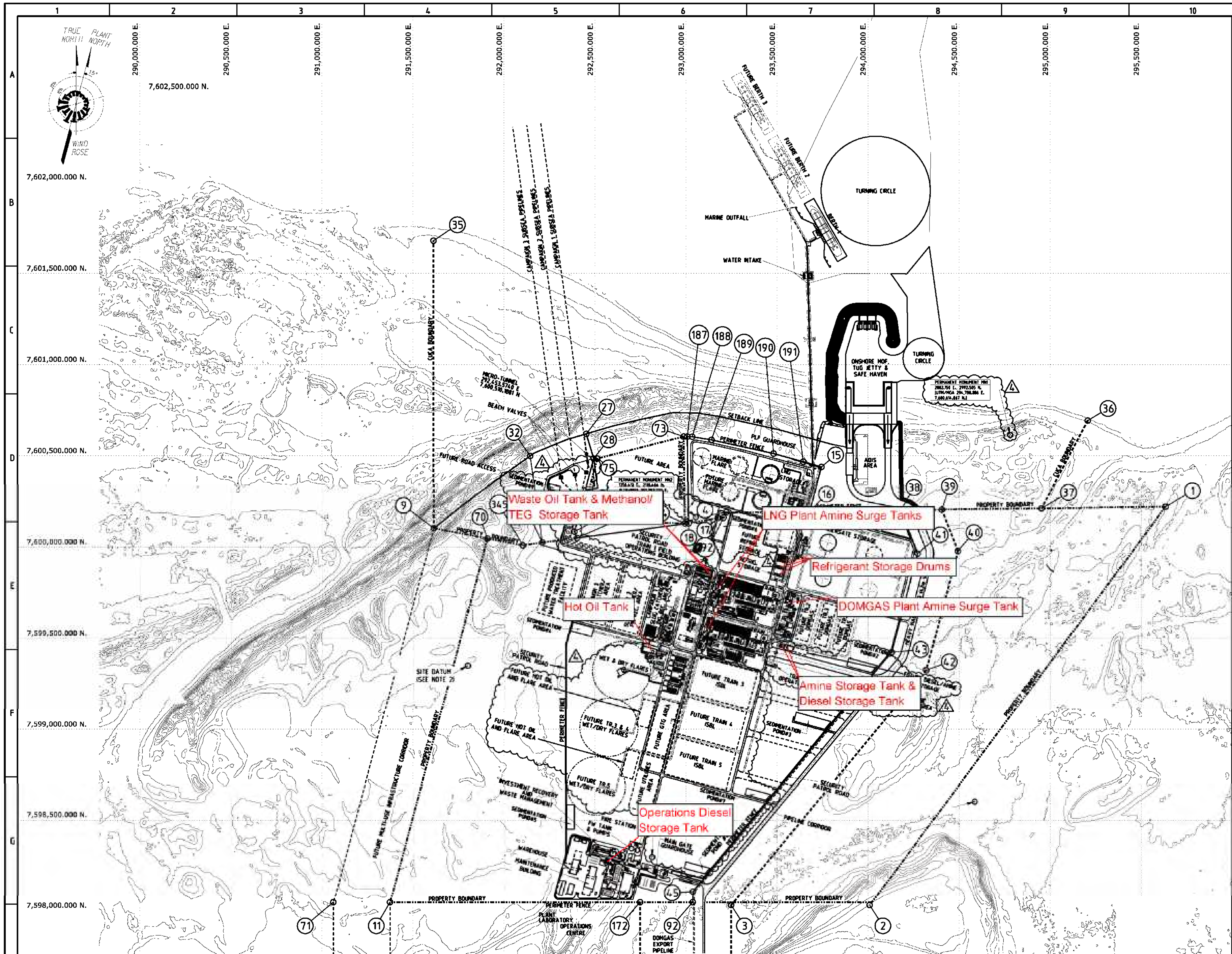


BOUNDARY COORDINATES

POINT ID	EASTING	NORTHING
1	E. 295633.000	N. 7600220.000
2	E. 294009.000	N. 7598034.000
3	E. 293248.000	N. 7598034.000
4	E. 293220.000	N. 7600189.000
9	E. 291613.000	N. 7600103.000
11	E. 291374.000	N. 7598050.000
15	E. 293744.000	N. 7600439.000
16	E. 293678.000	N. 7600194.000
17	E. 293174.000	N. 7600160.000
18	E. 293013.000	N. 7600130.000
27	E. 292452.000	N. 7600620.000
28	E. 292493.000	N. 7600485.000
32	E. 292144.000	N. 7600499.000
35	E. 291613.000	N. 7601679.000
36	E. 295207.000	N. 7600693.000
37	E. 294952.000	N. 7600211.000
38	E. 294179.000	N. 7600201.000
39	E. 294404.000	N. 7600204.000
40	E. 294493.000	N. 7599978.000
41	E. 294272.000	N. 7599965.000
42	E. 294319.000	N. 7599325.000
43	E. 294128.000	N. 7599424.000
45	E. 293037.000	N. 7598109.000
70	E. 291908.000	N. 7600046.000
71	E. 291063.000	N. 7598050.000
73	E. 292987.000	N. 7600605.000
74	E. 292993.000	N. 7600130.000
75	E. 292513.000	N. 7600485.000
76	E. 292421.000	N. 7600140.000
85	E. 292385.000	N. 7600084.000
92	E. 293037.000	N. 7598050.000
172	E. 292748.000	N. 7598050.000
187	E. 293007.000	N. 7600605.000
188	E. 293034.000	N. 7600604.000
189	E. 293140.000	N. 7600587.000
190	E. 293481.000	N. 7600512.000
191	E. 293644.000	N. 7600467.000
192	E. 293204.000	N. 7600160.000
345	E. 292101.000	N. 7600009.000
346	E. 292400.000	N. 7600049.000
347	E. 292210.000	N. 7600024.000

NOTES:
1. ALL COORDINATES ARE IN METERS.
2. PLANT COORDINATES 250.000 E, 1000.000 N, EL. 100.000 ARE EQUIVALENT TO 291,800.000 E, 7,599,350.000 N, AHD EL. 7.000, MGA ZONE 50, GDA 94 DATUM.

0 200 400 600 800 1000
SCALE IN METRES

WHEATSTONE PROJECT
LNG PLANT
OVERALL SITE PLAN
2 X 4.45 MTPA
TRAIN 1 & 2
BECHTEL DRAWING NO. 25657-000-P1-0000-00001 REV. 002
SCALE NTS
CLIENT DOCUMENT NO. WS1-0000-PIP-PPM-BEC-000-00101-000 REV. 4
A.C.N. 086 197 757
CVX_ENG_A1_BDR.REF

Figure 4.4-1: Indicative Locations of the Major Hydrocarbon and Chemical Storage Equipment

4.5 Wastewater and Surface Runoffs Handling

Variety of wastewaters and surface runoffs are expected from the LNG and Domgas Plants. This section elaborates on the types of water streams, clarifies their different level of contaminants, and further explains respective levels of treatment that will be implemented to minimise potential environmental impacts. Facilities including drainage, sewage and effluent treatment systems are designed to protect land, groundwater and the marine environment from contamination. The handling and treatment system for wastewater and stormwater received from the LNG and Domgas Plants facilities is designed to:

- collect and treat the various wastewater and stormwater runoff streams throughout the LNG and Domgas Plants facility so that the treated wastewater can be eventually discharged to a permitted effluent discharge outfall and the concentrated wastewater solids produced by the treatment processes can be disposed off-site in appropriately licensed and approved facilities.
- collect and appropriately treat stormwater runoffs as the facility will be subject to periods of intense rainfall, and some of the runoff may be contaminated.

Water streams will therefore be discussed in two main categories of i) Wastewater, and ii) Stormwater and / or Surface Runoffs. A flow diagram for water stream handling and treatment system for the Wheatstone Project permanent facilities illustrated in Figure 4.5-1, and the remainder of this section describes those relevant to the scope of this WAA.

4.5.1 Wastewater

Wastewater streams will be segregated according to the classification and the type of pre-treatment and/or treatment process required. The expected wastewater from Wheatstone LNG Plant permanent facilities are accordingly categorised as below:

- Process wastewater
- Sanitary wastewater

<u>Process Wastewater</u>

Process wastewaters are water streams which are contaminated or have the potential for contamination with oil and hydrocarbons. The sources of process wastewater include:

- Drains from machinery base plates
- Water drawoffs and blowdowns for vessels containing hydrocarbons
- Maintenance drains
- Effluent from Wet Gas KO drums
- Combustion turbine detergent washings and drains from compressor area collection tanks
- Combustion turbine detergent washings and drains from power generation area
- Wastewater from Acid Gas Thermal Oxidizer KO drum
- Wash down from Gas turbine generator area
- Discharges from Stabilizer system
- Discharges from Dehydration Unit and AGRU systems

- Blowdown of wastewater contaminated with soluble amine from the AGRU

Process wastewater flow rates and concentration of contaminants are variable. The streams will be collected in oily wastewater lift stations and sent to the primary treatment units for treatment by pumps operated on level control. The primary treatment units include Corrugated Plate interceptor (CPI) system, Dissolved Air Flotation (DAF) system, and DAF Effluent Filters as shown in Figure 4.5-1 and will be described in Section 4.5.3.

Sanitary Wastewater

Sanitary sewage flows from various buildings, such as field operations center, operations, laboratory, fire station, product loading facility, permanent village, canteen, and other buildings are collected in sanitary lift stations. Each lift station is provided with spared pumps designed especially for sewage pumping. These pumps are operated on level control. Under normal conditions, only one pump per lift station will be operating, the other will be a stand-by. Sewage collected in operating site will be pumped to the Permanent Sanitary Treatment Plant. The STP and associated permanent ocean outfall, as highlighted in Figure 4.5-1, will be included in a subsequent works approval application.

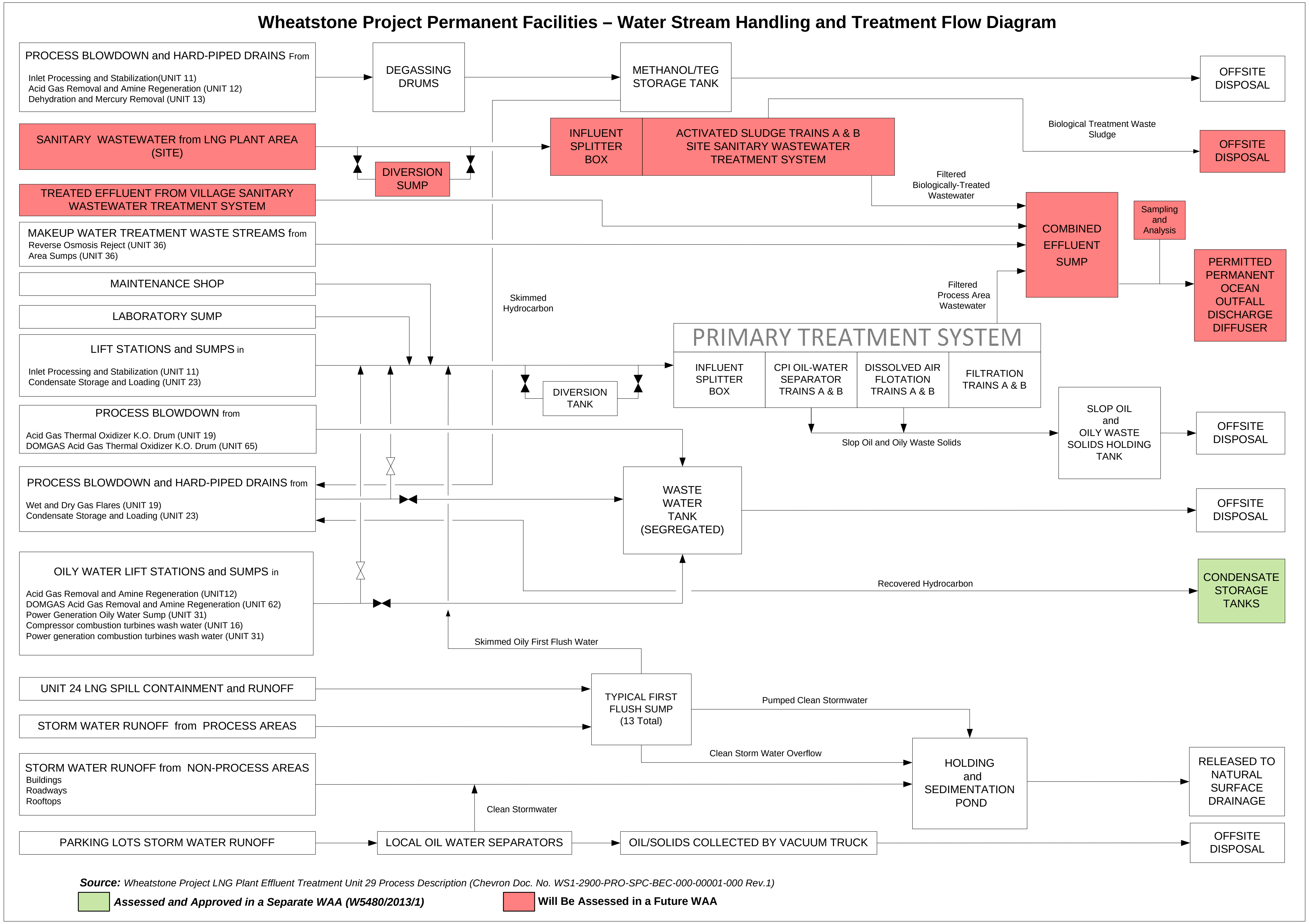


Figure 4.5.1-1: Wheatstone Project Permanent Facilities – Water Stream Handling and Treatment Flow Diagram

4.5.2 Process Wastewater Treatment

Process wastewater and contaminated stormwater are designed to be treated by two treatment trains (referred to as Trains A and B in Figure 5.4-1). A flow splitter box is utilized to receive flow from oily water lift stations, process unit sumps and first flush sumps and split the flow evenly to each CPI oil/water separator train.

The Primary Treatment System receives process wastewater and contaminated stormwater from process areas and is used to remove free oil and suspended solids prior to sending it to the pressure media filter for further removal of fine suspended solids. A diversion tank is provided upstream of the CPI which will have the capacity to store 17 hours of wastewater from the plant in the event that any of the primary treatment equipment is out of service for maintenance. The diversion sump is normally bypassed. Process units utilized in the Primary Treatment System include:

- Corrugated Plate Interceptor (CPI) System: The wastewater is pumped continuously at a controlled rate by the CPI feed pump to the CPI unit. Reduced flow velocity in the CPI allows free oil and low specific gravity particles to rise to the top and heavier solid particles to settle on the bottom of the separator. Free oil and other floating hydrocarbons overflow by gravity into the CPI oil reservoir. The recovered oil is then pump to the Waste Oil Tank. The settled solids in the CPI are pumped to the Sludge Holding Tank to allow further solids concentration. The concentrated solids are then hauled out by a vacuum truck for disposal offsite at an appropriately approved / licensed facility. The water draw from the tank is recycled back to the CPI system via the DAF Filter Backwash Sump and the Flow Splitter Box.
- Dissolved Air Flotation (DAF) System: Effluent from the CPI is routed to the DAF Surge Tank where the effluent is then pumped continuously at a controlled rate feeding to the DAF system. Polymer is added at the DAF inlet feed line to aid in breaking emulsions and to facilitate flocculation of the colloidal suspended solids and oils. A portion of the DAF clarified effluent is pressurised with air in the DAF saturation tank. The dissolved air flotation system blends recycled effluent saturated with air, at elevated pressure, with the incoming coagulated wastewater to release microscopic air bubbles that cling to the oils and solids particles forcing them to float to the top of the flotation cell where they are skimmed off into the DAF Float Reservoir. The removed float is then pumped to the Waste Oil Tank. Heavier solids settled in bottom of the DAF will be transferred to the Sludge Holding Tank. The DAF treated effluent flows by gravity into the DAF effluent tank where it is then pumped to the DAF Multimedia Effluent Filter for further effluent polishing.
- DAF Multimedia Effluent Filter: Effluent from the DAF Effluent Tank is pumped through downflow multimedia filters to remove oil and grease and suspended solids. The multimedia filter has anthracite in the top layer, sand in the middle, and garnet gravel on the bottom. When impurities collect in or on the media bed, a backwash cycle cleans the filter. The filtered water is then sent to the final treated effluent sump for release to the permitted outfall discharge diffuser along with the other treated wastewater streams.

4.5.3 Stormwater and Surface Runoffs

The design philosophy for the stormwater and surface runoffs system is to control stormwater runoffs discharges to prevent and mitigate impacts to the surrounding environment. The design incorporates measures to:

- prevent contamination of the surrounding environment from stormwater collected at the LNG Plant site
- collect and segregate stormwater for suitable treatment and/or disposal as appropriate
- prevent and control erosion and sedimentation.

The intent of the system is to segregate stormwater runoffs areas of different risk contamination. This includes four categories of stormwater:

- Contaminated runoffs
- Potentially contaminated runoffs
- On-site clean (uncontaminated) runoffs
- Intercepted off-site clean runoffs.

Contaminated stormwater runoffs are surface runoffs that occur from areas that have high risk of contamination. Runoffs from the LNG and Domgas plant process areas and areas that are involved in handling of hydrocarbons are considered contaminated. Runoffs from other areas that have a moderate to low risk of contamination are considered potentially contaminated. Areas in this category include the storage tank diked areas, car parks and other smaller miscellaneous areas. Clean (uncontaminated) runoffs are those associated with low risk areas where contaminants are unlikely to exist. These areas consist of unpaved areas, roadways, rooftops, occupied buildings, etc.

An overview of the system is shown in Figure 4.5.3-1. Figure 4.5.3-2 provides a schematic diagram delineating different stormwater pathways (within the scope of this WAA) with respective treatment designed for each pathway.

<u>Stormwater from the Process Areas</u>

The first 25 mm of stormwater runoffs from process areas are collected in first flush sumps located in various areas throughout the facility. Runoffs in excess of the first 25 mm are considered clean and diverted by an overflow weir to a sedimentation pond. Following a storm event water collected in the first flush sumps is sampled to determine if it is contaminated or clean. Sampling and analysis is proposed to be performed for pH, Turbidity and Total Petroleum Hydrocarbons (TPH). The proposed water quality target criteria for these contaminants are below. Water meeting these criteria is considered as clean and is forwarded to the sedimentation ponds. Water not meeting these criteria is considered as contaminated and is forwarded to the Primary Treatment System.

- pH: 6 – 8
- Turbidity: 370 NTU
- TPH: 15 mg/L

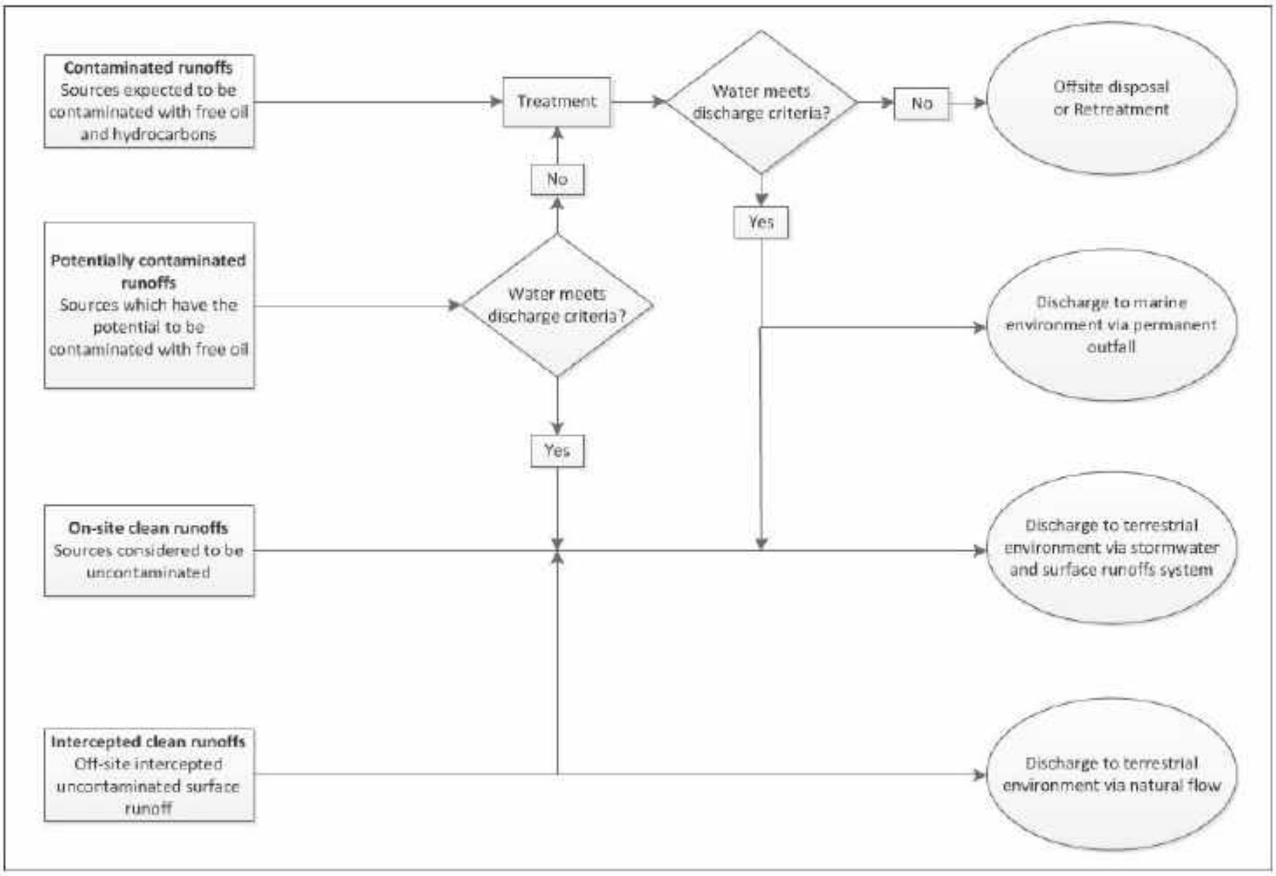


Figure 4.5.3-1: LNG and Domgas Plants – Overview of the Stormwater System

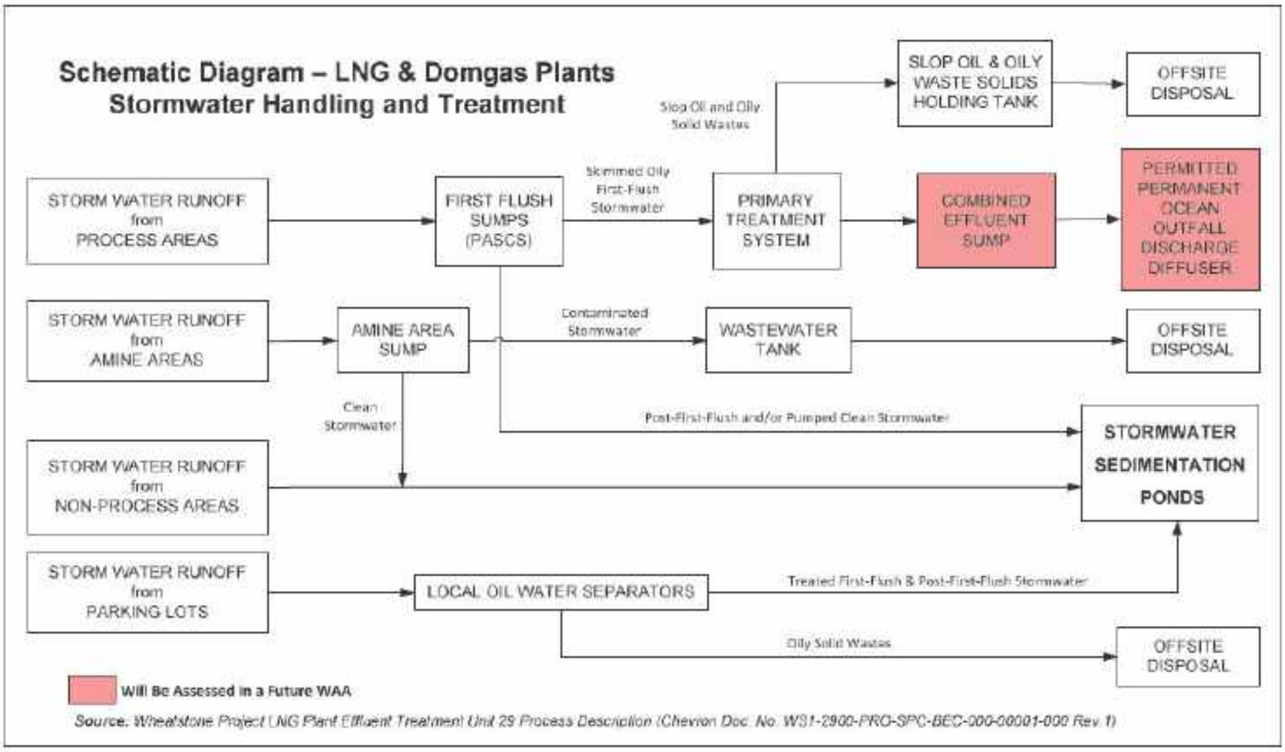


Figure 4.5.3-2: LNG and Domgas Plants – Stormwater Handling and Treatment

Stormwater from the Primary Treatment System

Contaminated stormwater runoffs treated at the Primary Treatment System are sampled and monitored accordingly via continuous or composite sampling similar to the approach previously approved for the construction marine outfall prior to being directed to the Combined Effluent Sump and then to the marine outfall, once available. Target water quality criteria are to be prescribed via a separate (future) WAA.

Stormwater from Amine Area

Stormwater runoffs from the Amine Storage Containment Area drain to the Amine Area Sump. Under normal operating conditions, contamination is not expected in this area. If the stormwater runoffs are deemed clean via inspection the runoffs will be released to the stormwater and surface runoffs system via a valve. If amine contamination is detected via inspection then the runoffs will be collected from the sump for offsite disposal at an approved licensed facility.

Stormwater from Non-Process Areas

Stormwater runoffs from non-process areas including, but not limited to, unpaved areas, roadways, rooftops, occupied buildings, etc., are deemed clean (uncontaminated) and suitable for discharge without treatment. These runoffs are captured by the stormwater and surface runoffs system and routed to stormwater sedimentation ponds for controlled release to the environment.

Stormwater from Parking Lots

Stormwater runoffs from parking areas are considered potentially contaminated. Unlike other areas considered potentially contaminated that are directed to first flush sumps, runoffs from parking areas will be routed through drainage ditches equipped with in-line oil and sediment traps. These traps shall partially filter free oil and turbidity from the runoffs prior to the runoffs entering the stormwater and surface runoffs system.

Stormwater from Sedimentation Ponds

The control of stormwater runoffs from the LNG Plant site is through proper segregation and treatment as appropriate dependent upon contamination risk. Stormwater runoffs will either be released to the marine environment after treatment, to the terrestrial environment via the sedimentation ponds, or will be collected for offsite disposal at an approved licensed facility.

Stormwater from non-process areas, treated stormwater from parking lots, and clean stormwater from the first flush sumps and the amine area sump is routed to various sedimentation ponds. The sedimentation ponds will be designed to allow access for grab sampling to be performed to analyse pH, Turbidity and TPH to ensure the quality of stormwater meets the proposed water quality target criteria for release to the environment. Release from the sedimentation ponds will be through percolation, evaporation, or controlled discharge via the sedimentation pond discharge culverts.

Figures 4.5.3-3 and 4.5.3-4 illustrate the overall LNG plant drainage system and locations of the sedimentation ponds. The proposed water quality target criteria for these contaminants are below.

Construction and Commissioning Phases	Operations Phase
Turbidity: 2000 NTU	Turbidity: 370 NTU; pH: 6 – 8; TPH: 15mg/L

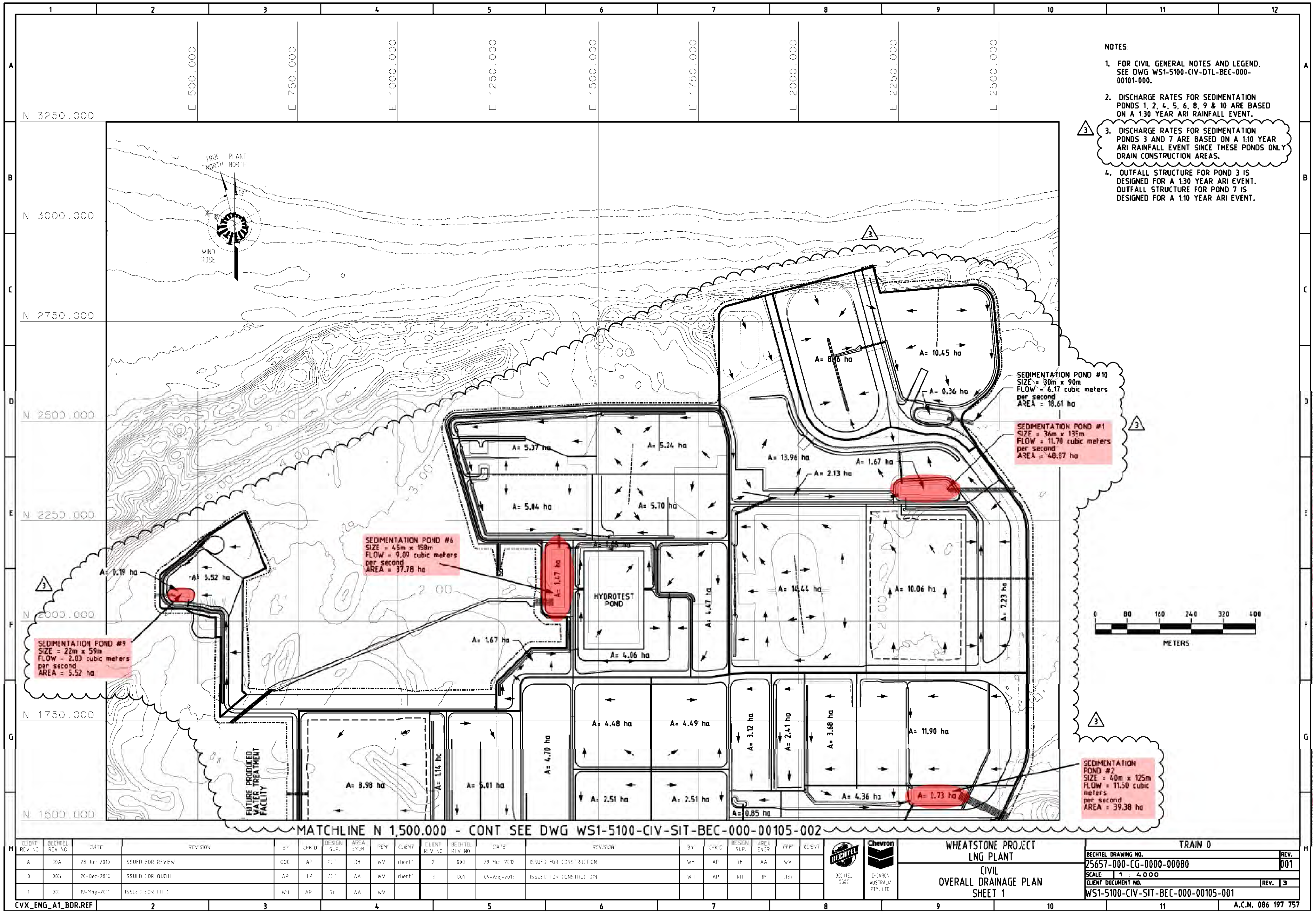


Figure 4.5.3-3: LNG Plant Site - Overall Drainage Plan (1 of 2)

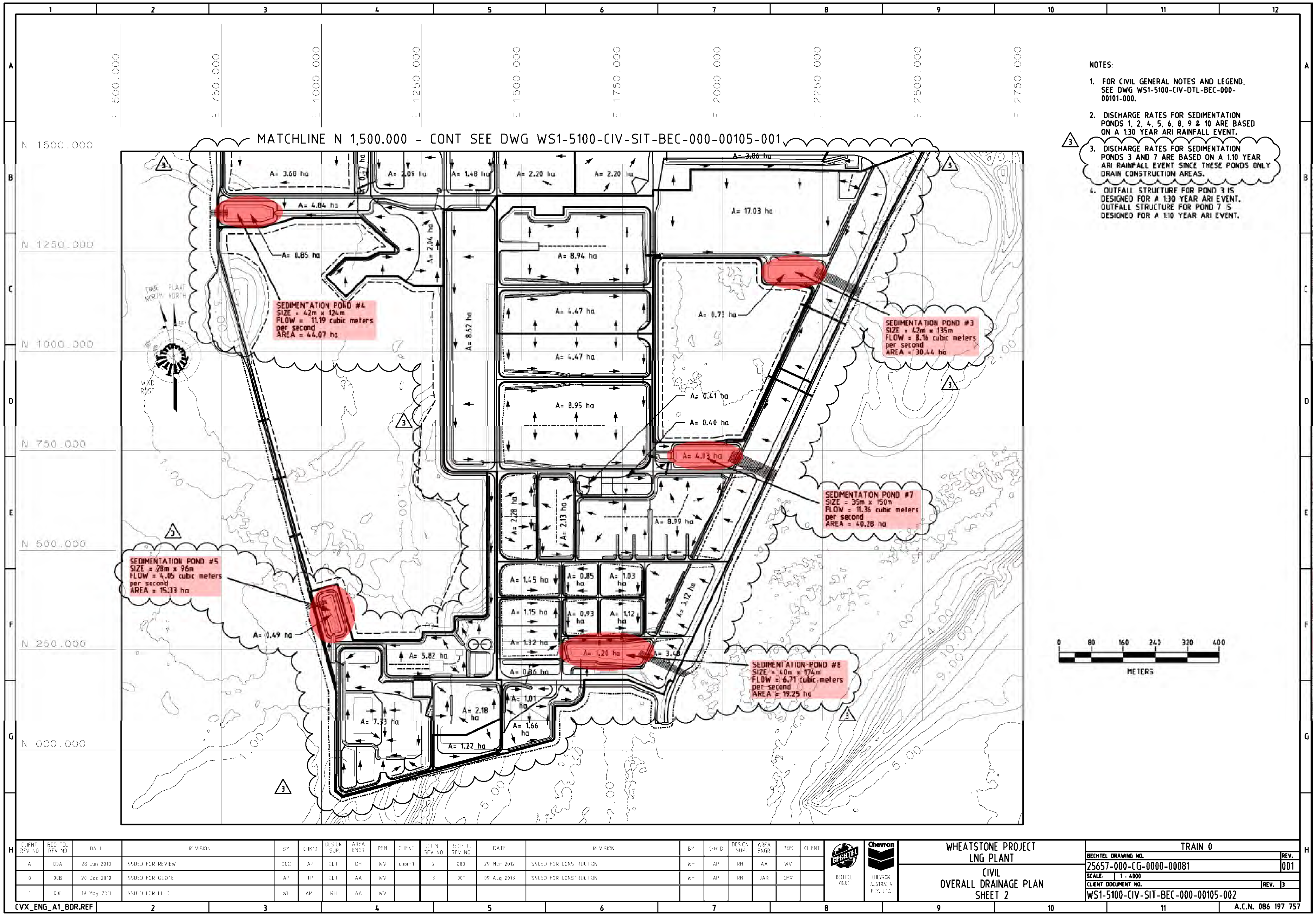


Figure 4.5.3-4: LNG Plant Site - Overall Drainage Plan (2 of 2)

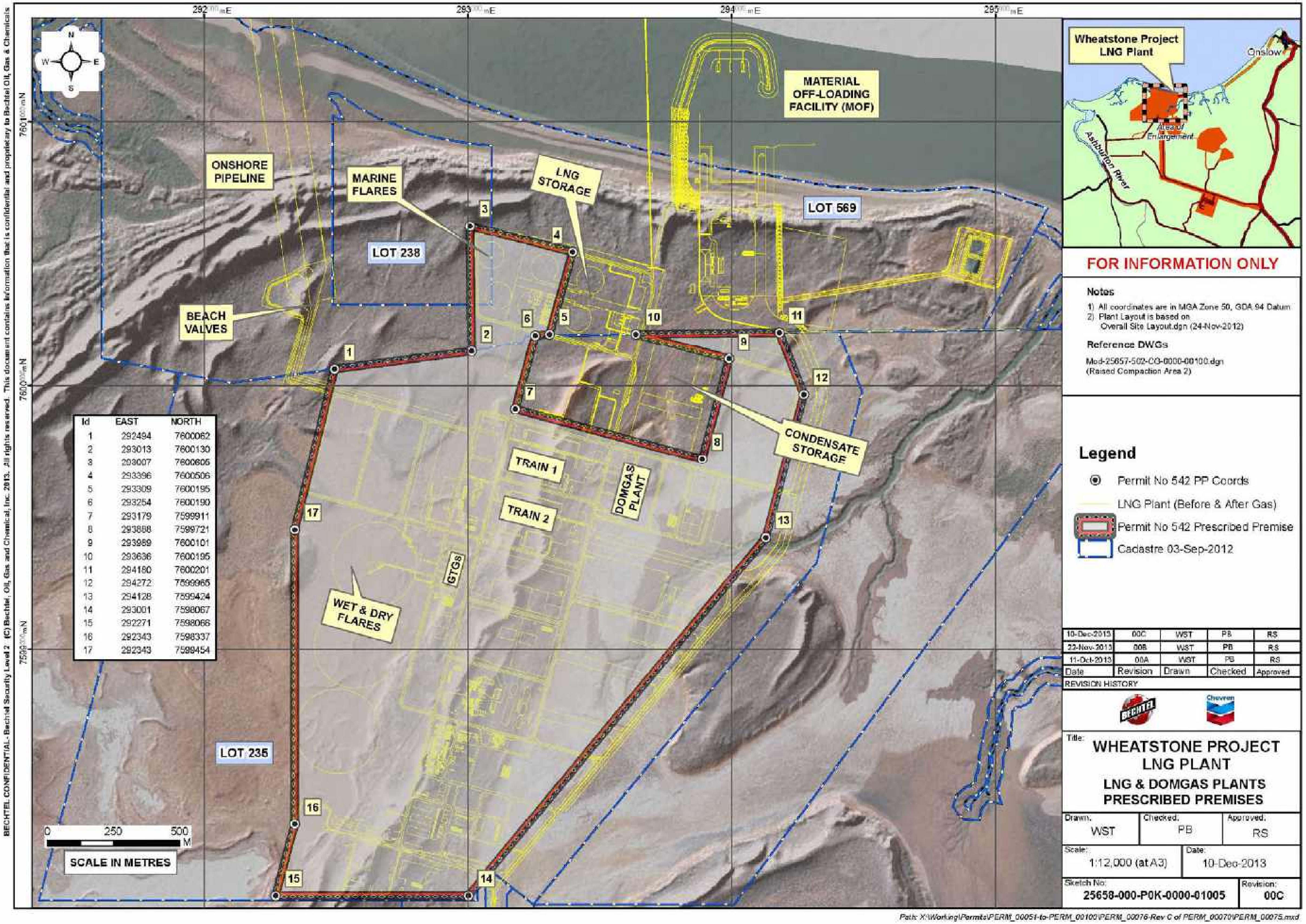
4.6 Prescribed Premises Boundary Layout

The proposed prescribed premises boundary will include the LNG and Domgas Plants, supporting utilities and general facilities including flares and GTGs will be located on Part Lots 235, 238 and 569 on Plan 195206. The permanent ocean outfall, quarantine approved premises, offloading facilities are not included in the prescribed premises. Figure 4.6-1 shows the prescribed premises for this WAA.

Coordinates for the boundary of the proposed prescribed premises have been included in Table 4.6-1 and Figure 4.6-1, these areas encompass all infrastructure associated with the prescribed activities.

Table 4.6-1: LNG and Domgas Plants Prescribed Premises Boundary Coordinates

MGA System		
No.	East	North
1	292494	7600062
2	293013	7600130
3	293007	7600605
4	293396	7600506
5	293309	7600195
6	293254	7600190
7	293179	7599911
8	293888	7599721
9	293989	7600101
10	293636	7600195
11	294180	7600201
12	294272	7599965
13	294128	7599424
14	293001	7598067
15	292271	7598066
16	292343	7598337
17	292343	7599454



Id	EAST	NORTH
1	292494	7600062
2	293013	7600130
3	293007	7600606
4	293396	7600506
5	293309	7600195
6	293254	7600190
7	293179	7599911
8	293888	7599721
9	293989	7600101
10	293636	7600195
11	294180	7600201
12	294272	7599965
13	294128	7599424
14	293001	7598067
15	292271	7598066
16	292343	7598337
17	292343	7599454

Figure 4.6-1: Wheatstone LNG Plant - LNG and Domgas Plants Prescribed Premises

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4.9 Air Emission Design

As required by State (WA) Ministerial Approval, MS 873 (Conditions 18-1 and 18-2), Wheatstone Project is to implement below measures in design and operation of air emitting facilities:

- Demonstrate that specific design features have been implemented to minimise and monitor emissions to air, in particular:
- Minimising emissions of VOCs and NO_x;
- Optimising the smokeless capacity of flares so as to minimise the frequency and duration of visible smoke;
- Minimising non-emergency flaring of gas;
- Demonstrate that operations management measures have been implemented to minimise emissions to air;
- Benchmark emissions of VOCs and NO_x to similar LNG Projects in Australia and internationally.

Therefore, this section summarises the main emission sources and respective emission reduction measures implemented in the design. Detailed information is provided in the Wheatstone Foundation Project Air Emissions Design Report (*Chevron Document No. WS0-0000-HES-RPT-CVX-000-00102-000*) which is available in Appendix A.

4.9.1 Air Emission Key Sources

The key sources of air emissions within scope of this WAA and associated emissions are listed in Table 4.9.1-1. This table shows main emissions to air from listed combustion equipment, flares and vents (as described in MS 873) are:

- NO_x, including nitrogen oxide (NO) and nitrogen dioxide (NO_2)
- Sulfur oxides (SO_x), typically represented by sulfur dioxide (SO_2)
- Carbon monoxide (CO)
- Airborne PM_{10} and visible smoke from flares
- VOCs typically aliphatic HCs excluding methane (CH_4), and aromatic HCs including BTEX.

Indicative location of the key air emission point sources are shown in the Figure 4.9.1-1, and their locations coordinates as undertaken in the modeling assumptions can be found the Wheatstone LNG Foundation Project - Air Quality Assessment (*Chevron Document No. WS0-0000-HES-RPT-CPM-000-00002-000*) which is available in Appendix C.

Table 4.9.1-1: Key Air Emission Point Sources and Associated Emissions

Project Key Emission Sources	Associated Air emissions
[redacted]	[redacted]
[redacted]	[redacted]
One Domgas Plant Regeneration Gas Process Heater [redacted]	NO_x, PM_{10}, SO_2, VOCs[1], CO
[redacted]	[redacted]
[redacted]	[redacted]
Acid Gas Thermal Oxidiser Vents: [redacted] one within the Domgas Plant	NO_x, PM_{10}, SO_2, VOCs[1,2], CO

***SOURCE:** Wheatstone Foundation Project Air Emissions Design Report (Appendix A)*

[1] VOCs related to natural gas combustion streams typically contain unburnt aliphatic HCs.

[2] VOCs related to acid gas thermal oxidiser vents may contain aromatic compounds.

Note: BTEX are a subset of VOCs and have been accounted for under VOC emissions.

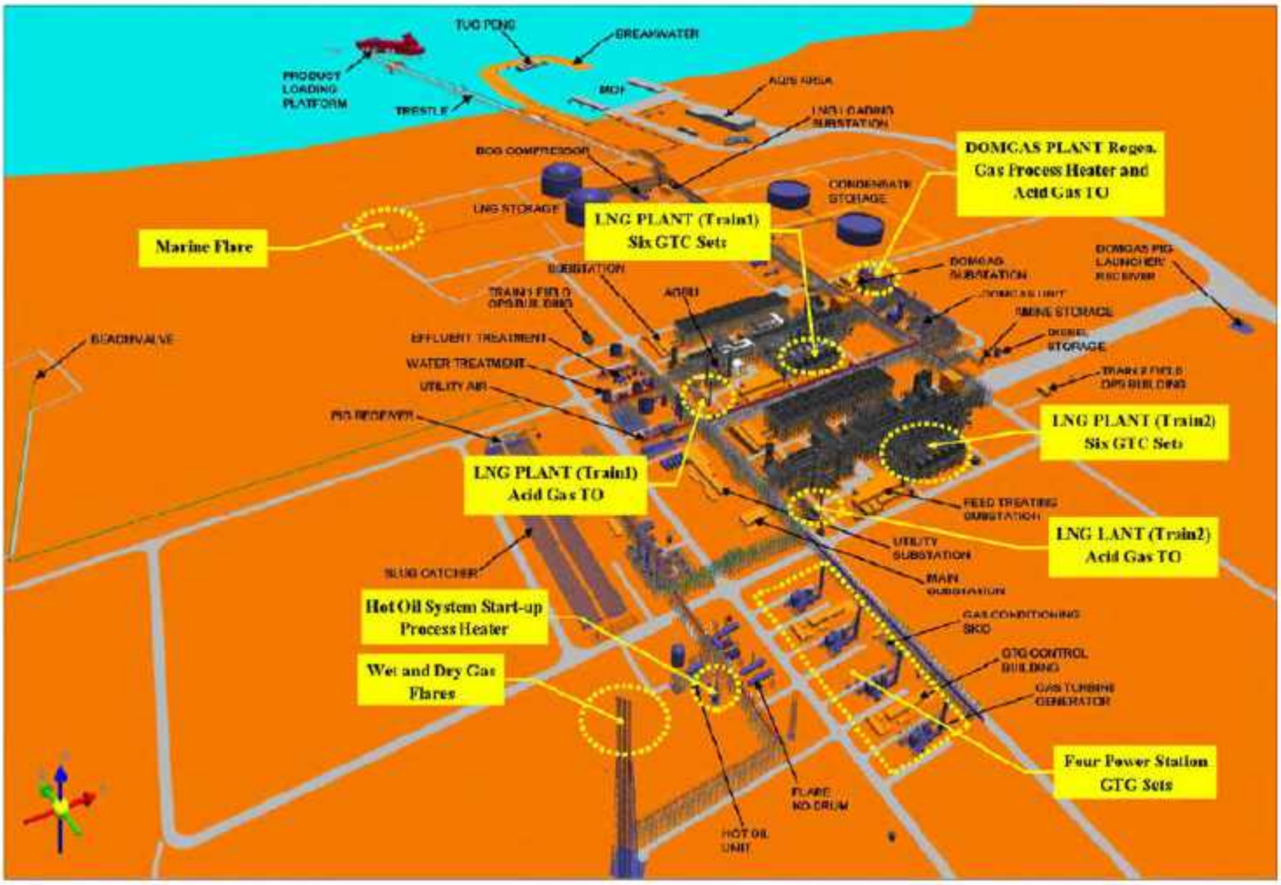

Figure 4.9.1-1: Indicative Locations of the Key Air Emission Point Sources

4.9.2 Air Emissions Inventory

Vendors provided performance guarantees, where available are used to estimate emissions. Manufacturer emission guarantees generally tend to be more conservative than the actual emissions. Table 4.9.2-1 provides a summary of emission estimates from normal operations based on the average feed gas composition / average ambient temperature flow-rates and assuming steady-state conditions, and it includes emission estimates for routine and planned non-routine operations (e.g. maintenance and testing). The estimates would be validated as appropriate during operations monitoring and testing as are described in Section 7.1, to ensure that manufacturer emissions guarantees are met.

Table 4.9.2-1: Emission Estimates for Normal Operation[1,2]

Emission Source	Equipment Count	Duration[4] (hr/yr)	Estimated Emissions (g/s)					
			PM	NO_x	CO	SO_2[3]	VOC	BTEX[3]
[redacted]								
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Domgas Plant Routine Emissions								
Acid Gas Thermal Oxidiser	1	8,690	0.005	0.5	0.8	0.1	0.4	0.32
Fugitive Emissions	-	8,278	-	-	-	-	0.5	0.001
Regen Gas Heater	1	3,621	0.1	0.2	0.1	0.0005	0.02	0.025
[redacted]			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]								
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
DomGas Submerged Combustion Vaporizer	1	240	0.7	1.3	0.6	0.003	0.09	0.15

***Source:** Wheatstone Foundation Project Air Emissions Design Report (Appendix A)*

1 Air emissions estimates that are based on vendor provided data are preliminary and subject to change.
2 Emissions provided are worst case short term emissions in g/s.
3 Based on Front End Engineering and Design Case 3 (Average Flow / Average Temperature) Heat & Material Balance.
4 Based on basic plant data and operation availability for the LNG Trains (94.5%).
5 Based on operating load assumptions.
6 Condensate Ship Loading is not within Prescribe Premises of this WAA.

4.9.3 Emission Reduction Measures in Design

Factors such as gas field location, composition and variability, HC liquids content, ambient operating temperature, maximum and minimum processing capacities all play an important role in determining the particular technologies suitable for a specific project. This section briefs the current features that have been incorporated into the design of the key emission sources to minimise emissions of VOC and NO_x. The design features to minimise visible smoke and non-emergency flaring is described in Section 4.9.4. The evaluation process applied for selecting the emission reduction design features to minimise NO_x and VOC emissions include the following criteria:

- Ability to achieve or improve upon relevant environmental (DER and EPA) standards
- Preference for primary (at source) over secondary (end-of-pipe) pollution control measures to minimise waste generation
- Technology Risk – proven versus unproven technology or process. The Chevron Technology Qualification Process requires that selected technology or process has a documented track record in the field, for a defined environment, to be considered 'proven' and of acceptable operational risk
- Energy Efficiency – the energy efficiency is central to each design option, be it thermal, electric or mechanical energy efficiency. A reduction in energy efficiency results in increased fuel requirements and consequently increased emissions
- Operability / Maintainability – design options that are difficult to operate or require high maintenance may result in higher emissions through suboptimal operating conditions and any additional shutdown and start-up events that may be experienced
- Availability – impact of pollution control technology on combustion equipment availability
- Health, environmental, and safety – additional considerations including waste generation, use of natural resources (e.g. water), occupational health exposures, and safe operations.

In summary, combustion type process equipment that have been selected best match the requirements of the Wheatstone Project because these will operate within the optimal combustion envelopes during routine operations, minimising emissions of CO, VOC and PM_{10}. Trade-offs between NO_x reduction, and combustion and energy efficiency, also influenced equipment selection. The specific design features which have been incorporated into the Wheatstone Project LNG and Domgas Plants to minimise NO_x and VOC emissions are detailed in the Wheatstone Foundation Project Air Emissions Design Report (Appendix A, Section 7). The design emission rates consequently calculated for the key emission sources (except for flares) during normal operation and emission targets are presented in Table 4.9.3-1.

Table 4.9.3-1: Emission Rates and Targets for Key Air Emission Point Sources during Normal Operation

Project Key Emission Sources	Design Emission Rates	Associated Air Emissions				
		NO_x	PM_{10}	SO_2	VOC	CO
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Domgas Regeneration Gas Process Heater	Rate (g/s)	0.2	0.1	0.0005	0.02	0.1
	Concentration (mg/Nm^3) (iv)	102	50	0.2	7	52
	Target (mg/Nm^3) (v)	350	50	N/A	40	125 (vi)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Domgas Plant Acid Gas Thermal Oxidiser	Rate (g/s)	0.5	0.005	0.1	0.40	0.8
	Concentration (mg/Nm^3) (iv)	110	1.0	24.2	20	168
	Target (mg/Nm^3) (v)	350	50	N/A	20	125

SOURCE: *Wheatstone Foundation Project Air Emissions Design Report (Appendix A)*

(i) Emissions shown in the table are for total Twelve (12) turbines.

(ii) Emissions shown in the table are for total of four (4) turbines.

(iii) For gas fired turbines, reference conditions are dry, 273 degree Kelvin (K), 101.3 kPa at 15% O_2.

(iv) For gas fired process heaters and thermal oxidisers, reference conditions are dry, 273 degree Kelvin (K), 101.3 kPa at 3% O_2

(v) Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DER.

(vi) CO emissions concentration (for TOs) is based on vendor guaranteed concentration (150 ppmv) and exhaust gas flow. The expected concentration as stated in vendor proposal is 100 ppmv (<125 mg/Nm^3). Note that the feed gas to AGRU TO is 99% CO_2 (dry basis), which limits the conversion of VOCs to CO_2.

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[redacted]

Table 4.9.4-1: Design Emission Rates for Elevated Flares

Project Key Emission Sources	Operation Conditions	Design Emission Rates (g/s)				
		NO_x	PM_{10}	SO_2	VOC	CO
[redacted]	[redacted] [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted] [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted] [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted] [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: *Wheatstone Foundation Project Air Emissions Design Report (Appendix A)*

(i) Estimated emissions from flares during routine operations (pilot + purge)
(ii) Upset scenario based on a blocked NRU vent outlet.
(iii) Upset scenario based on a thermal oxidiser trip event.
(iv) Upset scenario based on a loss of a BOG compressor.

4.10 Air Quality Modeling

Air quality modeling for the Wheatstone Project was developed by Air Assessments in 2013. A copy of this modeling report can be found in Appendix C (*Chevron Wheatstone LNG Foundation Project - Air Quality Assessment*). This modeling assessment utilises two models;

i) AERMOD for predicting local impacts on a scale out to 13 km from the Wheatstone Project plant site, and

ii) TAPM-CTM for predicting regional scale ozone and NO_2.

The following sections provide a summary of the model including the assumptions used and the results achieve. Detailed information can be found in the model report (Appendix C).

4.10.1 Emission Sources and Compositions

The model considered main emission streams and major pollutant sources from the Wheatstone Project to predict the pollutants impacts during operation of the LNG and Domgas Plants, supporting utilities and general facilities on the surrounding areas and environment. Below is a list of the main sources modelled and associated primary emission composition and marginal sources not included in the model.

The primary emission sources from the Wheatstone Project are:

- Twelve compressor gas turbines on the two LNG trains (six per LNG train). Emissions of concern are primarily NO_X;
- Four power station GTG. Emissions of concern are primarily NO_X;
- Two recuperative thermal oxidisers (RTO) used to combust the acid gas AGRUs associated with the two LNG trains, with one RTO for the Domgas plant acid gas stream. Emissions from the RTOs are primarily NO_X and SO_2 with residual emissions of BTEX due to incomplete destruction by the oxidiser;
- The regeneration gas process heater and the hot oil start up process heater. The emissions of concern are primarily NO_X;
- Flares. Under routine operation, the flares will operate with pilot and purge gas only and therefore will have low emissions. Under non routine conditions however, large quantities of gas are flared which will result in significant quantities of NO_X, CO, VOCs (including BTEX) being emitted. The flares include the main plant high pressure and low pressure flares (each handling wet and dry gas streams) and the marine flare for boil off gas (BOG).

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4.10.2 Evaluated Emission Scenarios

For the assessment of the Wheatstone Project, Chevron reviewed the range of possible event scenarios with six scenarios selected to cover the range of likely events. These scenarios are:

1. Normal Operations;
2. Regenerative thermal oxidiser trip for one LNG train where the AGRUs vent gas is directed to the LP flare;
3. Blocked Nitrogen Rejection Unit (NRU) outlet vent. The gas stream emitted consists of concentrated N_2 with trace amount of methane (less than 1.5 mol %) which is vented directly to atmosphere. NRU vent, with high nitrogen content, routed to the dry gas LP flare during valve failure;
4. Loss of BOG compressors, where the boil off gas from the LNG tankers will be routed to the marine flare;
5. Loading a condensate ship, where VOC rich vapours are displaced from the ships hold. This is estimated to occur for only 156 hours per year (not within the prescribed premises and outside the scope of this WAA); and

   Start-up of an LNG train with use of a start-up oil heater and non-routine flaring to the LP flare.

There is no distinct worst-case scenario achieved by the air quality modeling as depending on the pollutant of concern the worst-case scenario varies. Scenario 4 is considered to be the worst-case for NO_x and CO, and scenario 5 is the worst-case for VOC and benzene.

4.10.3 Ambient Air Quality Criteria

The criteria for Ambient Air Quality in Western Australia (WA) are taken from the Ambient Air Quality NEPM Standards and Goals originally published by the National Environment Protection Council (NEPC) in 1998. These standards with the Particles as $PM_{2.5}$ values (added in 2002) are presented in Table 4.10.3-1. Air Toxics NEPM published in 2004 identifies monitoring investigation levels for BTEX, as listed in Table 4.10.3-2, with a goal to gather sufficient data nationally to facilitate development of standards for air toxics.

Table 4.10.3-1: NEPM - Ambient Air Quality Standards and Goals

Pollutant	**Averaging Period**	**Maximum Concentration**		**Goal**
		(ppm)	**(µg/m³)[1]**	**Maximum Allowable Exceedances**
Carbon Monoxide	8 hour	9.0	*11,240*	1 day a year
Nitrogen Dioxide	1 hour	0.12	*246*	1 day a year
	1 year	0.03	*62*	None
Photochemical Oxidants (as Ozone)	1 hour	0.1	*214*	1 day a year
	4 hours	0.08	*171*	1 day a year
Sulphur Dioxide	1 hour	0.20	*572*	1 day a year
	1 day	0.08	*228*	1 day a year
	1 year	0.02	*57*	None
Lead	1 year	-	0.50	None
Particles as PM_{10}	1 day	-	*50*	5 days a year
Advisory Reporting Standards and Goal				
Particles as $PM_{2.5}$	1 day	-	25	-
	1 year	-	8	-

Source**:** National Environment Protection Council (1998)

[1] Concentration of gaseous pollutants in italics have been converted from the NEPM standard quoted at 0 °C and 101.3 kPa

Table 4.10.3-2: NEPM - Air Toxic Monitoring Investigation Levels

Pollutant	**Averaging Period**	**Monitoring investigation Level (ppb)**	**Equivalent Concentration at 101 kPa and 25 °C (µg/m³)**
Benzene	Annual average	3	9.6
Benzo (a) pyrene as a marker for Polycyclic Aromatic Hydrocarbons	Annual average	0.3 ng/m³	NA
Formaldehyde	24 hours	40	49
Toluene	24 hours	1000	3770
	Annual average	100	377
Xylenes (as total of ortho, meta and para isomers)	24 hours	250	1085
	Annual average	200	868

Note: The 8-year goal (date 2012) of the air toxics NEPM is to gather sufficient data nationally to facilitate development of a standard.

National Exposure Standards have been declared for CO, NO_2, SO_2 and particles as PM_{10} [NOHSC:1003 (1995)]; however, the 8-hour averaged maximum concentrations for these are in excess of the NEPM (Ambient Air Quality) allowances so these are not referenced further.

4.10.4 Local and Regional Air Quality Model Results

The model predicted local concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$, BTEX, formaldehyde and H_2S using the model AERMOD and local measured meteorological data. In this report, “local” is defined as within 13 km of the plant including the Town of Onslow where the maximum concentrations of these pollutants occur. Concentrations of ozone modelled using TAPM-CTM to predict concentrations on the “regional” scale to include the interaction with regional sources, as the peak concentrations may occur up to 100 km away from the source. A summary of the model results is given below.

Predicted Local Concentrations

The model discusses the predicted maximum concentrations at any location and on the land outside the lease boundaries. Detail results for each scenario with illustrated contour plots can be found in the model report (Appendix C, Section 6). A summary of the achieved maximum results concentrations including ambient background concentrations as a percentage of the criteria are presented in Table 4.10.4-1. Achieved results indicate:

- The predicted concentrations outside the lease boundaries are generally low compared to their respective criteria, with the 1-hour NO_2 concentrations being closest - up to 21.5% of the criteria, with all other pollutants contributing less than 5% of their respective criteria. Concentrations at nearby sensitive receptors are even lower; and

- For all scenarios there is generally little variation in the predicted concentrations apart from higher concentrations of benzene, toluene and xylenes from the ship loading scenario – case 5. That the emissions from the various flaring scenarios do not significantly change the predicted concentrations is a result of the very large amount of heat released and subsequent large plume rise from the flares. For the condensate loading case, though the concentrations do increase they are still low, at most 3.6% of the annual average benzene criterion and 0.65% of the 24-hour xylenes criterion outside the lease boundary on land.

- The background concentrations are generally low and make little contribution to the levels. Results show with all background levels apart from PM_{10} and $PM_{2.5}$ being below 4% of the criteria. For PM_{10} and $PM_{2.5}$, background levels make up a significant fraction of the criteria, but for these the contribution from the Wheatstone Project is small and the predicted cumulative concentrations remain below the criteria. Therefore, the consideration of background concentrations does not result in out-of-guideline value for predicted pollutant concentrations.

Table 4.10.4-1: Predicted Maximum Concentrations (as a percentage of Criteria) outside the Lease Boundary – Background Levels Included

Pollutant	Ave. Period	Conc. Statistic	Criteria Value	Units	Back-ground (%)	Routine Case 1 (%)	Non Routine: TO Trip Case 2 (%)	Non Routine: Blocked NRU Vent Case 3 (%)	Non Routine: BOG Comp. Trip Case 4 (%)	Non Routine: Conden-sate Loading Case 5 (%)	Non Routine: Start Up Case 6 (%)
CO	8-hour	Max	9000	ppb	1.1	1.6	1.6	1.6	1.6	1.6	1.5
NO_2	1-hour	Max	120	ppb	1.7	23.2	23.2	23.2	23.2	23.2	15.9
	1-year	Ave	30	ppb	3.3	8.0	8.0	8.0	8.0	8.0	8.2
SO_2	1-hour	Max	200	ppb	0.0	0.5	0.3	0.5	0.5	0.5	0.3
	1-day	Max	80	ppb	0.0	0.4	0.2	0.4	0.4	0.4	0.2
	1-year	Ave	20	ppb	0.0	0.2	0.2	0.2	0.2	0.2	0.1
PM_{10}	1-day	Max	50	$\mu g/m^3$	54	56	56	56	57	56	56
$PM_{2.5}$	1-day	Max	25	$\mu g/m^3$	24	29	29	29	29	29	27
	1-year	Ave	8	$\mu g/m^3$	62.5	66	66	66	66	66	65
Benzene	Annual	Ave	5	$\mu g/m^3$	0.6	2.1	1.9	2.0	2.1	4.9	1.8
Toluene	24-hour	Max	1000	ppb	0.05	0.03	0.02	0.03	0.03	0.40	0.02
	Annual	Ave	100	ppb	0.05	0.08	0.08	0.08	0.08	0.21	0.07
Xylenes	24-hour	Max	250	ppb	0.05	0.06	0.06	0.06	0.06	0.67	0.05
	Annual	Ave	200	ppb	0.015	0.02	0.02	0.02	0.02	0.05	0.01
Formaldehyde	24-hour	Max	40	ppb	0.55	1.6	1.6	1.6	1.6	1.6	1.5
H_2S	1-hour	99^{th}	1.11	$\mu g/m^3$	0.0	1.0	0.6	1.0	1.0	1.0	0.7

Source: *Wheatstone Foundation Project Air Emissions Air Quality Assessment (Appendix C)*
Note: Includes background concentrations and other existing and approved sources.

Air emissions modelled were less than 70 % of the standard for all operating scenarios. Detailed modelling results are included in Appendix C.

Predicated Regional Concentrations

Regional concentrations of ozone and NO_2 were predicted for the various scenarios before and with the Wheatstone Project. A summary of the predicted concentrations as a percentage of the adopted criteria is presented in Table 4.10.4-2. The achieved model results indicate that:

- Maximum existing ozone concentrations at isolated areas in the Pilbara are relatively high, with the major contributor being emissions from bush fires. The maximum existing ozone concentrations (2009) predicted anywhere on the model grid are 87 and 95% of the 1-hour and 4-hour ozone standards respectively. Using what is considered the more appropriate second highest concentration when including natural sources, the predicted concentrations are 74 and 86% of the standard;
- With the addition of future industry and the Wheatstone Project, the maximum ozone concentrations predicted anywhere on the model grid remain essentially unchanged and, for some statistics and averaging periods, will even decrease. The minor impact or even reduction is due both to fires being the dominant source and the non-linearity in the atmospheric chemical reactions, where additional NO_2 can (in some circumstances) reduce ozone concentrations;

- At residential locations, the predicted maximum 1-hour ozone concentrations for existing sources are between 43 to 60 ppb. With the addition of future industry (excluding the Wheatstone Project), these maximums are predicted to increase only marginally, typically less than 1 ppb. The exceptions to this are at Barrow Island where a large increase in ozone levels is predicted due to the Gorgon Project and for Mardie where there is a significant reduction in the maximum and second highest 1-hour ozone concentrations. This reduction at Mardie is due to the industrial sources impacting on a smog event due to fire emissions, where the additional NO_2 is predicted to reduce the ozone formation; and

- With the addition of the Wheatstone Project, under routine operations there is predicted to be negligible change in the concentrations at residential sites (including Onslow) apart from the Minderoo station with increases of no more than 1 ppb. For the non-routine scenarios, the above result applies, except for the ship-loading condensate case where an increase of up to 3 ppb in the 1-hour concentrations at Minderoo station is predicted, though with the concentrations still being only 45% of the 1-hour NEPM standard. That the Wheatstone Project has such a minor impact on ozone concentrations is due to the emissions being relatively small, estimated to comprise only 0.13 to 4.9% of future anthropogenic emissions in the Pilbara.

Table 4.10.4-2: Predicted Maximum Concentrations of Ozone and NO_2 Anywhere on the Model Grid as a percentage of their Criteria

Pollutant	Ave. Period	Statistic Used	Criteria Value (ppb)	Existing 2009 (%)	Future without Wheat-stone (%)	Future with the Wheatstone Foundation Project					
						Routine Case 1 (%)	TO Trip Case 2 (%)	Blocked NRU Vent Case 3 (%)	BOG Trip Case 4 (%)	Conden-sate Loading Case 5 (%)	Start Up Case 6 (%)
Nitrogen Dioxide	1-hour	Max	120 [1]	63	63	63	63	63	63	63	63
	1-hour	2nd	120	38	38	38	38	38	38	38	38
	1-year	Ave	30	31	31	31	31	31	31	31	31
Ozone	1-hour	Max	100 [1]	87	86	86	86	86	86	86	86
	1-hour	2nd	100	74	67	67	67	67	67	68	67
	4-hour	Max	80 [1]	95	94	94	94	94	94	94	94
	4-hour	2nd	80	86	79	79	79	79	79	80	79

Source: *Wheatstone Foundation Project Air Emissions Air Quality Assessment (Appendix C)*

[1] The NEPM 1-hour goal allows for 1 day of exceedances per year with the modelling including natural sources. As such with natural sources compliance is if less than 2 days of exceedances are measured.

The achieved model results showed that maximum existing ozone and nitrogen dioxide concentrations at the assessed areas are relatively high, and with the addition of future industry and the Wheatstone Project, the maximum concentrations predicted anywhere on the model grid remain essentially unchanged or will even decrease. Therefore, overall impacts on regional air quality from the Wheatstone Project are small. More detailed information and contour plot illustration can be found in Appendix C.

4.11 Noise Modeling

A noise model was developed (for a five train facility) and used to predict noise levels associated with construction piling, normal operations and emergency flaring at receptors near the vicinity of the plant (SVT 2009).. Predicted noise levels were for the worst-case weather conditions for sound propagation and have also been compared with the regulatory noise limits and ambient noise levels to determine noise impacts.

This section will give a summary of the used assumptions and input data used by the model and the achieved results. More detailed information can be found in the model report attached to this WAA as Appendix D. The actual results from the two train facility and scope of this WAA are expected to be significantly less than the model results for the five trains, as the model undertook noises generated from additional three future LNG trains and facilities outside the prescribed premises boundary.

4.11.1 Noise Sensitive Receptor Locations

Total numbers of six locations in the vicinity of the LNG Plant site were identified as the noise sensitive receptors, although Onslow town is known as the nearest residential area to the Wheatstone LNG Plant. Ambient noise levels were assessed in five of these noise sensitive receptors as follows:

1. Onslow Town (nearest residential area)
2. Four Mile Creek (public access beach and popular fishing and BBQ area)
3. Five Mile Pool (camping area)
4. Old Onslow Heritage Site (original site of Onslow)
5. Ten Mile Dam (the workforce accommodation camp)

The model predicted noise levels at the same sensitive noise receptor locations as well as in the nearest industrial sensitive receptor:

6. Onslow Salt (the north-west corner of the Onslow Salt boundary)

4.11.2 Background Noise Levels and Noise Limit Criteria

Ambient noise levels were measured in the sensitive receptors and are set as the Baseline Noise Levels for this project and the Background noise levels in the model. Table 4.11.2-1 outlines the background noise levels as L_{A10}, and L_{A90}. The L_{A90} noise level is applicable for representing background noise levels, and L_{A10} will be used to compare against the predicted levels.

The Noise Regulations specify maximum noise levels (assigned levels) which are the highest noise levels that can be received at noise-sensitive premises, commercial and industrial premises. Old Onslow, 4 Mile Creek, and 5 Mile Pool are public access areas, but are not considered as premises. Since the noise regulations apply only to noise received at premises, the assigned noise levels do not apply and noise limit criteria are not defined for these locations. The potential for noise impacts at these locations is determined by comparing predicted noise levels with measured background noise levels. The regulations define three types of assigned noise level: $L_{A\,max}$, L_{A10}, L_{A90}. The L_{A10} noise limit is the most significant for this study since this is representative of continuous noise emissions from the LNG Plant.

Table 4.11.2-1 shows the applicable assigned noise level for the sensitive receptors, except for Onslow Salt which is an industrial site and its L_{A10} assigned noise level is 65 dB(A) at all times of the day and night.

Table 4.11.2-1: Background and Assigned Noise Levels (dB(A)) at Sensitive Receptors

Sensitive Receptors	Assigned Night-time Levels	Daytime	Evening	Night-time
Underlying Background Noise Level (Average L_{A90})				
Onslow Town	-	38	41	34
4 Mile Creak	-	38	40	36
5 Mile Pool	-	34	28	25
Old Onslow Heritage Site	-	36	34	25
10 Mile Dam	-	38	30	24
Underlying Background Noise Level (Average L_{A10})				
Onslow Town	35 at >450m from industrial Zoning	45	45	39
4 Mile Creak	NA	46	45	41
5 Mile Pool	NA	44	35	30
Old Onslow Heritage Site	NA	45	39	28
10 Mile Dam	35	52	39	32

***Source*:** Draft EIS / ERMP for the Proposed Wheatstone Project, Chapter 4 (emissions, discharges and Wastes), Section 5 (Noise)

4.11.3 Noise Modeling Methodology, Scenarios, and Assumptions

An acoustic model has been produced using the SoundPlan noise modeling program that calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. The noise modeling was carried out for construction and operation of the Wheatstone Project. Construction modeling focused on piling which is outside the scope of this WAA. Operational modeling included noise emissions from the prescribed premises and is discussed below.

Noise modeling for the operation phase has been undertaken for the following two operating scenarios:

- Normal plant operation assuming 5 LNG trains and associated Domgas;
- Emergency flaring.

Noise levels were predicted for two types of weather and wind conditions:

- Calm conditions; and
- Worst-case meteorological conditions.

4.11.4 Noise Sources and Sound Power Levels

Noise sources associated with the LNG Plant used in the noise model are listed in Table 4.11.4-1. This table also shows the equipment's sound power levels included in the noise model. The cumulative total sound power level for all equipment in the normal operating scenario is 137 dB(A).

Table 4.11.4-1: Noise Sources and Associated Sound Power Levels Used in the Noise Modeling

Equipment	Octave band & overall sound power levels – dB(A)									Comment
	63	125	250	500	1000	2000	4000	8000	A-wt	
LNG Train Sources (5 operating trains)										
Air fin coolers	108	115	117	118	117	117	112	101	124	Assuming individual fan sound power level of 99 dB(A)
Methane compressor	75	82	91	100	106	105	96	101	110	2 compressors per train, each comprising LP, MP & HP stages
Ethylene compressor	93	94	97	100	105	108	106	100	113	2 compressors per train, each comprising LP & HP stages
Propane compressor	90	91	94	97	102	105	103	97	109	2 compressors per train, each comprising LP & HP stages
Compressor turbines	80	91	95	102	103	107	106	104	112	6 turbines per train (3 x 2 compressors)
Compressor piping	49	80	99	108	116	113	110	107	119	Distributed as line sources over length of compressor area
Regeneration gas compressor	72	83	93	99	103	102	102	94	108	1 per train
Fuel gas compressor	87	91	96	103	107	106	106	98	112	1 per train
Lean solvent charge pump	80	100	98	103	103	103	100	89	109	1 per train
Lean solvent booster pump	74	94	92	97	97	97	94	83	103	2 per train
LNG transfer pump	80	100	98	103	103	103	100	89	109	1 per train
Feed gas expander	87	91	96	103	107	106	106	98	112	1 per train
Hot oil circulation pump	80	100	98	103	103	103	100	89	109	1 per train
Thermal combustion unit	81	84	92	98	100	98	96	87	105	1 per train
Other Sources										
Gas turbine generator	91	94	98	101	104	108	106	102	112	11 generators operating
Coolers at Domgas plant	97	104	105	104	104	104	99	98	112	Assuming individual fan sound power level of 99 dB(A)
Export compressor at Domgas plant	87	91	96	103	107	106	106	98	112	1 per plant
Boil off gas compressor	87	91	92	97	100	108	109	99	112	2 compressors operating
Instrument air compressor	68	78	84	93	99	100	98	93	105	1 compressor operating
Water pumps	71	90	96	99	100	99	95	91	106	Cumulative total for demineralised, service and potable water pumps
Inlet feed gas air coolers	90	97	99	97	97	97	92	82	105	Assuming individual fan sound power level of 99 dB(A)
Stabiliser overhead compressor	87	91	96	103	107	106	106	98	112	Inlet feed gas area
Elevated flare	111	117	120	124	131	135	133	121	138	3 flares operating at 85 m height (flaring scenario only)
Marine flare	84	90	93	97	104	108	106	94	111	2 flare operating at 13 m height (flaring scenario only)
Pile driver	90	109	117	119	121	117	109	98	125	12 units operating at plant site and 2 at end of jetty (construction scenario only)

Source: *Wheatstone Project Environmental Noise Impact Assessment (Appendix D)*

4.11.5 Noise Modeling Results

Predicted noise levels under worst wind conditions showed higher levels than calm conditions therefore noise levels under calm conditions are not presented in here. As explained in Section 4.11.2, predicted noise levels will be compared against background noise levels when the Assigned Levels are not available. Additional detailed information can be found in the Environmental Noise Impact Assessment report in Attachment C.

Table 4.11.5-1 outlines the predicted noise levels at the sensitive receptor locations and also includes the background noise level and Assigned Levels. Figures 4.11.5-1 and 4.11.5-2 depict noise level contours for each scenario.

Table 4.11.5-1: Predicted Noise Levels (L_{A10} dB(A)) - Operation Phase

Sensitive Receptors	Assigned Night-time Levels	Background Night-time (L_{A90})	Predicted Noise at Worst Wind Conditions	
			Normal Operations	Emergency Flaring
Onslow Town	35	34	27	30
4 Mile Creak	NA	36	37	41
5 Mile Pool	NA	25	28	32
Old Onslow Heritage Site	NA	25	36	41
10 Mile Dam	35	24	24	27
Onslow Salt	65	-	35	41

Source: *Wheatstone Project Environmental Noise Impact Assessment (Appendix D)*

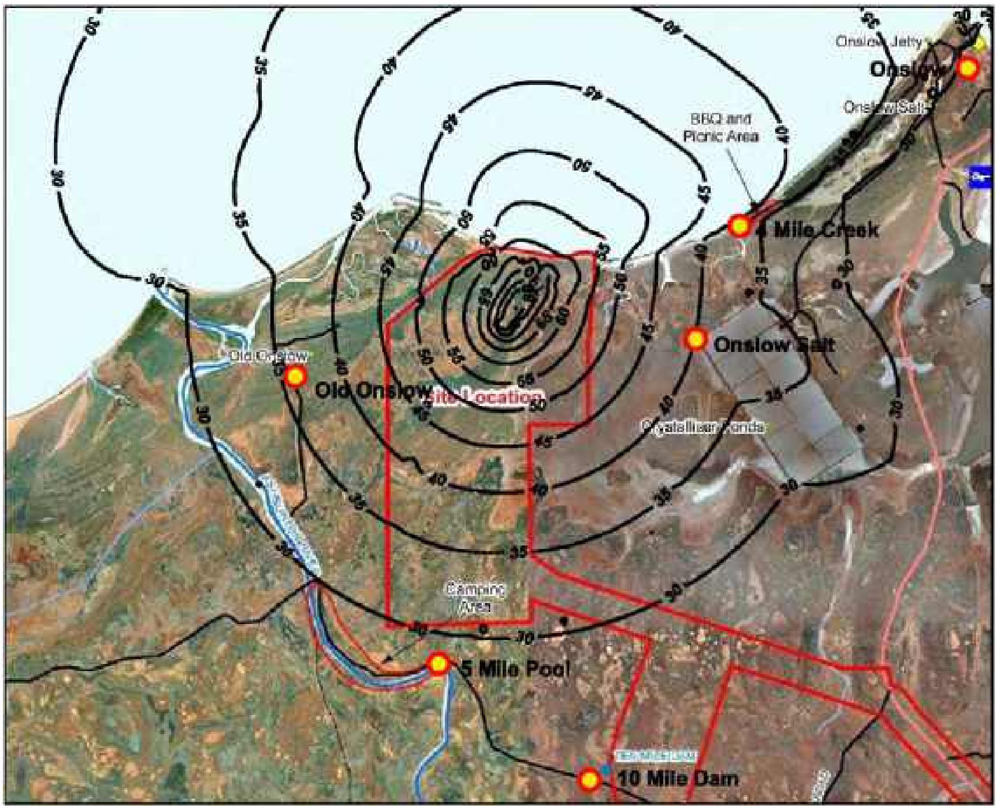

Figure 4.11.5-1: Noise Contours (Operation Phase) – Normal Operation at Worst Wind Conditions

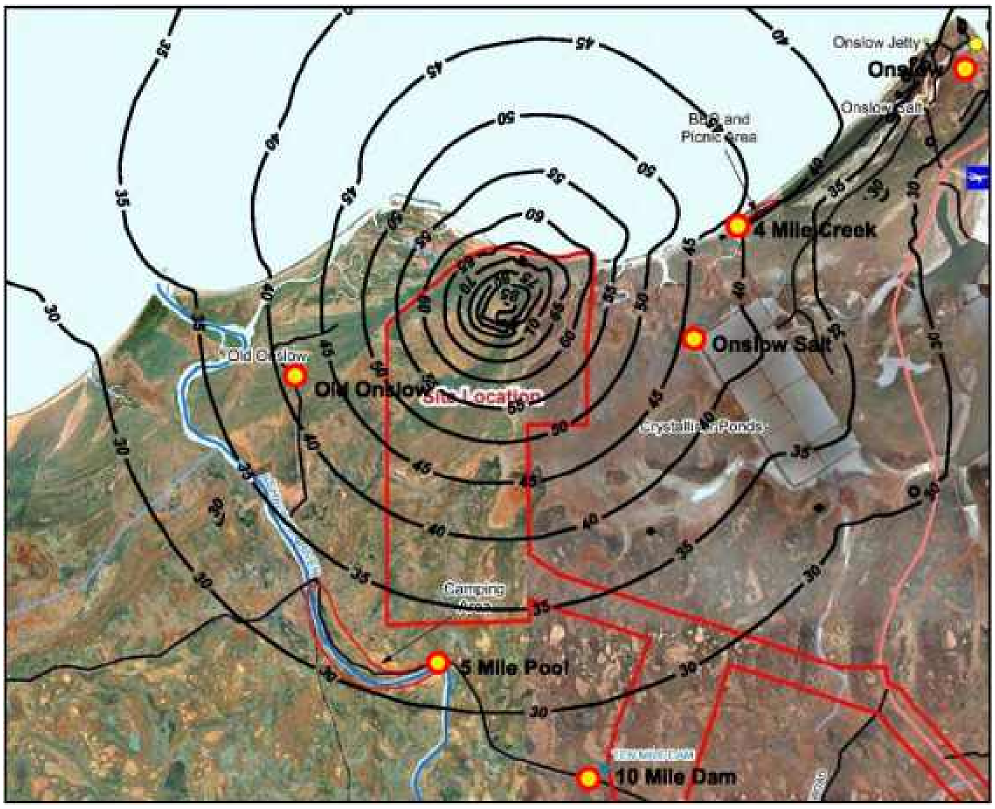

Figure 4.11.5-2: Noise Contours (Operation Phase) – Emergency Flaring at Worst Wind Conditions

4.11.6 Noise Model Conclusion

Predicted noise levels for normal plant operation are compliant with the most stringent night-time assigned noise levels imposed under the Noise Regulations assuming that industry standard noise controls are applied to compressor piping and gas turbines.

The LNG Plant is unlikely to be audible above background noise at Onslow town site even under worst-case meteorological conditions for sound propagation. The proposed location for the workforce accommodation camp is sufficiently distant from the LNG Plant site that received noise levels will be significantly below the assigned noise levels.

Predicted noise levels for normal plant operation at the public access areas (4 Mile Creek, 5 Mile Pool, and Old Onslow Heritage Site) are higher than underlying background noise. It is possible; therefore, that plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation.

Predicted noise levels from emergency flaring comply with the assigned noise levels.

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7.0 EMISSIONS IMPACTS AND MANAGEMENT

This section describes potential emissions from the LNG and Domgas Plants and common utilities and general facilities and indicates how they may potentially impact the local environment. A description of emission monitoring and management measures that will be applied is provided below.

7.1 Air Emissions

Air emissions may impact the environment including human health, amenity and vegetation and fauna. Air emissions sources, characteristics, qualities, and quantities differ during construction, commissioning, and operation of the plant. Therefore, air emissions and management will be discussed separately for the construction, commissioning and operation phases.

A comprehensive assessment of the predicted air emissions from the LNG and Domgas Plants and common utilities and general facilities was undertaken. Emissions of expected air pollutants were modelled to predict potential local impacts in the vicinity of the plants as well as regional impacts on areas up to 100 km distant from the plants. The air quality model assessed significant sources of air emissions under several scenarios.

Results for local and regional air emissions demonstrated ambient air quality standards would be met and Wheatstone Project is not expected to cause any out-of-criteria pollutant in the local and regional areas. Therefore, the predicted concentrations are relatively low and overall impacts on the environment are considered relatively minor during commissioning and operation of the LNG and Domgas Plants and common utilities and general facilities.

Refer to Section 4.10 and Appendix C for more detail of this modelling.

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Table 7.1.1-1: Construction Phase Ambient Air Quality Monitoring Program

Project Phase	Emissions Monitored	Monitoring Equipment
Pre-construction (during EIA studies) & Construction	NOx / SOx / VOC / PM / Dust Deposition	Passive Diffuse Samplers / OSIRIS Particle Counters

OSIRIS: Brand name of an instrument that uses laser nephelometer technology

Figure 7.1.1-1: Wheatstone LNG Plant Ambient Air Quality Monitoring - Existing and Proposed Stations

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7.2 Dust Emissions

Dust emissions from construction activities have the potential to smother vegetation and reduce a plant's ability to be able to photosynthesise. Dust emissions can also be a nuisance to the public and affect their enjoyment of public and private amenity (Department of Environment 1998).

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7.2.2 Operations Phase

During the operations phase the main sources of dust emissions will be from vehicle movements and short duration maintenance activities associated with the Plant, such as minor blasting and painting and some minor earthworks associated with maintenance of roads.

Management and Monitoring

The majority of the plant site area will be sealed with either a gravel surface or paving further reducing potential fugitive dust emissions; noting some areas will remain unsealed (e.g. non-process areas, around flares). As a result of the low potential for propagation of dust during the operations phase there are no ongoing management measures planned to be implemented to support day to day operations. For non-routine activities (e.g. maintenance and upgrades) that may occur during operations, an assessment of potential environmental impacts will be undertaken with relevant management measures implemented to reduce the impacts associated with those activities.

As discussed in Section 7.1, dust deposition will continue to be monitored initially during the operations phase as part of the ambient air quality monitoring program.

7.3 Odour Emissions

Odour emissions have the potential to adversely affect the welfare, health, convenience, comfort and enjoyment of public amenity. The EP Act protects against “unreasonable emissions” of odour (Department of Environmental Protection 2002).

Generation of odour is not expected during construction of the LNG and Domgas Plants. Minor odour emissions may be created from time to time during commissioning and operation of the LNG and Domgas Plants. As there is no camp accommodation or residential areas within the vicinity of the LNG and Domgas Plants site, minor odour emissions from the LNG and Domgas Plants are not predicted to result in unreasonable odour at nearby sensitive receptors.

Painting and blasting will produce odour over a localised area for a short duration. Therefore, odour emissions from these activities are unlikely to impact sensitive receptors and are considered to be insignificant.

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7.3.2 Operations Phase

Management and Monitoring

The sources of potential odour emissions that may be generated during the operations phase are not expected to differ significantly from those during the commissioning phase. Therefore, the management measures discussed above for the commissioning phase will continue to function during the operations phase, including the LDAR program.

7.4 Noise Emissions

Noise emissions have the potential to cause long-term adverse health effects and increase ambient levels in the environment impacting fauna populations. Noise expected from the Wheatstone LNG Plant onshore activities during construction and operation phases were modelled to support the assessment of the Draft EIS / ERMP. This modelling indicated:

- General construction noise emissions (except noise from pile driving that is outside the scope of this WAA) were assessed as being below the guideline limits and assigned values of the Noise Regulations. As a result, construction noise levels from the activities in the scope of this WAA are expected to be below and compliant with the assigned values, and construction noise impacts are expected to be insignificant.
- The predicted noise levels for two operating scenarios (normal operations and emergency flaring) showed compliance with the most stringent night-time assigned noise levels imposed under the Noise Regulations. The LNG Plant is unlikely to be audible above background noise at Onslow town and Ten Mile Dam (the accommodation camp location) even under worst-case meteorological conditions for sound propagation.
- Predicted noise levels for normal plant operation at the public access areas (4 Mile Creek, 5 Mile Pool, and Old Onslow Heritage Site) are higher than underlying background noise. Therefore, plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation; however, it is marginal and impact is expected to be insignificant.
- Overall, significant noise impacts are not expected to occur during construction, commissioning or operation of the LNG and Domgas Plants.

A more detailed summary of this modelling is provided in Section 4.10, and the full document available in Appendix D.

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7.4.2 Operations Phase

Management and Monitoring

The LNG and Domgas Plants will be operated in compliance with the Noise Regulations. No noise specific noise management measures are proposed for the operation phase; however, and if deemed necessary, acoustic enclosures will be provided around rotating and other 'noisy' equipment.

For the same reasons discussed above for the construction and commissioning phases, no noise monitoring is proposed outside of the Wheatstone Project boundary during the operation phase. However, as will be undertaken during commissioning, noise monitoring is proposed to be undertaken on a regular basis within the Wheatstone Project boundaries during operations for ongoing validation of equipment noise levels.

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7.5.1 Construction and Commissioning Phases

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7.5.2 Operations Phase

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7.6 Discharges to Water

Discharges of pollutants to surface water bodies have the potential to adversely impact on the health of marine and freshwater flora and fauna. Water pollution has flow-on effects on natural resources and recreational values.

Wastewaters and surface runoffs are discussed in Section 4.5, and it is identified that:

- Wastewater expected from the prescribed premises during construction will consist of sanitary and desalination plant reject, and stormwater runoff will mostly be uncontaminated.
- A wide range of wastewaters are expected during commissioning and operation, which will be appropriately treated. Treated wastewater (effluents) will be discharged into the marine environment via the operation (permanent) marine outfall (subject to a separate (future) WAA).
- Stormwater runoffs collected in the first flush sumps will be diverted for treatment and then to the operation (permanent) marine outfall for release into the marine environment (subject to a separate (future) WAA).

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7.6.2 Operations Phase

Management and Monitoring

The wastewater and stormwater systems will be fully functional during the operation phase. These systems will be managed as described in Section 4.5, including monitoring of treated wastewater prior to discharge via the operation (permanent) marine outfall; to be addressed in a separate (future) WAA. Runoffs collected in the sedimentation ponds will be sampled and monitored as described in Section 7.7.2.

These facilities will be subject to a regular inspection and maintenance program throughout the operational life of the facility to ensure continued system integrity.

In addition to the inspection and maintenance program, wastewater and surface runoffs monitoring will be undertaken as described in Section 4.5. This monitoring program will also include monitoring treated wastewater prior to discharge via the operation (permanent) marine outfall; to be addressed in a separate (future) WAA. Runoffs collected in the sedimentation ponds will be sampled and monitored as described in Section 7.7.2.

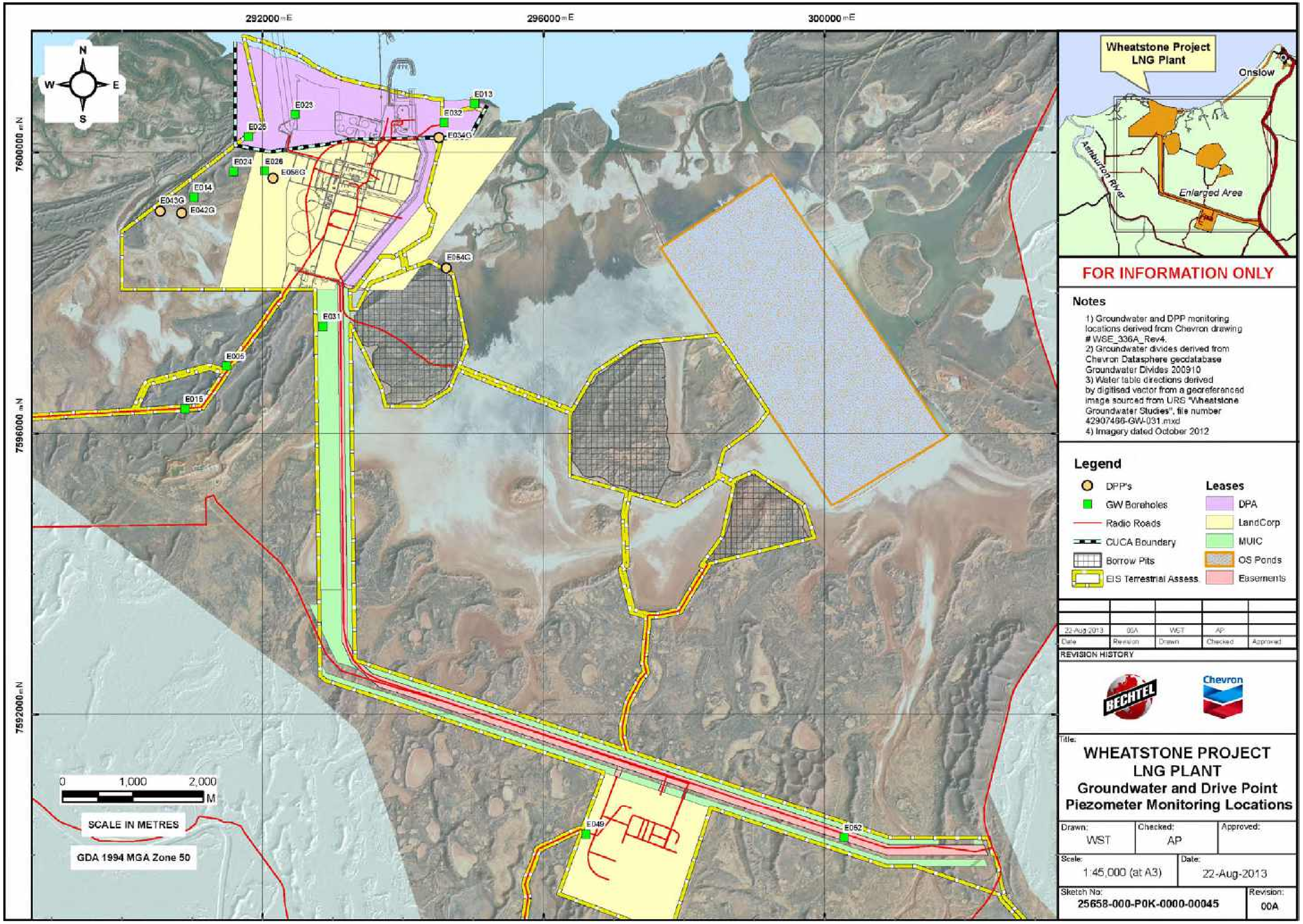

Figure 7.7.2-1: Wheatstone Project Groundwater and Drive Point Piezometer Monitoring Locations

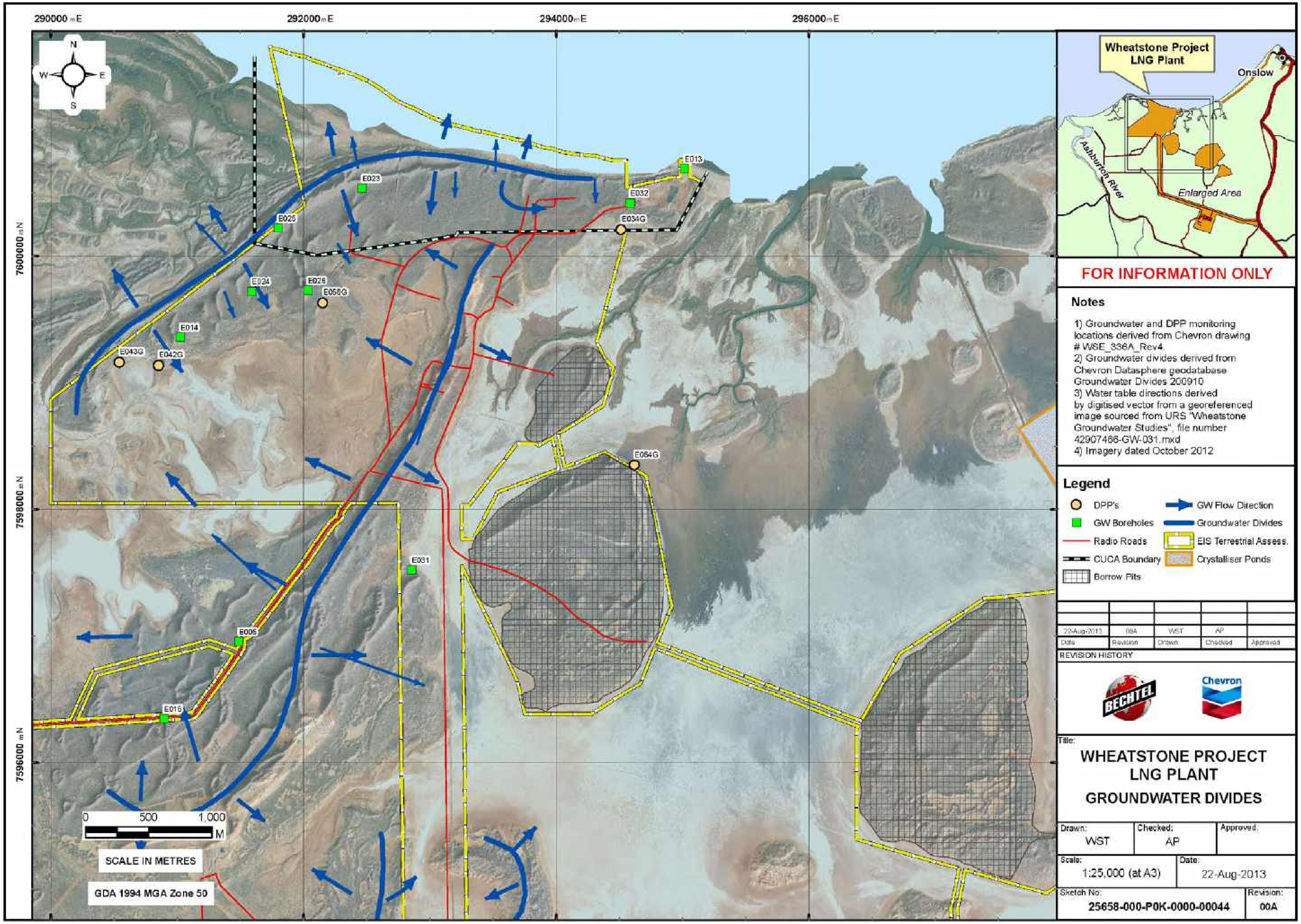

Figure 7.7.2-2: Wheatstone Project Groundwater Divides and Monitoring Locations

7.7 Discharges to Land

Discharges to land have the potential to alter soil nutrients and structure, which can adversely affect the growth of some native plant species as well as microorganisms and some fauna.

The only planned discharges to land throughout the construction, commissioning and operation of the LNG and Domgas Plants is stormwater. Hydrostatic testing of certain facilities and equipment (e.g. minor piping) will occur over a short duration. A hydrotest pond will be available for the storage of hydrotest water prior to disposal; the hydrotest pond was assessed in a previous WAA (W5480/2013/1) which requires the management of the hydrotest water stored within the pond to be detailed in a future hydrotest water management plan.

Measures described in Section 4.5, for the collection, segregation, and treatment of runoffs, are designed to prevent significant environmental impacts from discharges to land.

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7.7.2 Operations Phase

Management and Monitoring

The wastewater and surface runoffs during the operations phase are not expected to differ significantly from those during the commissioning phase. Therefore, the management measures and system discussed above for the commissioning phase, and as described in Section 4.5, will continue to function during the operations phase, including the management and monitoring approaches.

The stormwater and groundwater monitoring programs are yet to be fully developed as the Project has not matured to a stage where program details have been accurately addressed. This information is proposed to be provided to support the subsequent Licence application.

Stormwater sedimentation ponds will be designed to allow access for grab sampling to be performed to analyse pH, Turbidity and TPH to ensure the quality of stormwater meets the proposed water quality target criteria for release to the environment.

7.8 Solid / Liquid Waste Management

Solid and liquid wastes have the potential to adversely impact the environment and affect human health and wellbeing. Solid and liquid wastes can also be detrimental to an area's visual amenity and cause unreasonable odour.

This section does not address discharges to water and land; this is addressed in Sections 7.6 and 7.7 respectively.

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7.8.2 Operations Phase

Smaller volumes of waste will be generated during the operations phase compared to that generated during the construction phase. Waste streams are expected to include general solid waste (typically non-hazardous) as well as quantities of hazardous solid and liquid wastes.

Management and Monitoring

A waste transfer depot, to be located at the Plant Site, is proposed to be operated to support waste management activities during the operations phase. This transfer depot will receive wastes for segregation prior to disposal off-site by an appropriately licensed and approved waste contractor. This depot will be appropriately designed based on the likely waste streams and volumes to be transferred through it.

Hazardous and controlled wastes will continue to be appropriately collected and stored for disposal offsite in accordance with the Environmental Protection (Controlled Waste) Regulations 2004.

Some smaller-scale metal finishing and coating activities may be required throughout the operations phases to support maintenance activities; these activities will be undertaken in accordance with the requirements of the Environmental Protection (Abrasive Blasting) Regulations 1998 and Environmental Protection (Metal Coating) Regulations 2001.

An operations phase waste management plan is proposed to be developed and implemented to plan for and manage waste management activities during the operations phase.

7.9 Hydrocarbon / Chemical Storage

The storage of hydrocarbons and chemicals carries the risk of hazardous substance leaks and spills potentially polluting ground and surface water. These substances may also be harmful to humans and wildlife through direct contact or via inhalation. Many of these substances are flammable and there is an associated risk of ignition and fire.

There will be quantities of hydrocarbons and chemicals stored during construction of the LNG and Domgas Plants. Hydrocarbons (diesel) will be stored and used for construction equipment operation purposes. Compliant storage facilities will be constructed and operated during the relevant stages of construction where painting, chemical cleaning / passivating, hydrotest water treatment and other minor chemicals are required.

During commissioning and operation of the LNG and Domgas Plants large quantities of hydrocarbons / chemicals will be stored within the prescribed premises. Refer to Section 4.4 for a description of the major hydrocarbon and chemical storage facilities within the prescribed premises required to support the gas processing process. Additional smaller volumes of hydrocarbons and chemicals will also be required to support day to day operation of the plant (i.e. diesel).

The LNG and Condensate Storage Facilities were assessed in a previous WAA (W5480/2013/1) and are not included in this WAA.

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Management through operation

Good operational practices will be implemented at the LNG and Domgas Plants and associated facilities to minimise potential impacts to the environment and to maintain the health and safety of personnel. Some of the key management tools to be implemented include:

- Handling of fuel and operating facilities in accordance with the DMP Code of Practice
- Procedures in place for operators to ensure safe transfer at unloading or extraction / unloading points
- Regular facility / equipment inspections, monitoring and maintenance in accordance with operating procedures and safety management system under the plant MHF licence
- Where the facility exists (i.e. Diesel and Amine storage), spilt chemicals / hydrocarbons removed through sump vacuum truck extraction points to prevent further impact to the environment and reduce unnecessary loading on the stormwater drainage, sewerage and effluent treatment systems. The cause of spills will be investigated and reported per site operational procedures.

In addition, a new MHF Dangerous Goods Site Licence for the Wheatstone Project will be issued by DMP prior to commissioning. The MHF licence will include the LNG and Domgas Plants including the LNG and Condensate Storage Facilities.

As described in Section 7.7.2, the groundwater monitoring program provides a mechanism to detect any potential impacts to groundwater resources due to Project activities, including hydrocarbon and chemical storage.

7.9.2 Operations Phase

<u>Management and Monitoring</u>

Management controls discussed above for the major hydrocarbon and chemical storage facilities (i.e. ‘management through operation’ controls) will continue to apply during the operations phase. In addition, there may be the ongoing requirement for the storage and handling of minor quantities of hydrocarbons and chemicals outside of designated major storage areas. In such circumstances, the storage and handling of these substances will be undertaken by competent personnel in line with relevant legislation and standards.

As described in Section 7.7.2, the operations phase groundwater monitoring program is yet to be fully developed. This information is proposed to be provided to support the subsequent Licence application.

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10.0 DEFINITIONS AND ABBREVIATIONS

Acronyms/Terms	Definition
AGRU	Acid Gas Removal Unit
AGTO	Acid Gas Thermal Oxidiser
AHD	Australian Height Datum
aMDEA	methyldiethanolamine
ANRA	Australian Natural Resource Atlas
ANSIA	Ashburton North Strategic Industrial Area
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS	Australian Standards
Bechtel	Bechtel (Western Australia) Pty Ltd
Biota	Biota Environmental Sciences Pty Ltd
BOG	LNG Boil Off Gas
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
°C	Degrees Celsius
CAQMP	Construction Air Quality Management Plan
CAR	Carnarvon Bioregion
CCTV	Closed Circuit Television
CDMP	Construction Dust Management Plan
CECP	Construction Environmental Control Plan
CESMP	Construction Erosion and Sedimentation Management Plan
Chevron	Chevron Australia Pty Ltd
CNMP	Construction Noise Management Plant
COSRMP	Construction Onshore Spill Response Management Plan
CPI	Corrugated Plate Interceptor
CWMP	Construction Waste Management Plan
CWWMP	Construction Wastewater Management Plan
DAF	Dissolved Air Flotation
dB	Decibel
DEC	Department of Environment and Conservation (WA)
DEHWA	Department of the Environment, Heritage, Water, and the Arts
DG Act	*Dangerous Goods Safety Act 2004*

Acronyms/Terms	Definition
DG Regulations	Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007
DMP	Department of Mines and Petroleum (WA)
DMP Code of Practice	DMP have released a Code of Practice for the Storage and handling of dangerous goods
DoH	Department of Health (WA)
Domgas	Domestic Gas
DOTE	Department of the Environment (formally known as Department of Sustainability, Environment, Water, Populations and Communities)
DoW	Department of Water (WA)
DSD	Department of State Development (WA)
DOAS	Differential Optical Absorption Spectroscopy
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority (WA)
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection & Biodiversity Conservation Act 1999*
EPC	Engineering, Procurement and Construction
ERMP	Environmental Review and Management Programme
ES&H	Environment, Safety & Health
GHG	Greenhouse Gas
GTC	Gas Turbine Compressors
GTG	Gas Turbine Generators
HC	Hydrocarbon
HP	High Pressure
ISIRIS	Optical Spectrograph and Infra-Red Remote Imaging System
kg	Kilogram
kg/hr	Kilograms per Hour
km	Kilometre
km^2	Square Kilometre
KO	knockout
LDAR	Leak Detection and Repair
LNG	Liquefied Natural Gas
L	Litre
LP	Low Pressure
m	Metre

Acronyms/Terms	Definition
m^3	Cubic Metre
MEG	Mono Ethylene Glycol
mg	Milligram
mg/L	Milligrams per Litre
MHF	Major Hazard Facility
MHF Regulations	The Dangerous Good Safety (Major Hazard Facilities) Regulations 2007
mm	Millimetre
MS	Ministerial Statement
MS 873	Ministerial Statement No. 873: The State (WA) Primary Environmental Approval, and conditional requirements for the Wheatstone Project. Government of Western Australia, Minister for the Environment; Water, Hon. Bill Marmion MLA, 30 August 2011.
MSDS / SDS	Material Safety Datasheet / Safety Data Sheet
MW	Megawatt
µg	Microgram
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure
ng	Nano gram
NGER Act	National Greenhouse and Energy Reporting Act 2007
NMP	Wheatstone Noise Management Plan
NMVOC	Non-methane volatile organic compounds
Noise Regulations	Environmental Protection (Noise) Regulations 1987
NO_x	Nitrogen Oxide
NRU	Nitrogen Rejection Unit
NTU	Nephelometric Turbidity Unit
OTS	Operations Training Simulator
OWS	Oily Water Treatment System
PASCS	Process Area Spill Containment Sump
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 micrometres in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 micrometres in diameter
ppb	Pat per Billion
ppm	Pat per Million
RO	Reverse Osmosis
RTO	Recuperative Thermal Oxidisers
SO_x	Sulfur oxide

Acronyms/Terms	Definition
t	Metric Tonne
TAA	Terrestrial Assessment Area
TEOM	Transformer Environment Overcurrent Monitor
TIAH	Turbine Inlet Air Humidification
the Regulations	Environmental Protection Regulations 1987
TO	Thermal Oxidiser
TEG	Tri-Ethylene-Glycol
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
WAPC	Western Australian Planning Commission
WA	Western Australia
WAA	Works Approval Application
Wheatstone Project	Wheatstone Project LNG Plant
WHRU	Waste Heat Recovery Unit

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APPENDIX A:

WHEATSTONE FOUNDATION PROJECT AIR EMISSIONS DESIGN REPORT

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Wheatstone Project

Air Emissions Design Report - Foundation Project

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Company Document Control No.	Project	Area	Discipline	Type	Originator	Package	Sequence-Sht	Revision
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Wheatstone Project
Air Emissions Design Report - Foundation Project

Document No: WS0-0000-HES-RPT-CVX-000-00102-000
Revision: 1
Revision Date: 11/06/2013

WHEATSTONE PROJECT

Air Emissions Design Report - Foundation Project

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TABLES

FIGURES

ACRONYMS, ABBREVIATIONS AND TERMINOLOGY

AEDR	Air Emissions Design Report
AGRU	Acid Gas Removal Unit
aMDEA	Activated Methyldiethanolamine
API	American Petroleum Institute
Barg	Bar (gauge) – a unit for measuring pressure defined as 100 000 Pascals. Approximately equal to atmospheric pressure at sea level.
BOG	Boil Off Gas
BPM	Best Practicable Measures
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CEO	Chief Executive Officer of the Office of the Environmental Protection Authority
CCR	Central Control Room
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations (United States)
Chevron	Chevron Australia Pty Ltd
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COS	Carbonyl Sulfide
Cth	Commonwealth
DEC	Department of Environment and Conservation (WA)
DEH	Department of Environment and Heritage (Commonwealth)
DEWHA	Department for the Environment, Water, Heritage and the Arts (Commonwealth) – formerly DEH
DLE	Dry Low Emissions
Domgas	Domestic gas
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme
EP Act	*Environmental Protection Act 1986*
EPA	Environmental Protection Authority (WA)
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EPBC 2008/4469	The Commonwealth Primary Environmental Approval, and conditional requirements for the Wheatstone Project as amended from time to time. Commonwealth Government of Australia, Minister for Sustainability, Environment, Water, Populations and Communities, Hon. Tony Burke, 22 September 2011.
ESD	Emergency Shut Down
FFG	Flame Front Generator (system for flare ignition)
FMS	Flange Management System

g/s	Grams per second
GTG	Gas Turbine Generator
H_2S	Hydrogen Sulfide
HC	Hydrocarbon
HEI	High Energy Ignition (system for flare ignition)
HES	Health, Environment and Safety
HP	High Pressure (such as High Pressure Flare System)
hr	Hour
IAH	Inlet Air Humidification
ICSS	Integrated Control & Safeguarding System
K	Degree Kelvin
kg	Kilogram
km	Kilometre
KO	Knockout (such as Knockout Drum)
kPa	Kilopascal
LDAR	Leak Detection And Repair
LHE	Lean Head End
LNG	Liquefied Natural Gas
LP	Low Pressure (such as Low Pressure Flare System)
m	Metre
mg/Nm^3	Milligrams per Normal cubic metre
MS 873	Ministerial Statement No. 873 as amended from time to time: The State (WA) Primary Environmental Approval, and conditional requirements for the Wheatstone Project. Government of Western Australia, Minister for the Environment; Water, Hon. Bill Marmion MLA, 30 August 2011.
MTPA	million tonnes per annum
MW	Megawatt
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure
NH_3	Ammonia
NOHSC	(Australian) National Occupational Health and Safety Commission
NOx	Nitrogen Oxides (primarily NO or NO_2)
NPI	National Pollutant Inventory
NRU	Nitrogen Rejection Unit
OE	Operational Excellence
OEMS	Operational Excellence Management System
OEPA	Office of the Environmental Protection Authority
OTS	Operations Training Simulator

PCS	Process Control System
PM	Particulate Matter
$PM_{2.5}$	Particulate matter of diameter 2.5 microns or less
PM_{10}	Particulate matter of diameter 10 microns or less
ppm	Parts per million
ppmv	Parts per million by volume
ppmvd	Parts per million, volume dry
Project	Nearshore and offshore marine facilities, trunkline, and Onshore Facility
Proponent	Chevron Australia Pty Ltd
(the) Report	The Foundation Project Air Emissions Design Report
RCM	Reliability Centred Maintenance
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth) – formerly DEWHA
SCR	Selective Catalytic Reduction
Scf/yr	Standard cubic feet per year
SIS	Safety Instrumented System
SOx	Sulfur Oxides (typically sulfur dioxide - SO_2)
SO_2	Sulfur Dioxide
TJ/day	Terajoules per day
TO	Thermal Oxidiser
tpa	Tonnes per annum
USA	United States of America
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHRU	Waste Heat Recovery Unit
WA	Western Australia

1.0 BACKGROUND

1.1 Project Overview

Chevron Australia Pty Ltd (Chevron) will construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast, Western Australia (WA). The Wheatstone Foundation Project will process gas from various fields offshore in the West Carnarvon Basin. Ashburton North is the approved site for the LNG and Domgas production facility. The Foundation Project requires installation of gas gathering, export and processing facilities in Commonwealth and State waters and on land. The Foundation Project will produce gas from Production Licences WA-46-L, WA-47-L, WA-48-L and WA-49-L, 145 km offshore from the mainland, approximately 100 km north of Barrow Island and 225 km north of Onslow. Figure 1.1 shows the location of the Wheatstone Foundation Project.

The Ashburton North site is approximately 12 km south-west of Onslow along the Pilbara coast within the Shire of Ashburton. The Foundation Project will consist of two LNG processing trains, each with a capacity of approximately 4.45 million tonnes per annum (MTPA). The Domgas plant will be a separate but co-located processing train and will form part of the Foundation Project. Environmental approval was granted for a 25 MTPA LNG plant and associated Domgas facilities to allow for the expected future expansions. The development of the Domgas plant also includes an onshore pipeline installation to tie-in to the existing Dampier-to-Bunbury Natural Gas Pipeline (DBNGP) infrastructure. Figure 1.2 shows the Foundation Project Plant Layout of the LNG Plant and Domgas Plant and adjacent marine facilities.

1.2 Proponent

Chevron is the proponent and the company taking the action for the Project on behalf of its joint venture participants Apache Corporation, Tokyo Electric Power Company (TEPCO), Kuwait Foreign Petroleum Exploration Company (KUFPEC), Shell and Kyushu Electric Power Company (Kyushu).

1.3 Objectives

The Air Emissions Design Report (the Report) as required by State (WA) Ministerial Approval, Ministerial Statement No. 873 (MS 873) Condition 18-2, aims to meet the requirements of MS 873 Condition 18-1 to 18-3 (Table 1.1) for the Wheatstone Foundation Project. As set out in MS 873 Conditions 18-1 and 18-2, the Report shall:

- Demonstrate that specific design features have been implemented to minimise and monitor emissions to air, in particular:
  - Minimising emissions of volatile organic compounds (VOCs) and nitrogen oxides (NOx)
  - Optimising the smokeless capacity of flares so as to minimise the frequency and duration of visible smoke
  - Minimising non-emergency flaring of gas
- Demonstrate that operations management measures have been implemented to minimise emissions to air
- Benchmark emissions of VOCs and NOx to similar LNG Projects in Australia and internationally.

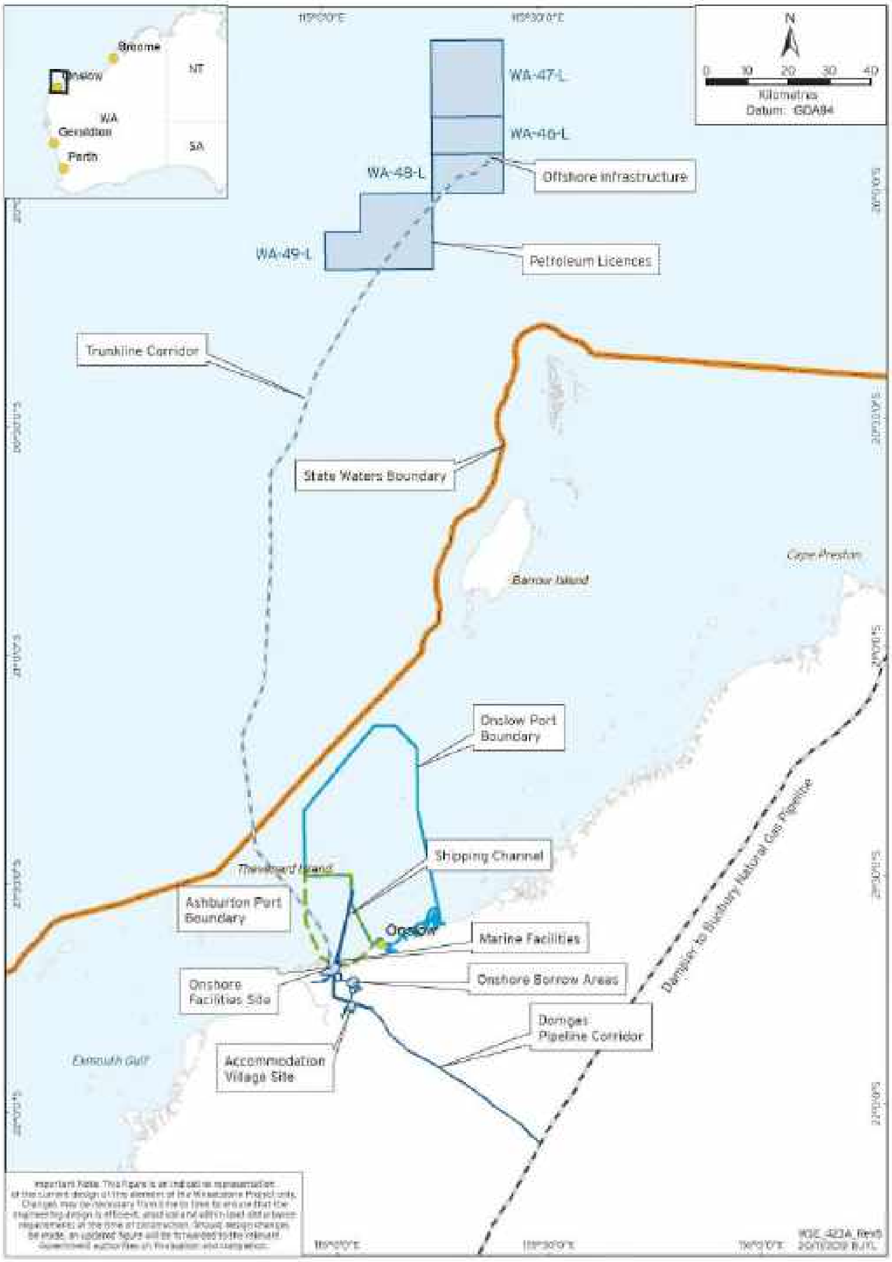

Figure 1.1: Location of the Wheatstone Project Area

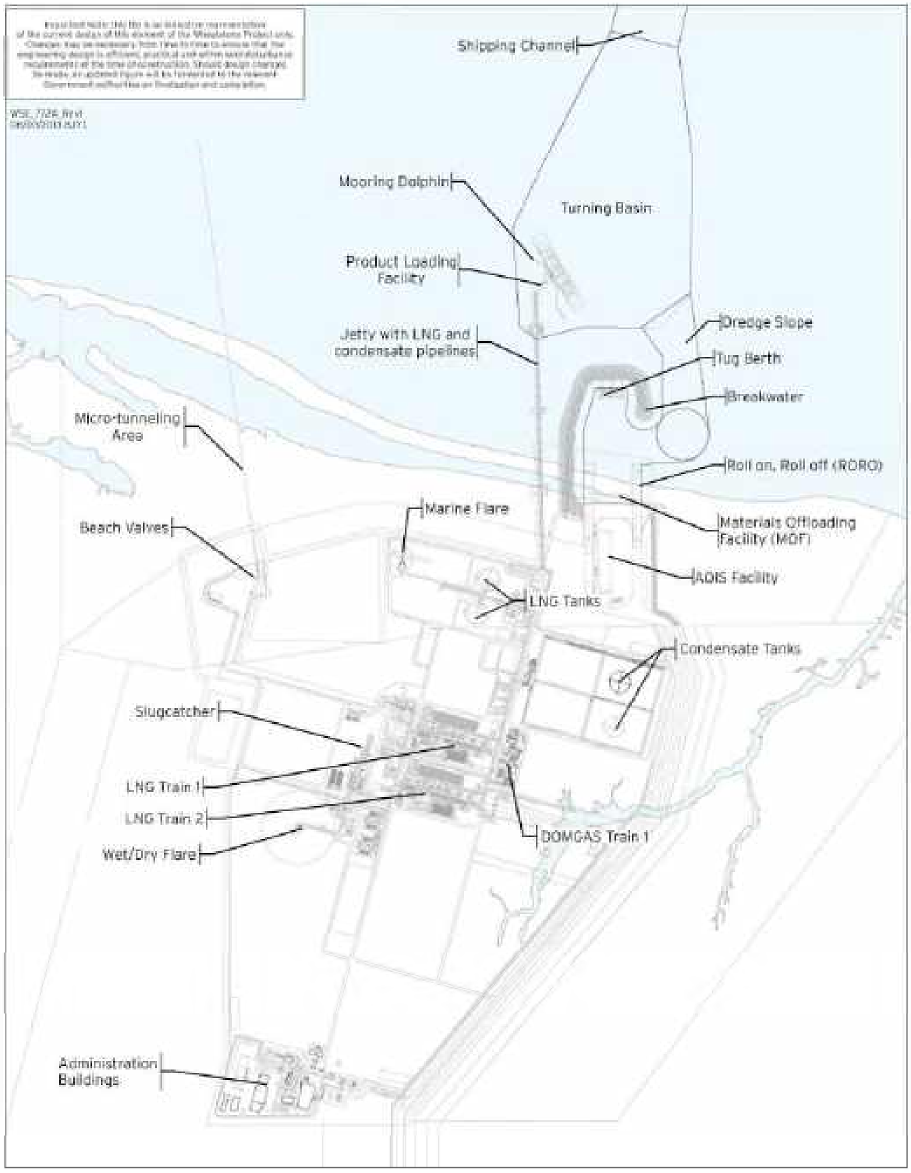

Figure 1.2: Foundation Project Plant Layout

Table 1.1: Western Australian Ministerial Conditions Statement No. 873

No.	Condition	Section
18	Emissions to Air	--
18-1	The Proponent shall install equipment in the LNG plants and Domgas plants and manage ongoing operations such that best practice for a liquefied natural gas/domestic gas facility is achieved in respect of:	--
18-1-i	minimising emissions of volatile organic compounds and oxides of nitrogen emissions;	4.0, 7.0
18-1-ii	optimising the smokeless capacity of flares so as to minimise the frequency and duration of visible smoke; and	8.0
18-1-iii	minimising non emergency flaring of gas	8.0
18-2	As part of its Works Approval application under Part V of the EP Act for the Foundation Project and also for Works Approval applications for subsequent LNG trains, the Proponent shall provide reports to DEC showing:	--
18-2-i	specific design features that have been used to minimise and monitor emissions to air, pursuant to condition 18-1;	7.0, 8.0, 9.0
18-2-ii	how the design features compare with current lowest emissions for similar operations and proposals internationally and within Australia; and	6.0
18-2-iii	a peer review report as required by condition 18-3	1.6
18-3	The Proponent shall commission peer reviewer(s), approved by the CEO to undertake the following, in accordance with terms of reference also approved by the CEO:	1.0
18-3-i	a review of the reports referred to in condition 18-2(i) and (ii);	--
18-3-ii	provide comment on the basis and validity of the conclusions in the reports; and	--
18-3-iii	provide comment on the relevance of the described Australian and international standards for this Proposal	--
18-4	Where practicable the Proponent shall replace plant and equipment with that which meets the best practice standards as at the time of replacement. Replacement equipment shall not result in an increase in emissions or reduction in air quality	--

1.4 Scope

Consistent with the objectives of Condition 18-1, this Report has been prepared to meet the requirements of Condition 18-2 and addresses emissions to air arising from the LNG and Domgas Plants of the Wheatstone Foundation Project. The key equipment in scope for the Report is listed in Table 1.2. Chevron considers the following emissions to air from combustion equipment, flares and vents as described in MS 873 to be within the scope of this report:

- NOx, including nitrogen oxide (NO) and nitrogen dioxide (NO_2)
- Sulfur oxides (SOx), typically represented by sulfur dioxide (SO_2)
- Carbon monoxide (CO)
- Airborne Particulate Matter of size 10 microns or lower (PM_{10}) and visible smoke from flares
- VOCs typically aliphatic hydrocarbons (HCs) excluding methane (CH_4), and aromatic HCs including benzene, toluene, ethylbenzene and xylene (BTEX).

Table 1.2: Key Sources of Emissions to Air

Foundation Project Emission Source	Associated Atmospheric Pollutants
Twelve 43 megawatt (MW) (nominal capacity) GE LM6000PF Aeroderivative Gas Turbines driving the Refrigeration Compressors within the LNG Plant	NO_x, PM_{10}, SO_2, VOCs[1], CO
Four 43 MW (nominal capacity) GE LM6000PF Aeroderivative Gas Turbines driving the Power Generators in the LNG and Domgas Plant	NO_x, PM_{10}, SO_2, VOCs[1], CO
One Domgas Plant Regeneration Gas Process Heater and One Hot Oil System Startup Process Heater	NO_x, PM_{10}, SO_2, VOCs[1], CO
Three Low Pressure, Three High Pressure (wet, dry gas + spare) Elevated Flares	NO_x, PM_{10}, SO_2, VOCs[1], CO
One Marine Flare	NO_x, PM_{10}, SO_2, CO
Two Acid Gas Thermal Oxidiser Vents within the LNG Plant and one Acid Gas Thermal Oxidiser Vent within the Domgas Plant	NO_x, PM_{10}, SO_2, VOCs[1,2], CO

[1] VOCs related to natural gas combustion streams typically contain unburnt aliphatic HCs.
[2] VOCs related to acid gas thermal oxidiser vents may contain aromatic compounds.
Note: BTEX are a subset of VOCs and have been accounted for under VOC emissions.

1.5 Out of Scope

Emissions from diesel generators and the submerged combustion vaporiser are out of scope of the Report because of the infrequency of their use. Any associated yearly air emissions will be very low. These sources are typically offline except for the following events:

- Diesel generators used for initial commissioning of the main power generation system
- Six (6) diesel generators used during LNG plant trips cold-start procedures and for their intermittent periodic testing (total up to 25 hr/yr/generator)
- Two (2) fire water pumps for up to 52 hr/yr/unit

- One (1) submerged combustion vaporiser for generating natural gas when the Domgas plant is shut down for periodic maintenance (up to 240 hr/yr, 40 days total during 4 yr).

Low sulphur diesel as sold in Western Australia (10 ppm) would be used to reduce sulphur emissions.

Consistent with the scope and objectives in Section 1.3 and 1.4, air emissions arising from activities outside the LNG and Domgas plants of the Wheatstone Foundation Project such as the emissions from shipping activities are out of scope for this report; management of air emissions from these activities will be detailed in future operational plans according to best practice guidance such as MARPOL Annex VI pertaining to VOC management for condensate ship loading activities. Greenhouse gas emissions including CH_4, carbon dioxide (CO_2) and nitrous oxide are also outside the scope of this report.

1.6 Environmental Approvals

The Wheatstone Project was assessed through an Environmental Impact Statement / Environmental Review and Management Program (EIS/ERMP) assessment process under the WA *Environmental Protection Act 1986* (EP Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Wheatstone Project was approved by the WA Minister for Environment; Water on 30 August 2011 by way of Ministerial Statement No. 873 (MS 873) and as amended by Ministerial Statement No. 903 (MS 903), Ministerial Statement No. 922 (MS 922), Ministerial Statement No. 931 (MS 931) and Attachment 1 and Attachment 2. Details of relevant Commonwealth and State regulatory requirements are provided in Section 2.1 and 2.2, respectively.

In accordance with MS 873 Condition 18-3, Chevron commissioned a Peer Reviewer, approved by the Chief Executive Officer (CEO) of the Office of the Environmental Protection Authority (OEPA), to undertake the following, in accordance with terms of reference also approved by the CEO:

- A review of this report
- Provision of comments on the basis and validity of the conclusions in this report
- Provision of comments on the relevance of the described Australian and International standards for the Proposal.

The aforementioned Peer Review of this report shall be submitted to the Department of Environment and Conservation (DEC) as part of the Foundation Projects Works Approval Application under Part V of the EP Act.

1.7 Revision of Air Emissions Design Report

The Air Emissions Design Report (AEDR) will not be reviewed on a predetermined schedule and will be revised where there are:

- Proposed changes or modifications to the plant equipment for the Wheatstone Foundation Project
- Subsequent work approval applications for subsequent trains (Wheatstone Expansion Project).

To the extent of any difference or inconsistency between the AEDR and the requirement of any works approval or licence for the Wheatstone Foundation Project, the requirement of the works approval or licence is to take precedence.

2.0 LEGISLATIVE REQUIREMENTS

The legislation listed below has been considered in the preparation of the Report and applies to the Wheatstone Project as relevant. The relevant legislation below is current at the time the Report is submitted. The relevant legislation may change from time to time, in which case Chevron will comply with the relevant law.

2.1 Commonwealth

2.1.1 Environmental Protection Biodiversity Conservation Act 1999

The EPBC Act provides the Australian Government with powers to provide for the protection of matters of national environmental significance.

2.1.2 National Air Quality Standards

Through the National Environment Protection Council (NEPC), the Australian, State and Territory Governments agreed to the National Environmental and Protection Measure (NEPM) for Ambient Air Quality on 26 June 1998. The measure sets air quality standards for six criteria air pollutants: CO, NO_2, photochemical oxidants (as Ozone), SO_2 and particles ($PM_{2.5}$ and PM_{10}). The NEPM threshold concentrations are shown in Table 2.1.

Table 2.1: National Air Quality Standards

Pollutant	Concentration and averaging period	Goal (Maximum allowable exceedances)
Carbon monoxide (CO)	9.0 ppm measured over an eight hour period	1 day a year
Nitrogen dioxide (NO_2)	0.12 ppm averaged over a one hour period 0.03 ppm averaged over a one year period	1 day a year None
Ozone	0.10 ppm of ozone measured over a one hour period 0.08 ppm of ozone measured over a four hour period	1 day a year 1 day a year
Sulfur Dioxide (SO_2)	0.20 ppm averaged over a one hour period 0.08 ppm averaged over a 24 year period 0.02 ppm averaged over a one year period	1 day a year 1 day a year None
Particles as PM_{10}	50 $\mu g/m^3$ averaged over a 24-hour period	5 days a year
Particles as $PM_{2.5}$	Advisory reporting standard: 25 $\mu g/m^3$ over a one day period; 8 $\mu g/m^3$ over a one year period	--

2.2 Western Australia

2.2.1 Environmental Protection Act 1986

The EP Act requires proposals likely to have a significant effect on the environment to undergo an Environmental Impact Assessment (EIA). The EIA is then assessed by the OEPA who recommend the applicable conditions, and approved by the Minister for the Environment if determined to be acceptable.

2.2.2 WA Environmental Protection Agency Guidance Statements

Schedule 4 of MS 873 defines 'best practice' as having the meaning outline in the WA Environmental Protection Agency (EPA) Guidance Statement 55. WA *EPA Guidance Statement 55, Implementing Best Practice in proposals submitted to the Environmental Impact Assessment process (EPA, 2003)* sets the following three relevant criteria to define best practice:

i. All relevant environmental quality standards must be met.
ii. Common pollutants should be controlled by proponents adopting Best Practicable Measures (BPM) to protect the environment.
iii. Hazardous pollutants (like dioxins) should be controlled to the Maximum Extent Achievable, which involves the most stringent measures available. For a small number of very hazardous and toxic pollutants, costs are not taken into account.

Guidance Statement 55 further defines the following:

<u>Best Practicable Measures</u>

> *Best Practicable Measures (BPM) incorporate technology and environmental management procedures which are practicable having regard to, among other things, local conditions and circumstances (including costs), and to the current state of technical knowledge, including the availability of reliable, proven technology.*

<u>Maximum Extent Achievable</u>

> *The maximum extent achievable is the degree of reduction in the emission of wastes which is equivalent to or greater than that which can be achieved by the application of best available technology or practices. In some circumstances it may require the application of new, original or innovative control technology or practices to a particular source (EPA Victoria 2001a) and must be effective and consistent with the level of risk that exists, without undue regard to costs. Maximum Extent Achievable measures are only intended to apply to hazardous pollutants as described above and set out in the Victorian EPA's State Environment Protection Policy for Air Quality Management (EPA Victoria 2001c). Nor are they intended to apply at pollutant concentrations that do not pose a creditable risk.*

2.3 Regulations, Standards and Guidelines

The use of best practice processes is relevant to the assessment of new proposals referred to the OEPA under Part IV of the EP Act, and also to applications for works approvals and licences under Part V of the EP Act. *WA EPA Guidance Statement 55* and other national and international standards, regulations and guidelines considered by the Wheatstone Project include but not limited to:

- *NSW Government Gazette, Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (NSW)*
- *Victoria Government Gazette, State Environment Protection Policy 2001 (Air Quality Management) (VIC)*
- *US EPA, 40 CFR 60, New Source Performance Standards, Protection of Environment, Sub Part KKKK, Standards of Performance for Stationary Gas Turbines*
- *US EPA*, Alternative Control Techniques Document – NOx Emissions from Stationary Gas Turbines (EPA-453/R-93-007).

The NSW Protection of the Environment Operations (Clean Air) Regulation (2010) emissions standards are used as a reference in the AEDR as this was most recently revised and compares well with other international standards such as the Integrated Pollution Prevention and Control - Best Available Techniques for Large Combustion Plants (2006).

3.0 FACILITIES DESCRIPTION

3.1 Overview

The Foundation Project comprises of two 4.45 MTPA LNG trains utilising the ConocoPhillips Optimized Cascade® Process, a nominal 200 terajoules per day (TJ/day) Domgas plant and supporting utilities and general facilities. Schematic diagrams of the LNG train and Domgas Plant are shown in Figure 3.1 and Figure 3.2 respectively.

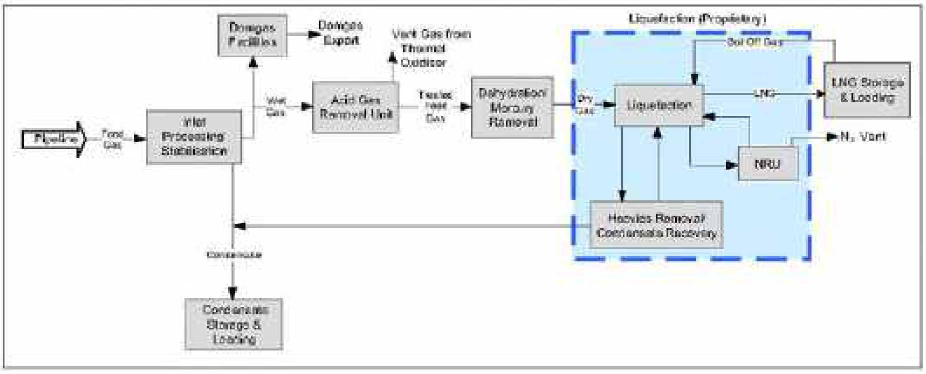

Figure 3.1: Simplified LNG Plant Block Flow Diagrams

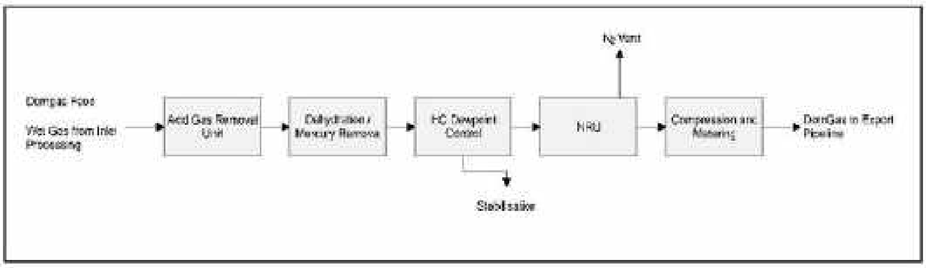

Figure 3.2: Simplified Domgas Plant Block Flow Diagram

The various process units, utilities and general facilities that comprise the Foundation Project LNG and Domgas Plants include the LNG Plant Process Units, Domgas Plant Units, and Utilities and General Facilities. The components in each are presented in the following sections.

3.1.1 LNG Plant Process Units

- Inlet gas conditioning and condensate stabilisation
- Acid gas removal
- Dehydration and mercury removal
- Liquefaction and refrigerant compression, including nitrogen rejection
- Heavy HC removal / condensate recovery and fractionation.

3.1.2 Domgas Plant Units

- Acid gas removal
- Dehydration and mercury removal
- Hydrocarbon dew point control and nitrogen rejection
- Compression and metering.

3.1.3 Utilities and General Facilities

- Fuel gas and recycle gas system
- Power generation system
- Heating medium system
- Pressure relief/liquids disposal
- Flare and vent systems
- Diesel storage and distribution
- LNG and condensate products storage and export facilities
- Refrigerant storage
- Process and stormwater treatment
- Firewater system and storage
- Plant and instrument air
- Water system
- Inlet Air Humidification (IAH)
- Nitrogen generation and supply.

3.2 LNG Plant Process Units

3.2.1 Inlet Gas Conditioning and Condensate Stabilisation System

The Wheatstone Onshore Inlet Facilities are designed to condition the dehydrated feed gas from the Wheatstone offshore platform and provide a stable process gas stream to the LNG trains and Domgas plant. Feed gas entering through the slug catcher is separated into process gas, HC condensate, and wastewater streams. Condensate is stabilised in the condensate stabiliser system, which strips off light-ends to meet condensate vapour pressure specifications, before sending the product to the condensate tanks. The stripped gas is compressed and transferred to the main gas feed line to the LNG trains for processing and wastewater is routed to the effluent water treatment unit.

3.2.2 Acid Gas Removal Unit

Process gas is routed to the Acid Gas Removal Unit (AGRU) to remove carbon dioxide and hydrogen sulfide (collectively known as 'acid gas') using conventional activated methyldiethanolamine (aMDEA) technology. Some BTEX in the process gas will also be absorbed by the aMDEA solvent. Heat is applied to the saturated aMDEA solution to regenerate aMDEA, which is returned to the absorber via a closed loop system. The stripped gas contains approximately 93% CO_2, water and trace amounts of BTEX and hydrogen sulphide (H_2S). This is disposed of through an Acid Gas Thermal Oxidiser (TO), which oxidises any HCs or sulphur compounds to CO_2, SOx and water. An Acid Gas TO is installed in each LNG train.

3.2.3 Liquefaction and Refrigerant Compression, including Nitrogen Rejection Unit (Licensor Proprietary Section)

The conditioned gas then passes into the liquefaction system, which progressively cools it to -160°C, at which point the gas liquefies into LNG. This process uses a "cascade" of successive refrigeration steps to progressively cool and liquefy the feed gas into LNG. There are three refrigerant services used: propane, ethylene and methane, each in their own circulation loops. Six LM6000PF aero derivative gas turbine drivers are used per LNG train to provide the motive power to the refrigerant compressors.

As the conditioned gas passes through a series of heat exchangers, it gives up heat to the successive refrigerants and cools. The cooled gas is then flashed (allowed to expand into a separator or drum) to atmospheric pressure, cooling it further. The resulting LNG is then pumped to the insulated LNG storage tanks and stored at atmospheric pressure and -160 °C. A cryogenic Nitrogen Rejection Unit (NRU) is used in the LNG trains to remove excess N_2 to meet LNG and fuel gas specifications. N_2 is cryogenically separated and concentrated in the NRU via a series of fractionation columns. The concentrated N_2 with trace amount of CH_4 (less than 1.5 mol %) is vented to the atmosphere.

3.2.4 Heavy Hydrocarbon Removal and Fractionation (Licensor Proprietary Section)

Condensed HC liquid from cooling of the conditioned gas is separated and fractionated to remove the heavier HC components. This prevents freezing of heavier HC compounds in the low temperature liquefaction section as well as satisfies heating value and composition specifications of the LNG product. These heavy components are recovered as natural gas liquids or condensate stream and are blended with the stabilised condensate from the inlet facilities to produce the final condensate product.

3.3 Domgas Plant Process Units

3.3.1 Acid Gas Removal Unit

The AGRU system is designed to remove acid gas components such as CO_2 and H_2S from the feed gas using an aMDEA system. The removed acid gas will be routed to a thermal oxidiser for destruction.

3.3.2 Hydrocarbon Dew Point Control and NRU

The HC dew point requires control to prevent the formation of liquids during pipeline gas transportation. The treated feed gas is cooled and then flashed (allowed to expand by reducing pressure) through a Joule-Thompson Valve (or equivalent process) to condense HC liquid and meet the product dew-point specification. The HC liquid is routed back to the inlet facilities for re-processing.

To meet the Domgas' inert gas content specification, N_2 must be removed from the gas. A slip stream of treated gas is taken from the dew point control unit and sent to a NRU where N_2 is cryogenically separated from methane and then vented to the atmosphere. The N_2 free gas stream is blended with the rest of the treated gas stream from the dewpoint control unit.

3.3.3 Compression and Metering

Once treated to meet sales specifications, the domestic supply gas is compressed, metered and sent to the distribution pipeline.

3.3.4 LNG Revapourisation

Domgas availability and continued delivery of domestic gas during extended outages such as planned Domgas Plant or Wheatstone Platform turnarounds requires the use of a LNG revapourisation unit. The LNG revapourisation unit takes LNG from either of the LNG storage tanks to produce natural gas. A Submerged Combustion Vapouriser is used to regasify the LNG. This will be operated only when there is no feed gas available from the offshore facilities.

3.4 Utilities and General Facilities

3.4.1 Fuel Gas and Recycle Gas Systems

The purpose of the Fuel Gas and Recycle Gas systems is to reliably provide fuel gas to users throughout the LNG facility. The fuel gas system is comprised of a high pressure (HP) fuel gas section which supplies fuel gas at about 45 barg to the Gas Turbines Drivers and Gas Turbine Generators (GTGs) and a low pressure (LP) fuel gas section which supplies fuel gas to the flare pilots and purges, the thermal oxidisers, the Domgas Plant regeneration gas heater and other miscellaneous users. The fuel gas is normally supplied by the methane compressor loop. Back up fuel gas can be supplied from the outlet of the dehydration unit and the inlet facilities.

3.4.2 Power Generation System

The power generation system will supply power to the two LNG trains, the Domgas Plant train as well as the common utility and offsite areas, including the LNG and condensate storage tanks, marine product loading facility, and the administration and maintenance areas. Four General Electric LM6000PF GTGs with IAH will supply sufficient power to meet the maximum plant power requirements over the entire site ambient temperature range in a load sharing N+1 configuration. The four GTGs will equally share the plant power load to provide adequate capacity, stability and redundancy to meet peak demand, even if one GTG trips off-line. During periods of lower ambient temperature or reduced power demand, only three GTGs will be operated with the fourth unit off-line and available for maintenance.

3.4.3 Heating Medium System

Waste heat recovery units (WHRU) are installed in exhaust ducts of each of the refrigeration compressor gas turbines. This system will supply essentially all of the LNG Plant's process heating requirements. A closed-loop, hot oil heating medium is used to transport heat from the WHRUs to supply major users, including the condensate stabilisation facilities, AGRU regeneration, Fractionation reboiler, etc. The Heating Medium System does not require any supplemental burners to meet plant heat demands. A small gas fired hot oil startup heater common to both LNG Trains would only be used during start up operations when the refrigerant gas turbine drivers are not operating.

3.4.4 Pressure Relief/Liquids Disposal, Flare and Vent Systems

A pressure relief and liquids disposal system, with both wet and dry service flare systems is provided to support the start-up, shutdown, emergency, and maintenance depressurisation requirements of the process facilities. A separate marine flare is provided to handle the vapour from the LNG Storage Tanks and excess boil-off vapour generated during LNG ship loading. The LNG plant flare system currently comprises a grouping of HP and LP flare structures, each containing, a wet, dry and a common spare flare.

The Wet Gas Relief and Flare System consists of large collection header, knockout (KO) drum, pumps, and flare stacks. A separate wet liquid header collects liquids from process equipment during de-inventorying for maintenance and from manual drains. The liquid is routed to the Wet Gas Flare KO drum where any light components will vaporise, and residual liquid can be separated and recycled to the process.

The Dry Gas Relief and Flare System consist of a large collection header, flare stacks, KO drum, and vaporisers. A separate header system is used to collect dry (no water) liquids and transport them directly to the Dry Gas Flare KO drum, avoiding the thermal stresses caused from cold liquids running down the bottom of the large diameter collection header.

3.4.5 Diesel Storage and Distribution

Diesel storage and distribution facilities provide diesel to many users such as essential power backup systems. Five diesel engine driven generators (each nominal 2 MW capacity) will be installed to supply the essential power for the LNG Plant when the main power supply system is tripped offline or is not available. The diesel generators are sized in an N+1 configuration so that all essential power is provided by four units and the fifth is available as a spare. These units also supply the power for initial commissioning of the first GTG. An additional dedicated diesel generator is installed in the Operations Centre to provide its essential backup power to the Central Control Room (CCR) and administration offices.

3.4.6 LNG and Condensate Products Storage and Export Facilities

The LNG will be stored at atmospheric pressure in two full containment tanks, of approximately 150 000 m^3 net capacity each. The tanks are insulated to minimise boiling of LNG and generation of Boil Off Gas (BOG). BOG is captured by a vapour recovery system which compresses the gas and returns it to the LNG plant. BOG is also generated during LNG ship loading activities. To help reduce the generation of BOG, and keep the loading piping systems cold between ship loading operations, LNG is circulated through the loading lines. Vapour recovery arms are installed to recover BOG.

Condensate will be stored at atmospheric pressure in two tanks of approximately 120 000 m^3 capacity each, and pumped to the loading berth to transfer to tankers via the two condensate loading arms. These condensate tanks will be external floating roof tanks to minimise the roof cavity and reduce evaporative emissions due to breathing and filling.

4.0 AIR EMISSIONS MINIMISATION PRINCIPLES IN FACILITY DESIGN

4.1 Chevron Operational Excellence Management System

Chevron's Operational Excellence Management System (OEMS) provides a standard approach for achieving world-class performance in Health, Environment, Safety, Reliability and Efficiency. Using a standard approach to systematically identify and close performance gaps, Chevron can continually improve Operational Excellence (OE) results. Using the OEMS, Chevron effectively integrates OE objectives, plans, processes, standards and behaviours into daily operations to protect people and the environment today and in the future. Further details on the Chevron OEMS are available at: <http://www.chevron.com/about/operationalexcellence/> (Chevron, 2012).

The key OE processes taken into account in developing the Report include:

- **Environmental Stewardship** – Process for addressing potentially significant environmental, social and health impacts from projects under consideration. Ensures all environmental aspects are identified, regulatory compliance is achieved, environmental management programs are maintained, continuous improvement in performance is achieved, and alignment with ISO 14001-2004 is achieved.
- **Risk Management** – Process for identifying, assessing and managing Health, Environment and Safety (HES), operability, efficiency and reliability risks.
- **Management of Change** – Process for assessing and managing risks stemming from permanent or temporary changes to prevent accidents.
- **Compliance Assurance** – Process for ensuring that all HES and OE related legal and policy requirements are recognised, implemented and periodically audited for compliance.

4.2 Design and Operations Philosophy

The environmental performance standards and design features have taken into account regulatory requirements, including guidance notes, Project environmental commitments, Australian and International Standards, and Chevron requirements (Chevron environmental performance standards). In the absence of quantitative guidance pertaining to emissions to air for stationary sources in the *WA State Environmental (Ambient Air) Policy 2009* (and relevant WA regulations and guidelines referenced in Appendix 1 and 2 of the policy), design emission targets sourced from the NSW Government Gazette, *Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (NSW)* was used as a reference in this Report.

The design and operations philosophy provided the following guidance pertaining to pollution prevention and control measures in the design of the LNG and Domgas Plants:

- Design and environmental performance requirements linked to NOx and VOC generating activities and equipment, including flaring and venting emissions
- Procurement strategies include requirements for major equipment vendors to provide environmental performance information for their equipment, which is a consideration in the equipment selection process
- Identification of environmental aspects associated with the change and assessment of potential environmental impacts using a risk-based approach

- Thermal efficiency and reliability, and energy efficiency process enhancements are key considerations for technology and equipment selection to reduce fuel usage
- Flaring Philosophy which includes the following considerations:
  - The flares are designed to operate smokeless during most flaring operations with visible emissions of Ringelman No. 1 or lower (i.e. 20% opacity or lower)
  - The flares are not designed for smokeless operation for infrequent, unusual emergency relief scenarios such as failure of the main refrigerant compressor shutdown system during a plant power failure.

In summary, pollution control measures used in the Wheatstone Foundation Project have been identified through a combination of technology selection and assessment across a range of criteria, including effectiveness, operability, maintainability, costs, and HES risk assessment of the residual risks associated with each option being considered.

5.0 EMISSIONS INVENTORY

5.1 Estimation Methodology

Vendor provided performance guarantees, where available are used to estimate emissions. Manufacturer emission guarantees generally tend to be more conservative than the actual emissions. For example, NOx and CO emissions from gas turbine and heaters are calculated based on the manufacturer's emission concentration guarantees (ppmvd of pollutants). Where the vendor guarantee is not available, emissions are estimated using material balance and design values, followed by USEPA AP-42 or National Pollutant Inventory (NPI) emission factors.

For SO_2 emissions, estimates are based on the design value of 1 ppmv H_2S (normal operations) in LP fuel gas. Reservoir characterisation of Wheatstone area fields for the Foundation Project indicates low levels of H_2S in the reservoir fluids significantly less than the design value; however the design value was used as a conservative estimate. During normal operations, the expected H_2S concentration in fuel gas based on heat and mass balance calculations is expected to be lower. Heat and mass balance calculations were also used to calculate flare upset emissions, based on the highest flow rates and material balance from multiple events requiring release to the flares.

The VOC emissions for all equipment, and PM emissions for gas turbines, are estimated using USEPA AP-42 factors. Plant fugitive emissions are estimated using NPI method 2 based on number of piping systems components (valves, flanges, pump seals etc.). There has been no emission reduction credit taken for Leak Detection and Repair (LDAR) or flange management program in the emissions estimates.

Table 5.1 provides a summary of emission estimates from normal operations including routine and planned non-routine operations (e.g. maintenance and testing). The estimates would be validated as appropriate during operations monitoring and testing as described in Section 9.0, to ensure that manufacturer emissions guarantees are met.

5.2 Emissions Inventory

The emission estimates for normal operations based on the average feed gas composition / average ambient temperature flowrates and assuming steady-state conditions are presented in Table 5.1.

Table 5.1: Emission Estimate for Normal Operations [1,2]

EMISSION SOURCE	Equipment Count	Duration [4] (hr/yr)	PM	NO_x	CO	SO_2 [3]	VOC	BTEX[3]
			g/s	g/s	g/s	g/s	g/s	g/s
LNG Plant Routine Emissions								
Refrigeration Compressor Gas Turbines[5]	12	8,278	3.2	38	64.6	0.1	1	0
Power Generation Gas Turbines[5]	4	8,278	0.7	14.3	24.3	0.02	0.25	0
Acid Gas Thermal Oxidisers	2	8,278	0.06	2.8	4.3	1.5	2.8	2.33
Marine Flare - Normal (Pilot & Purge)	1	8,760	0.01	0.03	0.3	0.0001	0.002	0
Dry Gas Flares - Normal (Pilot & Purge)	2	8,760	0.09	0.43	3.7	0.001	0.02	0.12
Wet Gas Flares - Normal (Pilot & Purge)	2	8,760	0.09	0.44	3.8	0.001	0.02	0.08
Fugitives		8,278	-	-	-	-	7.6	0.03
Domgas Plant Routine Emissions								
Acid Gas Thermal Oxidiser	1	8,690	0.005	0.5	0.8	0.1	0.4	0.32
Fugitive Emissions	-	8,278	-	-	-	-	0.5	0.001
Regen Gas Heater	1	3,821	0.1	0.2	0.1	0.0005	0.02	0.025
Total LNG Plant Routine Emissions			**4.1**	**56**	**101**	**1.6**	**11.4**	**2.6**
Total Domgas Plant Routine Emissions			**0.12**	**0.7**	**0.9**	**0.1**	**0.92**	**0.35**
Total Foundation Project Routine Emissions			**4.2**	**56.7**	**102**	**1.7**	**12.33**	**2.95**
Non-Routine Emissions								
Marine Flare (Upset Case: Loss of BOG compressor)	1	24	6.6	32.4	278	0.0003	0.4	0
LP Dry Gas Flare (Upset Case: Blocked NRU Vent Outlet)	1	22	1.8	9.1	78.1	0.08	1.14	1.1
LP Wet Gas Flare (Upset Case: Thermal Oxidiser Trip)	1	25	1	4.7	40.5	1.4	0.26	4.3
Condensate Ship Loading	-	156	-	-	-	-	532	5.2
Start up Oil Heater	1	720	0.4	0.9	0.4	0.002	0.06	0.1
DomGas Submerged Combustion Vaporizer	1	240	0.7	1.3	0.6	0.003	0.09	0.15

Notes:

(1) Air emissions estimates that are based on vendor provided data are preliminary and subject to change. Additional assumptions are provided in Section 5.1.
(2) Emissions provided are worst case short term emissions in g/s.
(3) Based on Front End Engineering and Design Case 3 (Average Flow/Average Temperature) Heat & Material Balance.
(4) Based on basic plant data and operation availability for the LNG Trains (94.5%).
(5) Based on operating load assumptions.

6.0 TECHNOLOGY BENCHMARKING

A survey was undertaken of LNG projects and gas processing projects in Australia and internationally. Information was obtained from publicly available documents published on the EPA website, on industry websites and in industry publications. Due to the nature of large capital projects, there may have been changes in the project scope and design that occurred after the cited documents were published. Best efforts have been made to use the most recently available documents with current information.

Table 6.1 shows LNG projects in Australia and their predicted air emissions as published in public statements. International LNG projects are listed in Table 6.2 with the type of liquefaction process and type of NOx control installed on the gas turbines. The information compiled indicates that the largest contributors to NOx emissions from an LNG plant are gas turbine drivers for refrigeration compression and power generation. The Karratha Gas Plant built in the 1980s/1990s was without NOx control on the Frame 5 industrial gas turbines. To reduce NOx emissions, Trains 1–3 were retro-fitted with Lean Head End (LHE) liners in 2006. Additional Trains 4–5 were designed with low NOx combustors on the gas turbines. The Darwin LNG facility approved in 1998 applied water injection and Dry Low NOx control technology for the refrigeration compressor drivers and power generation gas turbines, respectively. Secondary NOx control technologies, e.g. Selective Catalytic Reduction (SCR), have not been used by any LNG projects currently in operation, construction or design in Australia and internationally.

The normalised NOx emissions (predicted NOx emissions in tonnes divided by the nominal capacity of the project in tonnes of LNG produced) is the metric used for comparing NOx emissions. The survey of publicly available information did not find published data on NOx emissions from international projects that could be compared on a consistent basis. The NOx and VOC emissions presented in Table 6.1 are estimated for the two train Wheatstone Foundation Project as described in Section 5.0. The emissions are then scaled up to the full 25 MTPA development with no allowance for future improvements in efficiency or emission controls.

As discussed in Section 7.1, the General Electric LM6000PF aeroderivative gas turbines have one of the higher thermal efficiencies compared to other drivers used in the LNG industry. The NOx emissions shown in Table 6.1 are estimated based on vendor provided guarantee as described earlier in Section 5.1 and are expected to be conservative estimates. Based on the publicly available information presented in Table 6.1 and Table 6.2, the technology selected for the Wheatstone Foundation Project benchmarks well against peers in the LNG industry.

Table 6.1: Australia LNG Project Comparison

Project Name	Location	Nominal Size of Facility (MTPA)	Liquefaction Technology Selected	Refrigeration Compressors Drivers	Power Generation	NOx Control	Approval Year	NOx Emissions (tpa)	VOCs Emissions (tpa)	Normalised NOx Emissions (NOx tpa per MTPA LNG)	Reference
Northwest Shelf Project Karratha Gas Plant (Trains 1-3)[1]	Burrup Peninsula, WA	7.5 LNG (after debottle-necking)	Air Products and Chemicals Inc. (APCI) Propane / Mixed Refrigerant (MCR™).	GE Frame 5	GE Frame 5	Retro-fitted with LHE liners in 2006	1989	8430 (est. after retro-fit [1])		1124	EPA 2004
Darwin LNG Facility	Wickham Point, Northern Territory	3.7 LNG (in operation) 10 LNG (total proposed)	ConocoPhillips Optimized Cascade® Process	GE LM2500 aeroderivative	Solar Taurus with SoloNOx II	Water Injection and SoloNOx II for GTG	1998, revised 2002	6152	464	615	C. B. Meher-Homji et al. 2008 URS 2002
Northwest Shelf Project LNG Expansion (Trains 4, 5)	Burrup Peninsula, WA	Originally 8.0 revised to 8.8 LNG	Shell Propane / Mixed Refrigerant (C3/MR) Process with Waste Heat Recovery	GE Frame 7EA	GE LM6000 aeroderivative	Low NOx burners to meet AEC/NHMRC, 1985 guidelines of 70 mg/Nm^3	2000, revised 2006	1759 [2]		219	EPA 1999
Pluto LNG	Burrup Peninsula, WA	4.3 (initial LNG) 12.0 LNG 4.0 Domgas	Shell / Foster Wheeler C3MR System	GE Frame 7EA	GE Frame 6	Dry Low NOx	2010	2191.8	58.7	182	Woodside 2007a, 2007b

[1] Retro-fit was estimated to achieve 25% reduction from uncontrolled emissions of 11 241 tonnes per annum (tpa) (EPA, 2004).
[2] Calculated by difference from published 13 000 tpa for five trains less uncontrolled 11 241 for Trains 1–3 (EPA, 2004).

Project Name	Location	Nominal Size of Facility (MTPA)	Liquefaction Technology Selected	Refrigeration Compressors Drivers	Power Generation	NOx Control	Approval Year	NOx Emissions (tpa)	VOCs Emissions (tpa)	Normalised NOx Emissions (NOx tpa per MTPA LNG)	Reference
Gorgon Gas development	Barrow Island, WA	15.6 LNG 3600 m^3 condensate 300 Tj/day Domgas	APCI Propane Pre-Cooled Mixed Refrigerant (Split MR®) Process	GE Frame 7EA	GE Frame 9E	Dry Low NOx	2009	4430		295	Chevron 2005, 2011a
Wheatstone Development	Ashburton North, WA	8.9 (initial LNG)	ConocoPhillips Optimized Cascade® Process	GE LM6000PF aeroderivative	GE LM6000PF aeroderivative	Dry Low Emissions	2011	1681 (for 8.9 MTPA)[3]	666 (for 8.9 MTPA)	189	This Report (includes diesel usage and Condensate Ship Loading Emissions)
		25 LNG (total proposed)						4722 (for 25 MPTA)	1872 (for 25 MTPA)		
Australia Pacific LNG Project	Curtis Island, Queensland	9 (initial LNG) 18 LNG	ConocoPhillips Optimized Cascade® Process	GE LM2500+G4 aeroderivative	Solar Titan 130	Dry low NOx (SoLoNOx)	2011	3380	690	183	Katestone Environmental 2010 Australia Pacific LNG 2010

[3] Wheatstone emissions also include emissions from sources that are typically offline such as emergency generators and firewater pumps.

Table 6.2: International LNG Project Comparison

Project Name	Location	Nominal Size of Facility MTPA	Start-up Year	Technology Selected	NOx Control	References
Qatargas 1 (LNG Trains 1, 2, 3)	Qatar	Expansion from 6.4 to 9.5 LNG	Original 1996-1998, expansion 2003-2005	APCI Propane pre cooled Mixed refrigeration (MCR™)	Retro-fitted with LHE liner[4]	ILyasak 2011 Salisbury et al. 2007
Oman LNG (Trains 1,2,3)	Oman	9 LNG	1999, expanded 2005	APCI Propane pre cooled Mixed refrigeration (MCR™)	Retro-fitted with Dry Low NOx	Oman LNG 2005
RasGas Trains 3, 4, 5	Qatar	14.1 LNG	2003-2007	APCI C3MR (Split MR®)	Dry Low NOx (retro-fit of Trains 3 and 4, new on Train 5)	McKay 2010 RasGas 2009 Air Products 2008
Snohvit LNG	Norway	4.3 LNG	2006	Linde-Statoil Mixed Fluid Cascade	Electric motor driven liquefaction compressors[5] GE LM6000 Power generating gas turbines have Low NOx Burners	Heiersted and Lillesund 2002
Qatargas 2, 3 & 4 (Trains 4,5,6,7) Ras Gas Trains 6 & 7	Qatar	7.8 LNG each	2009-2010	APCI Propane pre cooled Mixed refrigeration/ N_2 (AP-X™)	Dry Low NOx	Air Products 2008

[4] LHE liners are estimated to reduce NOx emissions by 15–40% from uncontrolled levels.
[5] Snohvit LNG facility generates electric power and has access to the national power grid.

7.0 EMISSIONS REDUCTION MEASURES IN DESIGN

Factors such as gas field location, composition and variability, HC liquids content, ambient operating temperature, maximum and minimum processing capacities all play an important role in determining the particular technologies suitable for a specific project. This section describes the current features that have been incorporated into the design of the key emission sources to minimise emissions of VOC and NOx. The design features to minimise visible smoke and non-emergency flaring is described in Section 8. The evaluation process applied for selecting the emission reduction design features to minimise NOx and VOC emissions include the following criteria:

- Ability to achieve or improve upon relevant environmental (DEC and EPA) standards
- Preference for primary (at source) over secondary (end-of-pipe) pollution control measures to minimise waste generation
- Technology Risk – proven versus unproven technology or process. The Chevron Technology Qualification Process requires that selected technology or process has a documented track record in the field, for a defined environment, to be considered 'proven' and of acceptable operational risk
- Energy Efficiency – the energy efficiency is central to each design option, be it thermal, electric or mechanical energy efficiency. A reduction in energy efficiency results in increased fuel requirements and consequently increased emissions
- Operability/Maintainability – design options that are difficult to operate or require high maintenance may result in higher emissions through suboptimal operating conditions and any additional shutdown and start-up events that may be experienced
- Availability – impact of pollution control technology on combustion equipment availability
- HES – additional HES considerations, including waste generation, use of natural resources (e.g. water), occupational health exposures, and safe operations.

In summary, combustion type process equipment that have been selected best match the requirements of the Wheatstone Foundation Project because these will operate within the optimal combustion envelopes during routine operations, minimising emissions of CO, VOC and Particulate Matter (PM). Trade-offs between NOx reduction, and combustion and energy efficiency, also influenced equipment selection. The specific design features which have been incorporated into the Wheatstone Foundation Project LNG and Domgas Plants to minimise NO_x and VOC emissions are detailed in the following subsections.

7.1 Gas Turbines for Power Generation

7.1.1 Description of Equipment and Operating Regime

General Electric LM6000PF, two shaft, aeroderivative gas turbines equipped with IAH and Dry Low Emissions (DLE) combustor systems have been selected as the driver for the GTG units. Each turbine has a site rating of 34 MW (with IAH) when de-rated for aging, fouling and degradation. Although three GTGs running at full load will provide sufficient capacity to meet power demand under site conditions, the operating strategy is to have four GTGs running at partial load in an N+1 configuration to provide electrical power redundancy and stability. This ensures that sufficient power will be available to meet power demands even if one of the GTGs trips off-line.

The stability of the power supply is essential in maintaining steady-state operations of the LNG and Domgas trains. An unreliable electrical power supply would result in the LNG processing trains operating at less than peak efficiency, or in the worst case, requiring an unplanned shut down.The average loading of each turbine under normal operating conditions is expected to vary between 50% and 75% under routine load balancing operations.

7.1.2 NOx Control Technology

Primary NOx control technology typically reduces the flame temperature and residence time to limit the formation of thermal NOx whereas secondary control technology utilises a continuous stream of catalytic material, e.g. ammonia (NH_3), to remove NOx emitted from stack gases. Secondary measures are typically used as a polishing step to reduce NO_x emissions from an already low emission rate (due to primary pollution control being employed) to a very low emission rate in urban areas.

Table 7.1 shows NOx control technologies used in the industry. Primary and secondary NOx control measures options available for the GTGs include:

- Primary (limit formation of thermal NOx)
  - LHE Liners
  - Water or Steam Injection
  - DLE Combustors
- Secondary (remove NOx before emission)
  - Selective Catalytic Reduction (SCR)
  - Catalytic Oxidation with Subsequent Absorption.

Table 7.1: NOx Control Technologies for Gas Combustion Turbines [a]

Control Technology Description	Reduction in NOx Emissions / Residual Concentrations[b]	Comments
Water / Steam Injection: Reduction of flame temperature by introducing water/steam (i.e. a heat sink) into flame zone.	Up to 80% NOx @ 15% O_2: ~42 ppmv	Requires steady supply of demineralised water; technology is appropriate for variable fuel quality. Energy penalty with introduction of heat sink.
DLE: Staging of fuel in variety of combinations to a series of annular rings with pre-mixers during part power operations to maintain nearly constant flame temperature over the entire operating range.	50-90% above 50% engine load NOx @ 15% O_2: 15-25 ppmv	Ability to control NO_x emissions over the entire operating range (50–100% load). Peak flame temperature reduced through increased mixing and homogeneity, reduced residence time, reducing thermal NOx formation. No reagent required.
SCR: Involves injecting ammonia in the presence of a catalyst into the exhaust stream reducing NO_x to nitrogen and water.	~3 ppmv	Requires ammonia or urea, and exhaust temperature control. Reduction efficiency reduces over time with catalyst masking, poisoning, and sintering. Potential ammonia emissions.
Catalytic Oxidation with Subsequent Absorption: Post-combustion catalytic system that removes both NO_x and CO from exhaust gas using platinum catalyst and potassium carbonate absorbent.	~2 ppmv	Requires platinum catalyst and potassium carbonate and exhaust temperature control; waste sludge require disposal. Reduction efficiency reduces over time with catalyst degradation.

[a] Table has been consolidated from GE technical reports, Pavri and Moore, 2001; Davis and Black 2000; and AP-42 Chapter 3 data.

[b] NOx emissions reduction from uncontrolled combustion emissions at ~150 ppmv (USEPA; Alternative Control Techniques Document – NOx Emissions from Stationary Gas Turbines, EPA-453/R-93-007).

The NOx abatement option preferred by Chevron for the Wheatstone Foundation Project is to use primary control technology over secondary control technology. The key trade-off in selecting the most appropriate primary NOx control measure is the impact on GTG thermal efficiency. By lowering the flame temperature and residence time of combustion to reduce thermal NOx formation, turbine thermal efficiency and combustion efficiency will be reduced, leading to increased GHG emissions, and VOC and CO emissions.

While there is some impact on the overall efficiency of the turbines, primary control technologies do not require additional unit operations and the continuous supply and handling of hazardous material on site. In addition, the storage and disposal of hazardous material, e.g. ammonia/ ammonium salts, potassium nitrate sludge, pose HES risks to the project. Thus, the benefits in NOx emission reduction offered by secondary mitigation technology must be weighed against the following:

- Technical risk of attempting secondary mitigation measures in a first of a kind service in a LNG plant
- Increased complexity and cost of the power generation and emission control system

- Increased HES risk related to the storage, handling and disposal of hazardous chemicals and heavy metal catalysts
- Air quality impact caused by emissions of ammonia and ammonium salts.

In highly populated urban areas in California, USA, such as Los Angeles, San Diego and the San Joaquin Valley where the ambient air may have elevated levels of NOx or ozone, the risks of implementing secondary control technology in addition to primary control technology could be justified to ensure the ambient air quality of the region does not pose a risk to human health. New projects in these areas often require the installation of secondary control technology to limit emissions of pollutants that contribute to non-attainment of air quality standards (Baez, 2000). SCR can achieve NOx levels <3 ppm in some cases – but this is typically achieved by over injection of NH_3. Residual or fugitive NH_3 emissions are a frequent concern.

The Wheatstone Foundation Project is in a sparsely populated area with low ambient levels of NOx and O_3, and without heavy motor vehicle traffic to contribute to precursors of photochemical smog (SEWPaC, 2010). The main concern related to ambient air quality is periodic wind-blown dust. Air emission modelling has shown that the cumulative local ambient air quality for NOx and O_3 will not exceed the ambient air quality standards for the full 25 MTPA proposal. Consequently, while primary NOx reduction technology will be implemented, the operational complexity and higher cost of add-on, secondary NOx technology is not justified or necessary and was not further considered during LNG plant concept selection and equipment specification.

7.1.3 Emission Reduction Measures

A number of alternative power generation systems and configurations were evaluated to meet the required power load profiles of the Wheatstone Foundation Project. The comparison considered seasonal variation of ambient conditions, system stability and reliability needs, required spinning reserves, thermal efficiency, greenhouse gas emissions and cost.

The General Electric LM6000PF aeroderivative gas turbines have one of the higher thermal efficiencies compared to other drivers used in the LNG industry for power generation. While higher thermal efficiencies could potentially be achieved using larger aeroderivative gas turbines such as the LMS100, the LMS100's higher power output would result in operating these turbines routinely at low loads below 50%, resulting in low thermal efficiencies and consequently, higher emissions to air. In addition, the LMS 100 have never been used in LNG plant service, or selected for a LNG plant under design or construction and thus, pose a significant technology risk to the Project.

The gas turbines are equipped with IAH, which uses evaporative cooling to improve the overall thermal efficiency and power output during high ambient temperature conditions. Turbine power output is a strong function of the ambient air temperature and inlet cooling boosts power by 0.54–0.9% for every 1 °C of cooling (Meher-Homji et al. 2007). Weather conditions in Onslow are typically hot and dry, with a mean annual maximum temperature above 30 °C and mean relative humidity ranging from 44–57%. IAH improves turbine efficiency by approximately 4% at nominal conditions and up to 15% at high temperature conditions; IAH helps maintain consistent power output at high ambient temperatures.

Gas turbines are typically low emitters of exhaust pollutants because the fuel is burned with ample excess air to ensure complete combustion at all but the minimum load conditions or during start-up. Emissions of CO, PM and VOC arise from incomplete combustion, such as insufficient gas molecule residence time at high temperature or incomplete mixing in combustion chamber. Fuel gas supplied to the GTGs containing minimal concentrations of H_2S as discussed in Section 5.0, will result in negligible emissions of SOx (note that a nominal value of 1 ppmv H_2S is used to estimate SOx emissions to air in the emissions inventory, Table 5.1, as a conservative estimate).

The gas turbines must also be tuneable for maximum operability over the load range 50-100%, and be able to prevent combustion control upsets from potential swings in fuel gas composition, leading to stage down events. DLE was the most applicable NOx control technology for the Wheatstone Project because of its effectiveness over a wide range of load and fuel variability. A comparison of estimated NOx emissions (expressed as kg/hr of NOx per MW of power output; Figure 7.1) shows that the LM6000PF equipped with DLE has the lowest emissions over a wide range of power loads under similar test conditions, when compared with:

- Frame 7EA industrial gas turbine with Dry Low NOx combustors (used at the North West Shelf Project Train 4 and 5 expansions, Pluto and Gorgon)
- LM2500+G4 with DLE combustors (used at Darwin LNG and in proposed Curtis Island LNG projects).

Note that Figure 7.1 has been obtained from manufacturer proprietary information. General information on the LM6000PF and DLE technology can be found at the following websites:

- <http://www.ge-energy.com/products_and_services/products/gas_turbines_aeroderivative/lm6000.jsp> (General Electric 2012)

  and
- <http://site.ge-energy.com/prod_serv/products/tech_docs/en/downloads/ger3568g.pdf> (Davis and Black, 2000).

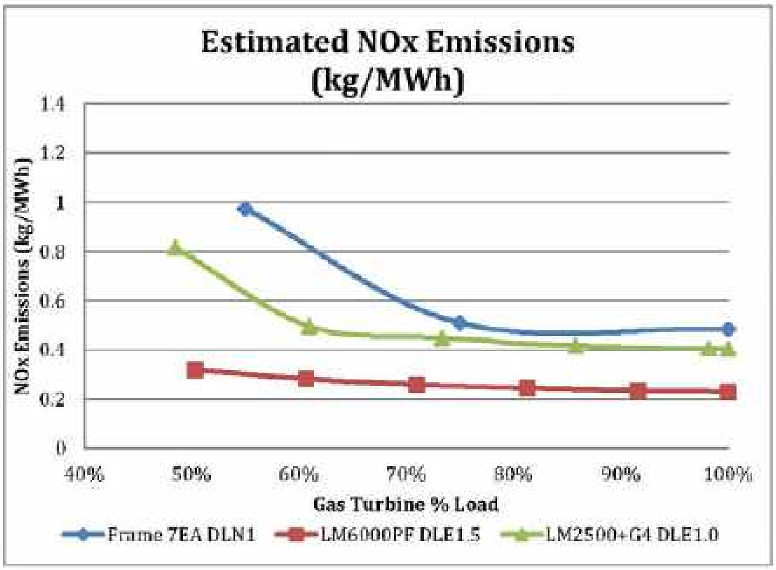

Figure 7.1: Gas Turbine Estimated NOx Emissions

While the LM6000PF utilises DLE1.5 to provide a guaranteed NOx emission level of 15 ppmv, this operates on a narrow fuel gas specification and requires a more stringent maintenance regime. Stability and efficiency issues associated with meeting the 15 ppmv specification will potentially lead to more train trips and flaring events, which significantly increase reliability, maintenance and operability, and efficiency risks to the Wheatstone Project. Due to the need to operate over a wide load range and a larger variance in fuel gas specification, and the objective to minimise stage-down events, the LM6000PF DLE1.5 was detuned to 25 ppmv, guaranteed for routine operation loads between 50–100%.

A number of measures were implemented to improve the ability of the DLE systems to handle changes in fuel gas composition, and control any stage down event leading to a loss of power. Dynamic simulations of the fuel gas supply system conducted, including the response times of the fuel gas chromatographs and the Wobbe meters, will be used to tune the DLE system performance. Mapping will be performed during the commissioning phase, after each major maintenance overhaul, and as required to determine the optimum operating boundary conditions. Remote monitoring and remote DLE mapping will also be evaluated. To further improve gas turbine availability, two out of two and two out of three voting and control logic have been utilised. The inlet air filters system is designed to reduce the fouling of the GT axial air compressor; thus periodic startup and shutdown of the GTGs for off-line water washing can be minimised; water wash would only be performed during routine turnaround activities.

In summary, the evaluation process identified that four GE LM6000PF equipped with IAH and DLE guaranteed to 25 ppmv NOx, operated in a 3 + 1 load balancing configuration, provided the best outcome in terms of optimum overall power output, minimising emissions and meeting reliability and flexibility requirements for the Wheatstone Foundation Project.

7.1.4 Design Emission Rates

The design emission rates calculated for the GTGs and the design emission targets are presented in Table 7.2.

Table 7.2: Power Generation Gas Turbine Emissions during Normal Operations [1]

Component	Design Emission Rate (g/s)	Design Emission Concentration[2] (mg/Nm^3)	Design Emissions Targets[3] (mg/Nm^3)
NOx	14.3	49	70
PM10	0.7	2.5	50
SO2	0.02	0.08	-
VOC	0.25	0.9	40
CO	24.3	83	125

1. Emissions shown in the table are for total of four (4) turbines.
2. For gas fired turbines, reference conditions are dry, 273 degree Kelvin (K), 101.3 kPa at 15% O_2.
3. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.

7.1.5 Deviation from Normal Operations

The four GTGs will equally share the power load during normal operating conditions. In the event of a single generator trip, the remaining generators will share the shortfall in the load by increasing the individual machine loading, while still maintaining NOx control effectiveness at 25 ppmv. Transient conditions are likely to occur during shutdown, start-up or significant changes in fuel gas compositions. Dynamic simulations of the fuel gas systems were conducted to assess the variability in heating value and Wobbe index while changing between different fuel gas sources. The results indicate that variances in the fuel composition will meet the specified GTG design and potential risks with unstable operating conditions are minimised.

In accordance with the manufacturer's recommendations, the LM6000PF GTGs are expected to be periodically shut down for maintenance as per the following schedule:

- Every three months for 12 hours for off-line water wash (This task is expected to be conducted during inspections, based on the design of the inlet air filtration system)
- Every six months for 18 hours for boroscope internal inspection
- Every 18 months for 30 hours for variable stator vanes brushing stage 3 to 5
- Every three years for 54 hours for hot section replacement and DLE mapping
- Every six years for 54 hours for depot maintenance and DLE mapping.

Where practicable, GTG maintenance shutdowns will be scheduled to coincide with other planned maintenance shutdowns in the LNG plant, or during periods of lower electric power demand (between ship loadings) or low ambient temperature (winter months).

7.2 Gas Turbine Drivers for Refrigerant Compressors

7.2.1 Description of Equipment and Operating Regime

The Wheatstone Foundation Project has selected the General Electric LM6000PF, two shaft, aeroderivative gas turbine as the driver for the main refrigeration compressors. The gas turbines are equipped with IAH and DLE NOx control technology, similar to the GTGs described in Section 7.1. Two 50% gas turbines drive independent propane, ethylene and methane refrigerant loops in parallel per train, i.e. all gas turbine drivers operate normally at full capacity. The gas turbines are controlled simultaneously by a load balancing control program, which allows the gas turbines to be started, shutdown, or placed on recycle without significant upset to the system by adjusting LNG production throughput.

7.2.2 Emission Minimisation Measures

A number of alternatives were evaluated for the liquefaction compressor drivers to determine the most suitable driver for refrigerant service. The list of nine refrigerant compressor driver configurations for each LNG train evaluated during the conceptual design phase was refined to the following four configurations:

- Seven LM2500+G4 (34 MW Aero-derivative gas turbines)
- Six LM6000 (43 MW Aero-derivative gas turbines)
- Two Frame 7E (87 MW) and two Frame 5D (33 MW) gas turbines
- Seven LM2500+G4 with IAH.

The analysis considered the range of LNG production rates, power margin, thermal efficiency, greenhouse gas emissions, reliability and the lifecycle cost of the alternatives. The evaluation process identified that the GE LM6000PF aeroderivative gas turbine fitted with IAH and DLE NOx control technology was the most suitable compressor driver with the highest thermal efficiency for the LNG trains. A total of 12 compressor gas turbines would be required to drive the Wheatstone Foundation Project LNG trains refrigerant circuits.

For routine operations, the refrigerant compressors will operate over a speed range of approximately 95–105%. They are designed for a speed range of 85–105%. The DLE combustors are optimised over this speed range to ensure a guaranteed NOx emission concentration of 25 ppmv; details of NOx control technologies considered are described in Sections 7.1.2 and 7.1.3. Based on engine testing, typical NOx emission levels are expected to be in the 18–20 ppmv range for the compressor gas turbines.

To improve the overall energy efficiency of the LNG trains, WHRUs are installed to recover waste heat from compressor gas turbine exhaust stacks for use as process heat within the LNG trains. Several other energy optimisation techniques were also deployed within the LNG trains, including but not limited to:

- Optimised approach temperature on the propane refrigerant condensers to reduce compression power requirements

  and

- Incorporated expander-generator in the LNG process train configuration to cool the gas by extracting energy to generate electricity (7 MW electricity per train is recoverable), thus improving the thermal efficiency of the LNG production process and reducing the load on the GTGs; expander-generator also improves LNG production rate by 7%.

In summary, the selected compressor turbine configuration provided the best overall power output, efficiency, reliability and flexibility while minimising greenhouse gas emissions for the Wheatstone Foundation Project.

7.2.3 Design Emission Rates

The design emission rates for the refrigerant compressor gas turbine drivers are presented in Table 7.3.

Table 7.3: Refrigeration Compressor Gas Turbines Emissions during Normal Operations [1]

Component	Design Emission Rate (g/s)	Design Emission Concentration[2] (mg/Nm^3)	Design Emissions Targets[3] (mg/Nm^3)
NOx	38	49	70
PM_{10}	3.2	3	50
SO_2	0.1	0.1	-
VOC	1	1.0	40
CO	65	83	125

1. Emissions shown in the table are for total Twelve (12) turbines.
2. For gas fired turbines, reference conditions are reference conditions are dry, 273 K, 101.3 kPa at 15% O_2.
3. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.

7.2.4 Deviation from Normal Operations

The Refrigeration Compressor Gas Turbines will be subject to the same transient conditions and maintenance schedule as described in Section 7.1.5 for the Power Generation Turbines. However, the compressor drivers may also be affected by other non-routine operating scenarios. During normal operating conditions, all compressor drivers are expected to be running at full load for maximum LNG production. If any one of the compressors shuts down or trips, the affected LNG train will ramp down at a controlled rate to ensure equipment integrity is maintained. Rigorous dynamic modelling of the refrigerant compressors will be conducted to ensure a smooth transition when taking one compressor string off-line and restarting one compressor string. Excess emissions caused by the transient of one compressor tripping and restarting will be minimised as a result of implementing the above mentioned better operating practices.

7.3 Process Heaters

7.3.1 Description of Equipment and Operating Regime

Gas fired process heaters will be used for two services in the Foundation Project facilities:

- Domgas Plant Regeneration Gas Heater – Periodically heats a slipstream of processed gas to regenerate the Domgas Plant mol sieve dehydration units and will run continuously only during the heating phase of the regeneration cycle
- Hot Oil System Start-up Heater - Used only during initial plant start-up or other periods when neither of the LNG trains is operating. Hot oil as a process heating medium must be provided for the inlet facilities, fuel gas system and/or Domgas Plant.

The Domgas Regeneration Gas Heater's normal operating cycle involves daily automated switching between full firing, deep turndown/standby and shut-down modes. This heater will be in standby mode for 30–50% of the time during a normal operating year. The Hot Oil Start-up Heater only operates for limited periods during a typical calendar year, may need to operate in low firing / standby mode, and is typically shut down when either LNG train is in normal operation. It is designed to be used only during plant start-up and when the Domgas Plant is running at full capacity with both LNG trains shut down. Once the gas turbine compressor units are in normal operation, all process heat will be generated using the WHRUs on these turbines and the Start-up Heater will be shut down.

7.3.2 NOx Control Technology

The key NOx control technologies that the project considered for small fired heaters, burning natural gas fuel are listed in Table 7.4.

Table 7.4: NOx Control Technologies for Process Heaters [a]

Control Technology Description	Reduction in NOx Emissions	Comments
Ultra Low NOx Burners: A combination of Flue Gas Recirculation and Low NOx Burner technologies.	60-90% NOx @ 3% O_2: ~25 ppmv	Typically used in continuously operated process heaters.
Low NOx Burners: Staging of fuel or air in a variety of combinations to partially delay the combustion process, resulting in a cooler flame.	40-85% NOx @ 3% O_2: ~60 ppmv.	Typically used in continuously operated process heaters.
Flue Gas Recirculation: Portion of flue gas is recycled from stack to burner windbox and mixed with combustion air prior to being fed to burner. 'Inert' stack gases act as diluents and also reduce O_2 concentration in combustion air.	50-60%	Typically used in continuously operated process heaters. Unsuitable for process heaters providing variable heat duty.
Combustion Tuning: Optimisation of fuel to air equivalence ratio at burners.	10-30% reduction from uncontrolled emissions	Specific only to design load of heaters, i.e. over narrow operational range.

[a] Summary of NOx Control Technologies summarised from various sources including, AP42 Chapter 1, section 1.4 (5th Ed), and manufacturer data.

7.3.3 Emission Minimisation Measures

Opportunities to improve the LNG train energy efficiency and consequently, reduce emissions to air, were evaluated and integrated into the design of the LNG trains. It was determined that all the routine process heat requirements for the inlet facilities, LNG trains and most of the Domgas Plant systems could be met by capturing the waste heat from the exhaust gases from the compressor gas turbines using WHRUs. The use of WHRUs precludes the need for the routine use of fired heaters or boilers to provide process heat within the facility, and thus, reduces the emissions of combustion pollutants.

The overall heat integration around the liquefaction process has been maximised to reduce process heating requirements by using a number of design features, including a propane subcooler/feed gas heater, and methane gas recycle streams to heat some of the reboilers in the fractionation and NRU units. In addition to the use of a waste-heat based hot oil system for process heating, selected WHRUs on the compressor gas turbine drivers in each liquefaction train are being fitted with separate heating coils to heat the treated gas stream which is used to regenerate the molecular sieve beds in the dehydration unit in each LNG production train.

The option of coupling heat recovery for the Domgas Plant has been considered. However, the coupling of both the Domgas Plant and LNG trains would significantly decrease the reliability and increase operational risks — trips to the LNG trains will also trip the Domgas Plant and impact on Domgas availability. Consequently, coupling of the Domgas Plant to the WHRU system was not a feasible option for the Wheatstone Foundation Project. A separate stand-alone fired heater was selected for the critical molecular sieve regeneration component of the Domgas Plant.

The Domgas Regeneration Gas Heater's normal operating cycle involves daily automated switching between full firing, deep turndown/standby and shut-down modes. The Ultra-low NOx burner technology could achieve the lowest emissions outcome for the process heaters at 25 ppmv NOx but would be a safety risk for the Regen Heater application. This risk is due to daily on and off firing rate changes requiring a stable flame over a wide turn down range without manual adjustments. Cold fire boxes, uncontrolled excess air at turndown, and large increases to firing rates are a known safety risk with Ultra-low NOx burner (API, 2006). Implementing Ultra-Low NOx burner technology would require these heaters to be operated continuously at nominal heat duties, resulting in significantly higher emissions to air.

Low NOx burner technology provided the best outcome in terms of minimising emissions, and meeting the flexibility requirements for the Wheatstone Foundation Project. The selected process heaters with Low NOx burner technology are guaranteed at NOx concentration of 60 ppmv at 3% O_2 and meet the referenced emission targets shown in Table 7.5 and Table 7.6.

7.3.4 Design Emission Rates

Design emission rates for the Domgas Regeneration Heater and Hot Oil Start-up Heater, respectively, are presented in Table 7.5 and Table 7.6.

Table 7.5: Domgas Regeneration Heater Emission Rates during Normal Operations

Component	Design Emission Rate (g/s)	Design Emission Concentration[1] (mg/Nm^3)	Design Emissions Targets[2] (mg/Nm^3)
NO_x	0.2	102	350
PM_{10}	0.1	50	50
SO_2	0.0005	0.2	--
VOC	0.02	7	40
CO	0.1	52	125

1. For gas fired process heaters, reference conditions are at a temperature and pressure of 273 K and 101.3 kPa, respectively, and 3% O_2.
2. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.

Table 7.6: Hot Oil Start-Up Heater Emission Rates during Project start-up

Component	Design Emission Rate (g/s)	Design Emission Concentration[1] (mg/Nm^3)	Design Emissions Targets[2] (mg/Nm^3)
NO_x	0.9	102	350
PM_{10}	0.4	50	50
SO_2	0.002	0.2	--
VOC	0.06	7	40
CO	0.4	52	125

1. For gas fired process heaters, reference conditions are dry, 273 K, 101.3 kPa at 3% O_2.
2. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.

7.3.5 Deviation from Normal Operations

The Domgas Regeneration Heater will be used periodically during normal operations to regenerate the molecular sieve dehydration units in the Domgas Plant. The Hot Oil Start-up Heater is not planned to be run during normal operations, since all the heat required by the hot oil system will be provided by WHRUs located in the exhaust of the gas turbine drivers in the LNG trains.

During periods where there are upsets in the molecular sieve dehydration system, it may be necessary to extend the time periods the heater is in full firing mode to completely regenerate the molecular sieve beds. This would not increase the emission rates shown in Table 7.6, but could increase the duration of heater operation by 10-20%.

The Hot Oil Start-up Heater will be used when neither of the LNG trains is operating and hot oil must be provided for the process needs of the inlet facilities, fuel gas system and/or Domgas Plant. Its primary use will be during initial start-up of the LNG plant and during and after a planned inspection / maintenance shutdown of both LNG trains.

When a process heater is being initially heated up and during periods of refractory (firebrick) dry-out, the operating temperature must be increased in slow increments to maintain the integrity of the internals and prevent damage until it reaches full process operating temperature. During this time, the firebox will not be hot enough for complete destruction of CO. Different burner tips may be used during heat up to maintain stable operation. The emissions of NOx and CO may be higher during heater commissioning/start-up to full operating temperature. At all times, the heaters will be operated in a manner consistent with good practice for minimising emissions.

7.4 Acid Gas Thermal Oxidisers

7.4.1 Description of Equipment and Operating Regime

Each LNG train and the Domgas Plant are fitted with a Recuperative TO to abate VOC and H_2S emissions to air arising from the AGRU regeneration process in the Wheatstone Foundation Project. The AGRU removes the acid gases from the feed gas during the absorption process and produces a concentrated acid gas stream during the regeneration process. The waste acid gas consist of greater than 99% CO_2 (dry basis) with low concentrations of H_2S and VOCs on a dry basis. The Recuperative TOs operate at a firing temperature greater than 760°C and more than one second residence time to achieve a destruction efficiency of greater than 99% for BTEX and H_2S. The VOCs and H_2S are oxidised in the Recuperative TOs to mainly CO_2 and SO_2, respectively.

7.4.2 Emission Minimisation Measures

The key function of the AGRU is to remove acid gas from the feed gas stream. Several acid gas disposal design options were evaluated by the Wheatstone Foundation Project to dispose of acid gas stream containing greater than 99% CO_2 (dry basis) to minimise emissions of VOCs and H_2S. Also, a brief evaluation of types of TOs that could potentially be applied for VOC and H_2S control was considered (Table 7.7). The evaluation considered associated environmental, energy and economic impacts such as destruction efficiency, energy efficiency, greenhouse gas emissions, reliability and the lifecycle cost of the alternatives.

Table 7.7: Acid Gas Disposal Technologies [a]

Technology Description	Destruction Efficiency	Comments
Thermal Oxidisers		
Direct Fired: Combustion/oxidation of VOCs and H_2S at high temperatures. No energy recovery. Method is suitable for processing any waste gas or liquids.	98 – 99.99+%	Energy intensive method as no heat recovery system implemented. High fuel consumption and greenhouse gas footprint. Very high destruction efficiency.
Catalytic: Catalytic assisted oxidation of VOCs at relatively low temperatures. Method is suitable for processing lean waste gases.	95 – 99%	Energy recovery possible. Good destruction efficiency. Catalyst easily degraded by H_2S. Moderate to low greenhouse gas footprint.
Recuperative: Combustion/oxidation of VOCs and H_2S at high temperatures. Energy recovery system implemented. Method is suitable for processing lean waste gases.	95 – 99.9+%	Stack fitted with WHRUs to recover energy to preheat feed gas to TO, reducing fuel requirement. Very high destruction efficiency. Moderate greenhouse gas footprint.
Regenerative: Oxidation of VOCs and H_2S in heat exchange bed media. High heat recovery requiring little or no additional fuel gas. Method is suitable for processing lean waste gases.	95 – 99%	Sensitive to variation in HC concentration. Impurities can plug heat exchange media. High destruction efficiency. Low greenhouse gas footprint.
Re-injection: Disposal of acid gases into depleted oil/gas well formations; CO_2 enhanced oil recovery.	–	Suitable geological formations required for disposal. Energy intensive process to transport and store acid gases under supercritical conditions.

[a] Summary of NOx Control Technologies summarised from various sources including, AP42 Chapter 10, section 1.4 (5th Ed), and manufacturer data.

The assessment process identified the Recuperative TO to be the most suitable acid gas disposal option for the Wheatstone Foundation Project, providing the best trade-off between energy efficiency, reliability and destruction efficiency of VOCs and H_2S. Recuperative TOs can handle large variations in the acid gas HC content between routine operations and potential upset conditions, maintaining a destruction efficiency of greater than 99%. The stack height of the TOs are specified to a height of 35 m to assist with the dispersion of formed SO_2 and any remaining VOC/H_2S to ensure ground level impact on air quality is minimal. Additionally, a first pass USEPA SCREEN3 air modelling was performed to ensure that Benzene emissions from TO stack meet National Occupational Health and Safety Commission (NOHSC) short and long term exposure standards. It should be noted that in the event of a failure to a Recuperative TO or shutdown for maintenance, the acid gas is automatically diverted to the LP stack of the wet flare system.

Solvent selection also plays a role in reducing the amount of dissolved or entrained HCs requiring disposal via the Recuperative TOs. BASF aMDEA has one of the lowest affinities for HCs, reducing the amount of dissolved or entrained HCs within the circulating solvent requiring disposal. The AGRU Rich Amine Flash Drum, designed for LP operation and extended residence time, further reduces solubility and entrainment of HCs within the circulating solvent. LP flashing removes most of the entrained HCs prior to solvent regeneration and is recovered for use as fuel gas. Thus, the volume of entrained HC in the acid gas stream requiring disposal via the Recuperative TOs is reduced. Best burner (combustion tuning) technology has also been specified to achieve relatively low NOx concentrations for acid gases containing 99+% CO_2 (dry basis).

7.4.3 Design Emission Rates

The design TO emission rates for the LNG trains and Domgas plant based on manufacturer's emission guarantees are given in Table 7.8 and Table 7.9, respectively.

Table 7.8: LNG Trains - Acid Gas Thermal Oxidisers Emissions Rates - Normal Operations

Component	Design Emission Rate (g/s)	Design Emission Concentration[1] (mg/Nm^3)	Design Emissions Targets[2] (mg/Nm^3)
NO_x	2.8	113	350
PM_{10}	0.06	2.2	50
SO_2	1.5	61	-
VOC	2.5	20	20
CO[3]	4.3	171	125
BTEX[4]	2.33	-	-
H_2S[4]	0.008	-	-

1. For thermal treatment plants including TOs, reference conditions are dry, 273 K, 101.3 kPa at 3% O_2.
2. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010) The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.
3. CO emissions concentration is based on vendor guaranteed concentration (150 ppmv) and exhaust gas flow. The expected concentration as stated in vendor proposal is 100 ppmv (<125 mg/Nm^3). Note that the feed gas to AGRU TO is 99% CO_2 (dry basis), which limits the conversion of VOCs to CO_2.
4. BTEX and H_2S emissions use a vendor guaranteed destruction efficiency of 99%. The expected destruction efficiency of 99.9% has been stated in vendor proposal.

Table 7.9: Domgas - Acid Gas Thermal Oxidiser Emissions Rates - Normal Operations

Component	Design Emission Rate (g/s)	Design Emission Concentration[1] (mg/Nm^3)	Design Emissions Targets[2] (mg/Nm^3)
NOx	0.5	110	350
PM_{10}	0.005	1.0	50
SO_2	0.1	24.2	-
VOC	0.4	20	20
CO[3]	0.8	168	125
BTEX[4]	0.32	-	-
H_2S[4]	0.0006	-	-

1. For thermal treatment plants including TOs, reference conditions are dry, 273 K, 101.3 kPa at 3% O_2.
2. Design emission targets are sourced from the New South Wales (NSW) EPA Protection of the Environment Operations (Clean Air) Amendment (Industrial and Commercial Activities and Plant) Regulation 2010 (Government of NSW, 2010). The NSW emission targets are used for comparison purposes in absence of numerical stack standards from WA DEC.
3. CO emissions concentration is based on vendor guaranteed concentration (150 ppmv) and exhaust gas flow. The expected concentration as stated in vendor proposal is 100 ppmv (<125 mg/Nm^3). Note that the feed gas to AGRU TO is 99% CO_2 (dry basis), which limits the conversion of VOCs to CO_2.
4. BTEX and H_2S emissions use a vendor guaranteed destruction efficiency of 99%. The expected destruction efficiency of 99.9% has been stated in vendor proposal.

7.4.4 Deviation from Normal Operations

AGRU upset events typically lead to HC spikes and composition changes to the waste acid gas stream requiring disposal. A key factor in the selection process was the robustness of the Recuperative TOs to handle these upset events and maintain the same destruction efficiency during upsets. In the event of a failure to a Recuperative TO or shutdown for maintenance, the acid gas is automatically diverted to the LP stack of the wet flare system.

The flare system has been designed to accommodate the high inert gas content of the waste acid gas stream. Secondary disposal via the flare system is expected to provide a destruction efficiency of 98%. In addition, the Wheatstone Foundation is believed to be the only LNG Project/Asset in Australia that does not vent waste acid gases to atmosphere during TO failure / maintenance, which reduce project emissions of VOCs and H_2S.

7.5 Fugitive Emissions

Fugitive emissions arise from HCs that escape from, including but not limited to HC storage tanks, valve packing, compressor seals, pump seals, flanges, and connectors. Fugitive emission reduction measures adopted by the Wheatstone Foundation Project include:

- Installation of full capacity BOG vapour recovery system for both LNG tanks and LNG loading facilities
- Fitting of external floating roof with primary and secondary roof seals to the two 120 000 m^3 condensate storage tanks
- Control of condensate vapour pressure and temperature via stabilization and fractionation systems, with secondary wet-surface air cooler to maintain condensate temperature and vapour within desired boundaries

- All HC service valves are specified as low emission valves, which meets a leakage requirement of less than 100 ppm CH_4 (above background at 1 cm from valve leak source as per US EPA Method 21, as directed by the WA EPA)
- Pumps are specified with mechanical seals to arrest leakage to the environment, with dual seals for more volatile services such as Ethane, Propane, Butane and Ethylene
- 'Can' pumps with no fugitive emissions are used for LNG service
- Main Refrigerant Compressors are designed with dry gas seals and seal gas recovery systems
- Use of welded joints inside the Cold Boxes (a few flange connections isolated in the valve boxes for servicing purposes are used) to limit fugitive emissions. The Cold Boxes in the LNG trains and Domgas Plant are purged with nitrogen; thus very small HC leaks can be easily detected
- Nitrogen blankets are installed on fixed roof atmospheric API tanks containing HC
- Covered corrugate plate interceptor separator for waste water system
- Open ended lines are designed with caps, plugs or a second valve at the open end. Sample connections are designed to be closed loop, if possible, and return the flushed fluid to the process or to the flare system, where necessary.

During initial commissioning and after major turnarounds, the Nitrogen/Helium leak detection method will be used to ensure system tightness. This technique enables detection and quantification of leaks at very low levels (between 5–50 scf/yr).

8.0 FLARE DESIGN AND OPERATIONS MANAGEMENT

8.1 Flare Design and Operations Philosophy

Flare systems are designed to safely and reliably collect and dispose of waste HC vapour and recover liquids produced during activities such as plant start-up and shut-down or during unexpected events, e.g. trips and equipment breakdown. The Wheatstone Foundation Project is committed to a 'no routine flaring' policy, i.e. no continuous, operational flaring of HC fuel gas above that required for safe operations is permitted. All sources of HC emissions will be captured and redirected back into the process, or recovered for use as fuel or product, where practicable.

Greenhouse gas and atmospheric pollutant emissions from flares are reduced through a series of design features and operational practices. These include the following best practices for flare systems outlined by the European Commission document, *Integrated Pollution Prevention and Control, Reference Document for Best Available Techniques for Mineral Oil and Gas Refineries* (EC 2003):

- Use flares as a safety system (start-up, shutdowns and emergencies)
- Ensure smokeless and reliable operation
- Minimise flaring by a suitable combination of:
  - Balancing the fuel gas system
  - Installing a gas recovery system
  - Using high integrity relief valves
- Reducing relief gas to flare by management/good housekeeping practices.

These practices have been incorporated into the design features and the proposed management of operations for the LNG and Domgas facilities.

8.2 Flare Description and Design

8.2.1 Flare Description and Operation

The flare system must be capable of handling a wide range of design cases ranging from very low volume gas streams during routine operations to relief cases involving large quantities of HCs, which could occur during infrequent upset conditions or emergencies such as power failure. In each of these cases, there needs to be sufficient heating value in the gas to support efficient combustion at the flare tip and good mixing with air and turbulence in the combustion zone to minimise formation of smoke and particulates. The flare system must also be able to disperse unburnt VOCs and H_2S routed from the AGRUs in the event of TO maintenance or failure.

Elevated flares were selected by the Wheatstone Foundation Project as they reduce the amount of fill required to sufficiently elevate the area to protect against storm surge flooding for ground flares. These also allow for better dispersion of unburnt VOCs and H_2S in the event of a TO failure, and also reduce the possibility of thermal radiation exposure to the workforce and facilities. There are three flare derricks to support the Wheatstone Foundation Project safety requirements:

- LP with three flare risers (wet, dry and spare)
- HP with three flare risers (wet, dry and spare)
- Marine Flare.

A stack height of approximately 95 m, 45 m and 45 m for HP, LP and Marine flares, respectively, are based on limiting radiation intensity at the sterile area boundary. The wet flare system handles gases that contain HCs with water or water vapour while the dry flare system handles HC vapour that does not contain any water. The wet flare system typically handles gases from plant systems which are 'warm' while the dry flare system handles gases from process systems which operate at cryogenic temperatures or where temperatures drop to cryogenic levels if the equipment is depressured. The wet and dry flare systems operate independently of each other.

Each of the wet gas and the dry gas flare systems consists of a large collection header with a series of laterals into each plant area, a liquid KO and pumps, and demountable flare stacks with specially designed burner tips. Separate 'warm' and 'cold' liquid collection headers are installed in parallel with the wet and dry flare headers to avoid two phase flow in the main flare header piping. A spare flare KO drum and flare stacks are provided to serve as a common backup system to both the wet and dry flare systems; this will allow these systems to be taken out of service for inspection and maintenance.

The marine flare only handles vapour from the LNG storage and loading system. The marine flare system will support safe loading of LNG carriers. It is designed to allow the cool-down and displacement of inert gases from LNG carriers which arrive at the loading berth in a warm condition or which are returning to service after dry dock inspection. Since no liquid condensation is possible in this flare header, liquid separation/collection/disposal facilities are not provided in this system.

Warm LNG carriers arriving from dry dock are often filled with inert gas (carbon dioxide or nitrogen) while in transit. During loading, as the ship's tanks begin to cool and fill with LNG, this inert gas combines with the BOG and is displaced into the BOG vapour return system. This gas mixture must be flared until the concentration of inert gas has decreased sufficiently to allow the BOG to be redirected back into the LNG trains for recovery.

Dual ignition sources are provided for the flare system: high energy ignition (HEI) electronic igniters are used as primary source and a flame front generator (FFG) is used as backup. A dedicated FFG ignition line will be routed to each pilot. A flare management system will allow both ignition sources (HEI and FFG) to be controlled by the local control panel located a safe distance from the flare stacks. The panel logic will be designed for automatic re-ignition of pilots plus manual operation. Each pilot is also monitored with two duplex thermocouples to monitor the flame to ensure pilots remain lit.

The flares are designed according to American Society of Mechanical Engineers / American National Standards Institute and American Petroleum Institute codes and standards. They are structurally designed to Australian Standards. They are built to withstand the wind forces and remain operational in a major cyclone, including up to Category 5 conditions. The pilot tips are performance tested at the design wind speed of 274 km/hr to ensure flare system operability and mechanical integrity during major cyclone event. The flare tips are designed with industry accepted practices to prevent flame lift off and flame lick.

8.2.2 Emissions Reduction Measures in Flare Design

The flares are designed to operate smokeless during most flaring operations with visible emissions of Ringelman No. 1 or lower (i.e. 20% opacity or lower). The flares are not designed for smokeless operation for infrequent, unusual emergency relief scenarios such as failure of the main refrigerant compressor shutdown system during a plant power failure. Measures to minimise smoky emissions during flaring operations include:

- Air assisted flares in the first stage of LP wet and dry flares, and marine flare

  - equipped with variable flow controlled air blowers which provide "air assist" to aid "smokeless" combustion and operation
- HP flare tips generate sufficient turbulence at the flare tips to ensure good mixing of air and HC and thus, does not need air assist to aid combustion; high efficiency flares will reduce smoke formation, particulate build-up and emissions of CO, VOCs and partially combusted HCs
- Staging of flares to handle the large range of relief flowrates from the LNG trains and Domgas unit (Note: the marine flare do not require staging as it handles only vapour from LP sources)
  - Staging of flares maintain sufficient back pressure to provide sufficient driving force for mixing at flare tips for wet and dry flares
- Flares are designed with velocity seals to help reduce the purge gas volume required to protect the stack against air infiltration
  - Continuous purging of flare headers with fuel gas is required to prevent flash-back, and maintain combustion efficiency and 'smokeless' performance during flaring of gas with low heat content.

During routine operations, the above controls will minimise smoke emissions to 20% opacity or lower. Emissions of HC from various sources are recovered and reused as fuel gas or product where practicable. This reduces the amount of HCs that are vented to flare and reduces overall emissions to air from flaring activities. Examples include:

- HC separated in the AGRU Rich Amine Flash Drums is recovered and used as LP fuel gas
- HC vapour generated in the LNG storage and loading system is recompressed by BOG compressors to the methane refrigeration loop:
  - The BOG compressor system consists of three electric motor driven BOG compressors. Two of the compressors are continuously operated during holding mode (no LNG carrier is loading), with the third operated during loading mode. All compressors are sized to handle 110% of the maximum BOG flowrate expected
  - BOG compression capacity is sufficient to avoid routing any BOG to the marine flare. However, warm LNG carriers require de-inerting prior to loading. LNG is used to cool down these vessels with a portion of the BOG generated routed to the marine flare until such a time where the product specification is met for recycle to the LNG trains
- Suitably sized KO drums in flare systems prevent carryover of liquid HCs to flare; liquid HCs are routed back to process for recovery where practical.

8.3 Minimising Non-Emergency Flaring

Overall LNG trains and Domgas Plant design and operation philosophy will significantly impact on the amount of flaring. The integrated approach to design undertaken by the Wheatstone Foundation Project reduces the amount of flare gases during planned non-routine activities such as maintenance. The Wheatstone Foundation Project is committed to a no routine flaring policy, flaring should only occur during unusual situations such as emergencies, process upsets, plant start-up and shutdowns.

Examples of activities where gases to flare are not practicable for recovery and will be flared include:

- Venting from process equipment – fugitive emissions, small purges from sampling connection, flare purge fuel gas requirements
- Cooling of warm ships during LNG loading.

The flare headers have continuous flow monitoring, and on-line overall plant and systems mass balances will be performed. As a result, leakage from pressure relief valves or blowdown valves into the relief system can be detected and the source identified and corrected. All Pressure Safety Valves (relief valves) have spares and can be independently isolated and taken out of service to allow for proper operation (except for small 'thermal relief' valves on liquid filled piping).

8.3.1 Design Features to Minimise Flaring

Design features to minimise venting to flares include utilising dry gas seals in the main refrigerant compressors. Gas escaping from the primary seals is first routed back to the LNG liquefaction process to minimise refrigerant losses and continuous emissions. Only in the event of a high operating pressure in the process loops would seal gas be routed to the flare system, which is required for safe disposal. Where practicable, all routine sources of HC emissions will be recycled back into the process, recovered for use as fuel or product. Build-up of non-condensable gases (primarily light HC) in the closed loop propane refrigeration circuit is purged to the fuel gas system and not flared.

The LNG Plant will be provided with an Integrated Control and Safeguarding System (ICSS) that enables continuous monitoring, control and safeguarding of plant specific processes. The ICSS will be the primary interface for the Operators to monitor and operate the Plant using a series of operator display and control consoles in the CCR. This control system will facilitate monitoring and controlled operation of the plant during start-up, normal operation, reduced rate operation and upsets. Safety features within the control system will provide protection for the plant via controlled trip actions and emergency shutdown (ESD). Major components of the ICSS include:

- Process Control System (PCS) – Provides the primary control, monitoring, and data acquisition functions for the plant.
- Safety Instrumented System (SIS) – Provides for the detection and actuation of devices concerned only with placing the plant into a safe state. The SIS is for the protection of personnel, environment, and equipment.

The PCS is designed to perform basic regulatory, advanced regulatory, sequential control, non-safety related interlocks, process monitoring, alarm management, data archiving, trending and reporting. Continuous on-line performance and condition monitoring will be implemented for critical equipment, such as motors and turbine drivers of more than 500 horsepower (372.85 kW). Performance data will be sent to the Machinery Support Centre, which is staffed by Chevron Energy Technology Company and General Electric personnel 24 hours daily. Continuous condition monitoring includes vibration, bearing oil temperature, and critical process parameters, which are used to detect potential equipment failures before a trip or breakdown occurs.

Key systems and equipment are fitted with inspection ports to permit remote digital video inspection of the internal condition of the vessels and piping. This will both enhance the maintenance of overall system integrity and avoid the need to completely depressure and purge the equipment to flare before conducting an inspection of the internal condition.

The plant process and equipment have been designed to operate for four years between major maintenance shutdowns/turnarounds to minimise start-up and shutdown periods. The design configuration of the plant uses two 50% parallel compressor systems in the refrigeration circuits within each liquefaction train to allow continued operation (at reduced rates) during periods of planned and unplanned gas turbine and compressor maintenance. This reduces the number of full plant shut downs and start-ups. The LNG train configuration and compressor design also allows the process refrigerants to remain contained within the refrigeration system during shutdown and restart. Use of defrost gas for drying out the cryogenic heat exchangers within the refrigerant systems prior to restart results in short periods of flaring. The refrigerant compressors do not need to be partially depressured to flare to permit startup, enabling much faster plant restarts and lower emissions.

It is necessary to ensure the safety of the operations staff in the gas processing facility by depressurising and purging the HC gas contained in those parts of the facility where equipment must be opened for inspection during a process train shut-down for maintenance or inspection. To avoid loss of refrigerants and minimise flaring, propane and ethylene storage drums are provided, with sufficient capacity to store the entire refrigerant inventory of one LNG train, plus additional capacity for refrigerant makeup. De-inventory pumps will be installed in each LNG train to facilitate the transfer of these refrigerants to the storage area. As part of the shutdown procedure, operating pressures will be reduced and HC gas in the systems being prepared for shutdown will be routed to recycle or fuel to the maximum extent feasible. Some HCs will be sent to the flare system as the systems and equipment are depressurized to atmospheric pressure and purged prior to opening or entry.

8.3.2 Startup and Commissioning

The initial commissioning of the plant requires purging (of air) and leak testing of all systems, followed by dryout and cool down of the liquefaction equipment and refrigeration circuits. All these activities require flaring of small volumes of gas for several days. Heated defrost gas will be utilised instead of feed gas to dry out the cryogenic systems more quickly, reducing the volume of gas flaring.

Detailed commissioning and start-up plans will be developed to reduce start-up time to minimise flaring including:

- Start the Regeneration Gas Compressor early to recycle regeneration gas to the upstream AGRU
- Send dry gas down the LNG train as soon as possible instead of flaring
- Perform cool down of several plant sections simultaneously.

For each plant area start-up, limited flaring will be necessary at the following locations until the product gas meets the specifications required by downstream processing units:

- Sweet gas, at the AGRU Absorber overhead (CO_2 and H_2S content specification)
- Dry gas, downstream of Mercury Removal beds (water and mercury content specification)
- Cold gas, at the Heavies Removal Column overhead (high freezing point HC content specification).

For the initial start-up, the plant will be started and off-spec gas flared until the gas is suitable for processing in the LNG trains. There are technical risks and possible equipment malfunctions due to uncertainties in equipment and piping dynamics if a lower start-up flowrate is used. (Note: Plant systems are designed to operate at a turndown flowrate of 35% of normal operating flow; start-up flowrates are expected to be significantly less than this, but must be reviewed on a case by case basis). After each plant area starts up, equipment data, lab analysis and flaring time will be reviewed and procedures will be adjusted to reduce future flaring volumes.

8.3.3 Operations Management

Detailed operational procedures will be developed with a focus on reliable, efficient and optimized operation to reduce flaring and venting. Operators will be trained in procedures for safe start-up, normal operation, and shutdown, and consequently, minimise flaring. In addition to customary classroom and in-plant training, a computer based Operations Training Simulator (OTS) will be developed, which will emulate the actual dynamic behaviour of the process plant systems and the distributed control & monitoring system. Operators will use the OTS to become familiar with how to start-up systems, respond to operating upsets, and shutdown, while avoiding overpressure conditions or trips which could result in flaring.

The gas supply pipeline from the Wheatstone Platform could be operated in a HP 'packed' operating mode to minimise fluctuations in gas supply flowrate; thus minimising LNG train upsets or downtime. Routine HC skimming in the AGRU equipment will be performed to avoid foaming incidents or off-spec amine, resulting in unit upsets and flaring. The LNG tanks will be provided with a predictive rollover management system, with continuous density monitoring at various liquid levels, providing an early warning, to trigger operator intervention to prevent excessive LNG vapour venting.

Systematic maintenance plans and procedures will be implemented to allow the LNG Plant to operate to maximise efficiency and production, while minimising upsets, breakdowns or unplanned shutdowns, resulting in reduced air emissions. This will include implementing Reliability Centred Maintenance (RCM), a process for determining equipment criticality and proactive maintenance tasks. In RCM, equipment criticality (likelihood and consequence of failure) is ranked to assist in the management of reliability and integrity. A process will be in place to determine spare parts requirements, based on considerations such as failure rate and criticality. This process will ensure that the correct parts and quantities are available on-site, or at an appropriate storage depot. Instrumentation will undergo regular preventive maintenance and testing.

If a flaring event occurs, it will be detected and recorded by the continuous flow monitoring system on the flare header(s) and the information will be immediately displayed in the PCS on the operations consoles in the CCR. A Closed Circuit Television (CCTV) camera system will also allow Control Room staff to monitor the appearance of the flare. After any significant flaring event (e.g. process upset, equipment malfunction leading to increased flaring), causal analysis will be conducted to identify future actions which can be taken to maintain plant stability and reliability, reducing the likelihood of recurring incidents which could cause potential flaring.

8.3.3.1 Emergency Flaring

Depressuring during an emergency situation will follow API 521 guidelines (API, 1997). The depressuring valves are sized and strategically located to quickly lower the pressure of specific isolated sections of the plant. The valve sizing is based on a depressuring rate that will reduce the pressure of the plant section selected to 50% of the system design pressure, or 6.9 barg, whichever is lower, in approximately 15 minutes.

An exception is the inlet slugcatcher, where a large volume of HP gas and HC condensate is contained in the large diameter pipe array. The slugcatcher is arranged in two halves and each half of the slugcatcher will have its own depressurization valve configuration. Depressurization of the slugcatcher will not exceed the capacity of the flare system. The design pressure of the slugcatcher is the same as that of the gas supply pipeline, which should minimise the likelihood that the pressure relief system on the slugcatcher will be triggered in the event of an ESD of one or both LNG trains.

To minimise flaring during an ESD event, the ESD control philosophy is to first isolate the plant area where the emergency condition has been detected, using a network of ESD valves and to shutdown rotating equipment and fired heaters. Then depressurization to the flare system can be initiated, if required, by the operations staff, using a specific control subsystem provided for that purpose.

To avoid ESD events, the SIS is configured with a voting logic so that automatic shutdown of a LNG train or of the refrigerant compressor system is only triggered if two out of three critical process sensors detect an unsafe, abnormal condition. For example, a high temperature shutdown of the main refrigerant compressor would require two out of three temperature indicators to signal that excessive temperatures were present. The plant design provides redundant instrumentation for these critical shutdown sensors, to allow this voting system to function. Experience with such systems in other major facilities has shown they can significantly reduce the number of spurious trips and shutdowns.

8.3.3.2 Flare System Design Emission Rates

The design emission rates for all flares based on the estimated pilot and purge, and streams to flare are given in Table 8.1, Table 8.2 and Table 8.3 for the dry gas, wet gas, and marine flare, respectively. The estimated emission rates for the worst case upset scenarios include blocked outlet of NRU vent which is routed to dry gas LP flare during valve failure, thermal oxidiser trip for one LNG train where the acid gases from AGRU are routed to the wet gas LP flare, and loss of BOG compressor due to partial power failure for marine flare. Several other likely scenarios were considered and worst cases have been presented in tables in this section.

Table 8.1: Dry Gas Flare System Design Emission Rates

Component	Design Emission Rate, Routine [1] (g/s)	Design Emission Rate, Upset [2] (g/s)
NO_x	0.43	9.1
PM_{10}	0.09	1.8
SO_2	0.001	0.08
VOC	0.02	1.14
CO	3.7	78.1

1. Estimated emissions from flares during routine operations (pilot + purge).
2. Upset scenario based on a blocked NRU vent outlet.

Table 8.2: Wet Gas Flare System Design Emission Rates

Component	Design Emission Rate, Routine [1] (g/s)	Design Emission Rate, Upset [2] (g/s)
NO_x	0.44	4.7
PM_{10}	0.09	1
SO_2	0.001	1.4
VOC	0.02	0.25
CO	3.8	40.5

1. Estimated emissions from flares during routine operations (pilot + purge).
2. Upset scenario based on a thermal oxidiser trip event.

Table 8.3: Marine Flare System Design Emission Rates

Component	Design Emission Rate, Routine [1] (g/s)	Design Emission Rate, Upset [2] (g/s)
NO_x	0.03	32.4
PM_{10}	0.01	6.6
SO_2	0.0001	0.0003
VOC	0.002	0.4
CO	0.3	278

1. Estimated emissions from flares during routine operations (pilot + purge).
2. Upset scenario based on a loss of a BOG compressor.

9.0 EMISSIONS MONITORING, TESTING AND VERIFICATION

Specific design features to minimise emissions to air from the Wheatstone Foundation Project have been discussed in Sections 7.0 and 8.0. Validation of these design features via monitoring and testing during steady-state operations are required to ensure that the equipment meet guaranteed emissions values and validate results from the ambient air quality modelling study conducted during the EIS/ERMP.

Air emissions dispersion modeling was conducted as part of the EIS/ERMP, to predict the cumulative impacts in the Ashburton North Strategic Industrial Area by the Wheatstone Project (25 MTPA LNG facility) on ambient air quality. Design emissions values similar to the emissions inventory provided in Section 5.0 were used (emissions values have been updated in Section 5.0 based on manufacturer information). The results indicated that ambient air quality standards would be met and thus, ambient air quality for the two-train Wheatstone Foundation Project would also be met. The emissions inventory will be updated during operations annually and compared to the design values to ensure that the initial input to the air emissions modeling remains valid.

9.1 Testing and Verification

Equipment will be tested during the commissioning phase to verify that the equipment meets manufacturer guaranteed emission levels, design emission rates, or better. Quarterly source testing using Australian Standards and/or using US EPA Methods or equivalent will be conducted on selected sources during the first year of Project operation, to ensure continuing equipment performance. If the first three consecutive sets of tests are satisfactory, the source testing frequency will be changed to annually or more thereafter. Interim monitoring using portable analysers will be conducted for major point sources except flares, on at least a quarterly basis for the first year (Chevron, 2010).

9.1.1 Gas Turbine Drivers and Power Generation

All gas turbines undergo a full initial performance test, conducted by the manufacturer, to verify that the power produced meets or exceeds the predicted power at a heat rate equal to or less than the rate quoted in the guarantee. This performance test provides the information needed to determine if turbine efficiency is greater than or equal to that agreed at the time of purchase. Each gas turbine and GTG set will be tested for NOx emissions at full load and at reduced loads to ensure it meets guaranteed levels.

Source testing will be conducted on site to demonstrate that the gas turbines can operate within emissions targets at field conditions. For gas turbines, testing for NOx concentration is performed using US EPA Method 7E or 20 (US EPA, 2012) or equivalent and consists of three one-hour runs using a continuous instrumental analyser. The flue gas flow rate, moisture content and oxygen content are determined using EPA Methods 19 and 3A (US EPA, 2012) or equivalent. The NOx concentration in the stack gas is then calculated on a dry basis and corrected to reference oxygen concentration for comparison to the design emission targets.

An emissions factor is calculated from these source testing results to represent the mass emissions of NOx per unit input of fuel. The emissions factor is updated whenever a new source test is performed. Fuel usage by the gas turbines is continuously tracked in the PCS to calculate emissions to air during operations.

9.1.2 Recuperative Thermal Oxidisers

A portable VOC and CO analyser will periodically measure the VOC composition at the stack of the recuperative TOs to validate the destruction efficiency of VOCs against manufacturer guarantees. Emission factors from the recuperative TOs will be calculated based on these test results to represent the mass emissions of VOCs per unit input of acid gas. The acid gas and fuel gas flow rates are continuously tracked in the PCS to calculate emissions to air during operations. The fraction of BTEX present in VOCs will be calculated from HC speciation data and verified periodically with sample analyses.

9.1.3 Process Heaters

Source testing will be conducted on gas fired process heaters using US EPA methods similar to those used for gas turbines (see Section 9.1.1). An emissions factor is determined from the source test results to represent the mass of NOx emitted per unit of fuel consumed. Using this emissions factor, the ongoing emissions are estimated from the fuel usage rate and tracked in the PCS. Source testing will be conducted initially on all fired heaters. One additional source test will be conducted on each continuously running heater(s) during the first three years and every six years thereafter. Testing will not be repeated for the start-up heater since it is seldom in operation.

9.1.4 Flare System

Samples to check the heat content estimate are taken at least annually from any of the primary sources of flared gas and analysed for composition. Using the measured flow rate data and estimated heat content, the total heat input and estimated emissions can be continuously calculated in the PCS (US EPA, 1995). Flare emissions are calculated using AP-42 emissions factors represented as mass of pollutant per unit heat input to the flare. The flow of gas to the flare is continuously recorded in the PCS. The heat content of the gas is estimated from engineering analysis of the source of the flare gas or from historical sample data.

9.1.5 Source Testing Schedule

Source testing which directly measures emission concentrations and other parameters validate calculated values obtained from monitored parameters. A sample source testing schedule is outlined in Table 9.1.

Table 9.1: Source Testing Schedule [1,2]

Equipment / Source	Source Testing Method	Source Testing Frequency
Gas Turbines	Thermal efficiency – manufacturer testing	Commissioning
	NOx concentration – USEPA Method 7E or 20 Flue gas flow rate, moisture content, oxygen content – USEPA Method 19, 3A or equivalent	Quarterly
Recuperative TOs	VOC and CO – Calibrated portable analyser	Quarterly
	Acid gas composition	Annually
Process Heaters	NOx concentration – USEPA Method 7E or 20 Flue gas flow rate, moisture content, oxygen content – USEPA Method 19, 3A or equivalent	Annually for first 3 years; followed by testing every 6 years
Flares	Composition of major streams venting to flare header	Annually
Fugitive Emissions	VOC emissions – Remote imaging, handheld infrared camera	Quarterly to Annually, depending on source and frequency of leaks

1. This table is provided as an example source testing program.
2. A more detailed source testing program would be developed during the next phase of the project.

9.2 Monitoring

Major point sources of air emissions monitored include the power generation plant GTGs, refrigeration compressor gas turbines and the recuperative TOs. All major point sources of air emissions will be monitored for important parameters to ensure proper functioning of the equipment. Emissions will be calculated based on fuel usage and emission factors to determine if manufacturer guaranteed emissions performance levels are achieved. The calculated emissions levels will be verified on a set schedule using standard sampling analytical procedure as described in Section 9.1. An example of parameters monitored for each equipment / source is outlined in Table 9.2.

Table 9.2: Source Monitoring Program [1]

Equipment	Monitored Parameters (continuous)	Comments[2]
Gas Turbines	Fuel gas flow rates to gas turbines Online compositional analyser	
Recuperative TOs	Metering and totalizing of all gas flow rates to recuperative TOs	
	Combustion chamber temperature Oxygen monitoring in flue gas	Ensure temperature is maintained above 760 °C for VOC destruction
Process Heaters	Metering of fuel gas flow rates to process heaters	
	Oxygen monitoring in flue gas	Optimise combustion efficiency at burners
	Correct flame pattern / firebox temperature range	
Flares	Metering and totalizing of all volumes of gases from various unit operations venting to flare header. Pilot gas and purge gas flow rates also be metered	Adjustment of purge gas requirement to avoid flashback; Alert operators to possible non-routine venting to flare headers and address root causes Duplex thermocouple for each pilot and automatic re-ignition provided to ensure flame presence
	CCTV cameras	Allow operators to monitor and detect increase in visible emissions from flares
Fuel Gas	Composition at the main High Pressure (for turbines) and Low Pressure (Flares, Heaters, etc.) fuel gas headers	

1. This table is provided as an example.
2. NO_x, PM_{10}, SO_2, VOCs, CO emissions will be calculated using emission factors derived from source testing program.

9.2.1 Fugitive Emissions

A LDAR Program will be developed for the plant, consisting of periodic monitoring to detect leaking components, followed by repair of the components and retesting to ensure that the leak has been corrected. Process systems with potential leak sources of BTEX or VOCs will be identified on a plot plan of the site. Potential leak sources will be monitored on a frequency ranging from quarterly to annually using a remote imaging technology such as a handheld Infrared Camera (IR camera). If a leak is found, it will be identified and tagged in the field. The leak is repaired or the component is replaced, if practicable, or the leak is minimised by tightening a valve packing or flange, or applying a sealant, or other method, if repair would require a shutdown. The emissions point is rechecked to ensure that it is below the leak threshold. Records of leak sources are kept to assist in evaluating performance of components.

During initial construction and all major turnarounds, a Flange Management System (FMS) will also be implemented to track the status and condition of all flanges. The FMS will address the use of proper gaskets, bolt torquing, leak testing, dates the flange was opened/closed, etc., to prevent leaks and assure the long term integrity of the flanges.

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No changemarks applied

APPENDIX B:

WHEATSTONE ADER – PEER REVIEW TO SATISFY CONDITION 18.3 OF MINISTERIAL STATEMENT 873

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Air Assessments

IJH Holdings Pty Ltd ACN 101 552 505
as trustee for NKH Family Trust
ABN 21 796 617 294

[redacted]

Chevron Australia Pty Ltd
GPO Box S1580
PERTH WA 6845

Attn: Mr Dan Weidlein

Dear Sir

WHEATSTONE AEDR – PEER REVIEW
TO SATISFY CONDITION 18.3 OF MINISTERIAL STATMENT 873

Please find attached my review of the "Wheatstone Project - Air Emissions Design Report" dated 11 June 2013 in accordance with the requirement of condition 18.3 of Ministerial Statement No. 873 "Wheatstone Development – Gas Processing, Export Facilities and Infrastructure, Shire of Ashburton and Roebourne".

If you should have any queries with the review, please do not hesitate to contact me.

[redacted]

WHEATSTONE AEDR – PEER REVIEW TO SATISFY CONDITION 18.3 OF MINISTERIAL STATMENT 873

Review

This report provides a peer review of Chevron's "Wheatstone Project - Air Emissions Design Report" dated 11 June 2013 in accordance with the requirement of condition 18.3 of Ministerial Statement No. 873 "Wheatstone Development – Gas Processing, Export Facilities and Infrastructure, Shire of Ashburton and Roebourne".

Condition 18 is reproduced in full below, with this report satisfying condition 18-3.

18 Emissions to Air

18-1 The Proponent shall install equipment in the LNG plants and Domgas plants and manage ongoing operations such that best practice for a liquefied natural gas/domestic gas facility is achieved in respect of:

i. minimising emissions of volatile organic compounds and oxides of nitrogen emissions;

ii. optimising the smokeless capacity of flares so as to minimise the frequency and duration of visible smoke; and

iii. minimising non emergency flaring of gas.

18-2 As part of its Works Approval application under Part V of the EP Act for the Foundation Project and also for Works Approval applications for subsequent LNG trains, the Proponent shall provide reports to DEC showing:

i. specific design features that have been used to minimise and monitor emissions to air, pursuant to condition 18-1;

ii. how the design features compare with current lowest emissions for similar operations and proposals internationally and within Australia; and

iii. a peer review report as required by condition 18-3.

18-3 The Proponent shall commission peer reviewer(s), approved by the CEO to undertake the following, in accordance with terms of reference also approved by the CEO:

i. a review of the reports referred to in condition 18-2(i) and (ii);

ii. provide comment on the basis and validity of the conclusions in the reports; and

iii. provide comment on the relevance of the described Australian and international standards for this Proposal.

18-4 Where practicable the Proponent shall replace plant and equipment with that which meets the best practice standards as at the time of replacement. Replacement equipment shall not result in an increase in emissions or reduction in air quality.

Summary of Conclusions

Overall it is concluded that the AEDR report meets the requirements of condition 18.2 and has sufficiently demonstrated the specific design features that have been used to minimise and monitor emissions to air and how the design features compare with current lowest emissions for similar operations and proposals internationally and within Australia.

It is noted that some equipment have been considered out of scope in the AEDR, including the start up diesel generators and submerged combustion vaporiser which are used generally very infrequently. Also considered out of scope are shipping emissions, including VOC emissions from loading condensate to ships, which the AEDR states will be covered under MARPOL Annex VI protocols.

For the plant, it is considered that the design philosophy involving the consideration of (and sometimes trade off between) the use of lowest practicable emissions equipment, achieving high efficiency (and therefore reducing gas consumption), and ensuring reliability and safety in operations, results in the overall emissions being minimised. This philosophy is critically important for LNG plants as non routine events from small equipment trips and failures can lead to large plant trips and the resultant venting of large amounts of gas to the flares. Therefore in design, a high priority is placed on the requirement for reliable, demonstrated technology, such that equipment failures and trips are minimised. Additionally, the above demonstrates the need not just to focus on tail pipe emission values only, but assessing the emissions per unit of output is often more meaningful in comparing equipment and controls.

Therefore considering these factors, in particular the selection of high efficiency GTs with the associated efficiency measures, the design of AGRU gas stream treatment with no direct venting to air and the designs to minimise flaring, it is considered that the Wheatstone Project meets the objectives specified in condition 18.

More Specific Details

With regards to points requested in section 18.

Specific design features that have been used to minimise and monitor emissions to air, pursuant to condition 18-1

The AEDR provides reasonably comprehensive details on the rationale for the specific design features of the LNG and Domgas plants. Some of the more important features are:

Gas Turbines

Gas turbines (GTs) are used for power generation and for the compressor drivers on the LNG refrigeration trains and are the major source of NO_X emissions from LNG plants. For both the GTs for the LNG train compressor drivers and for the gas turbine generators (GTGs) for electricity generation, high efficiency aeroderivative GTs with dry low emission (DLE) combustor systems guaranteed to meet 25 ppm have been selected. Aeroderivative turbines typically have a higher capital cost, but have higher efficiencies than the heavier, larger Frame machines, such as used on the Gorgon Project and Pluto LNG plant.

For the GTGs, additional to the selection of aeroderivative GTs, inlet air humidification (IAH) has been selected to improve the efficiency of the turbines and reduce further the gas consumption and therefore emissions. IAH by cooling the inlet air using foggers, can increase the efficiency by 4% at nominal conditions, to as high as 15% at high temperatures. It is understood that the Wheatstone Project will be the first LNG plant in WA to use such technology.

The DLE combustors selected can achieve NO_X emission concentrations of <25 ppm down to 50% load which is generally the lower operating range for DLE systems on GTs. This enables greater flexibility in the GTG operations whilst still ensuring low emissions. The choice of other NO_X control options with lower NO_X emissions is not considered practical as they increase the unreliability in the GTs due to a lesser ability to handle, rapid changes in the load and gas quality.

For the compressor drivers, additional major energy efficiency measures include the use of waste heat recovery on the exhaust air for use as process heat within the LNG trains and expander-generators in the LNG process to cool the gas. These can generate 7 MW per train and improve the LNG production by 7%.

Process Heaters

Emissions from the Process Heaters have been minimised primarily by minimising their usage by utilising heat from other sources (e.g. the waste heat recovery unit (WHRU) on the LNG trains) and secondly, through the choice of low NO_X burner technology. Utilising heat from other processes minimise their use at near full load to only a small percentage of the time, with the majority (30 to 50%) of the time being in standby mode. Low NO_X burners are considered preferable to the lower ultra low NO_X burners as the latter increase the safety risk as the heaters are required to operate automatically over a large range in gas firing and excess air rates.

AGRU Emissions

The Wheatstone Acid Gas treatment system is considered best practice within the LNG industry. This is achieved using aMDEA solvent to minimise VOCs capture from the gas, therefore minimising the amount reporting into the acid gas stream and importantly ensuring that the acid gas stream is combusted 100% of the time through either a recuperative thermal oxidiser (RTO) or when this is not available, with the gas directed to a flare.

A RTO system was selected as this is argued to provide the best trade off between energy efficiency, reliability and destruction efficiency of VOCs and H_2S. When the RTO is not available, directing the AGRU to the flare is considered best practice and will therefore minimise the emissions of

BTEX (benzene, toluene, ethyl benzene and xylenes). Other existing and under construction LNG plants in WA (the Karratha Gas Plant (KGP), Pluto and Gorgon Project), all vent the AGRU emissions to air whenever the thermal oxidizer systems (or in the case of Gorgon – re-injection systems) are not available. Therefore VOC and BTEX emissions which can be a significant air quality issue (see the proposed Browse assessment, EPA, 2012) are less than from other WA LNG plant (see later).

Flaring

The flare system is considered best practice with a commitment for no routine waste gas streams to be flared (apart from the small quantity of gas for the pilot and purge gas treatment). Non routine flaring will include flaring acid gas when the RTO are not available, and the boil off gas from warm LNG ships, but these are relatively infrequent. The report lists design features including:

- Capture and reuse of gas leakage from seals such as from refrigeration gas compressors;
- Implementation of control system to monitor equipment to detect possible failures and initiate maintenance. This includes monitoring bearing oil temperatures and other process parameters;
- Design of inspection ports to reduce the need to de-pressure and purge the equipment to flare before conducting an internal inspection;
- Design of refrigeration train to allow maintenance of parts of the system e.g. compressors without shutting down the train and therefore flaring;
- Ability to store all propane, and ethylene refrigerant during a train shutdown and therefore minimise flaring; and
- Use of heated defrost gas instead of feed gas to dry out the cryogenic systems more quickly, reducing the gas flaring during a start up.

Monitoring

The AEDR has provides detail on the proposed monitoring program required to verify emissions and to ensure compliance with any regulations. With respect to monitoring, the frequency that monitoring is required should be largely dependent on the variability in the emissions, with processes which are relatively stable when operating requiring less frequent monitoring, whilst processes which show greater variability and with potential discharges at levels that are of concern requiring more frequent and even continuous monitoring. For example, GT emissions are considered to be relatively stable over the normal operating range. Other processes which may be more variable, and with relatively high emissions, requiring more frequent monitoring.

For the Wheatstone project GTs, after the initial manufacturer testing (to ensure compliance with specifications), quarterly stack testing of NO_X is proposed. This is considered adequate as stated above because GTs emissions are reasonably consistent and also as total NO_X emissions from the plant are low and the plant is sited in a reasonably remote area.

Similarly the proposed process heaters testing at an annual frequency, being a small source, is considered adequate.

For the RTO, quarterly testing of VOC and CO in the exhaust and annual acid gas composition testing, with continuous monitoring of combustion chamber temperature and the O_2 in the exhaust is proposed. This appears adequate, though possibly more frequent testing of the composition of the acid gas stream is required to determine the variability of BTEX and that continuous monitoring of CO is required in the exhaust as a better measure of high VOC destruction.

The monitoring proposed for flares appears adequate with the totalising of volume of gas from the various units of operations.

How the design features compare with current lowest emissions for similar operations and proposals internationally and within Australia

The following comments on the three most important air pollutant emission sources:

Gas Turbines

The adoption of DLE to meet NO_X levels of 25 ppm is considered best practice in the LNG industry with this being adopted for all recent LNG plants that I am aware of in Australia and overseas. No alternative technology other than DLE is known to have been adopted for LNG GT compressors. Additionally, as noted the combination with high efficiency aeroderivative GTS with waste heat recovery or IAH is considered best practice.

Acid Gas Destruction

The combustion of acid gases for 100% of the AGRU up time is considered best practice. As noted previously, this will be the first LNG plant in WA to incorporate this design.

Flaring

The list of design features are detailed in the report and summarised before and the commitment to a no routine flaring policy is considered to be best practice within the industry.

Comparison to other Facilities - Emission Benchmarking

The AEDR provides a reasonably comprehensive comparison of the annual emissions on a per tonne of product basis. This has some limitations due to the difficulty in obtaining complete, accurate information. The data however, shows that the Wheatstone LNG project will emit 189 tpa NOx per Mtpa LNG, which is just above Pluto (182), Australia Pacific LNG (183), but below KGP 4 and 5 (219) and Gorgon (295). Note Gorgon have compression for CO_2 re-injection which contribute somewhat to this higher figure. The emissions are slightly higher than provided for Pluto and ALNG, but it is noted these for the other projects are estimates only, with full details on the assumptions used not provided. It is expected based on the technology, high efficiency GTs, IAH and waste heat recovery that the technology should result in lower emissions than from Pluto and therefore the numbers quoted should be seen with some uncertainty. The higher Wheatstone values may be partly explained by the assumption that four GTGs are considered at full load, when 3 or four at part load will be used, and a high assumption of the amount of bypass of the compressor GTs exhausts. Also, emissions from plant in hot environments will also be higher than in cold climates as GT efficiency decreases reasonably rapidly with higher ambient temperatures.

In terms of VOCs data for comparison, less data was available, but it is noted that the VOC emissions for the Wheatstone project are estimated at 12.3 g/s compared to "measured" 440 g/s of VOC for the KGP from the 2011/2012 NPI. Also total LNG plant BTEX emissions are estimated at 2.95 g/s (using conservative guaranteed low destruction efficiency of 99% and not the expected destruction efficiency of 99.9%), compared to the measured emissions from the KGP (2011/2012 NPI figures) of 27 g/s of BTEX.

Provide comment on the relevance of the described Australian and international standards for this Proposal.

The report uses for comparison the emission values in the NSW 2010 Clean Air Regulations. These are the most recent emission guidelines in Australian and are generally the most stringent. Of most relevance for this project is the NO_X emission level for gas turbines. The NSW DEC specify a NO_X (expressed as NO_2) emission limit of 70 mg/m^3 (dry, 15% O_2, 101.3 kPa). This is approximately 35 ppm.

These regulations have generally been used in the Queensland LNG projects to set "design" limits. The Australia Pacific LNG (2010) references the NSW regulations, but also noted a lower project standard for NO_X from GTs of 25 ppm (Australia Pacific, 2010, Section 13.4.3).

Internationally other NO_X emission standards for gas turbines include:

- The USEPA 2006 New Source Performance Standards (NSPS) (40 CFR 60 Standards of Performance for Stationary Combustion Turbines;)[1] which has a 25 ppm limit for new stationary gas turbines firing natural gas with a heat input at peak load greater than 50 MMBtu/hr and less than or equal to 850 MMBtu/hr - the range applicable to the Wheatstone GTs. These have been used to set design values for the Sabine Pass LNG export facility in Louisiana that was approved in April 2012 as the first LNG plant to be built in the USA which is stated as meeting the NSPS for NO_X (FERC, 2011); and
- European Commission (2001 and 2010) emission standards. This specifies GT emission limits (above 70% load only) of 50 mg/m^3 for gas turbines, with a limit of 75 mg/m^3 for gas turbines used for mechanical drives and combined cycle greater than 55% efficiency and combined heat and power systems with efficiency greater than 75–%. For single cycle turbines having an efficiency greater than 35% - determined at ISO base load conditions – the emission limit for NO_X shall be $50\eta/35$ where η is the efficiency expressed as a percentage. These have apparently been used for design for Snohvist (Statoil, Norway) who

[1] Available at http://www.epa.gov/ttn/atw/nsps/turbine/turbnsps.html

installed LM6000 with DLN [2] achieving 25 ppm. Sakhalin (Russia) 2007 used the European 2001 directive for setting air quality emissions (note 2001 is the same as 2010 limits)

Therefore internationally, there are lower GT NO_X emission standards for power generators, though the NSW regulations are in line with the European Commission standards limits for GTs used for mechanical drives (compressors). It is understood that at LNG plants, the large variations, particularly in the gas quality sometimes makes it difficult to always achieve 25 ppm. GT manufacturers guarantees for gas turbines are defined in terms of the ambient conditions (less than 40 deg C and higher than 40% relative humidity) and in terms of a specified fuel quality. As such, considering the variability in fuel quality, though the specifications for equipment are to meet 25 ppm at the standard conditions, in terms of setting licence limits, the NSW value of 70 mg/m^3 consistent with the European Union limit of 75 mg/m^3 may be more appropriate.

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[2] See http://en.murmanshelf.ru/files/statoil_seminar_2012/4.1_Construction.pdf

APPENDIX C:

WHEATSTONE LNG FOUNDATION PROJECT AIR QUALITY ASSESSMENT

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Wheatstone Project

Chevron Wheatstone WHEATSTONE LNG FOUNDATION PROJECT AIR QUALITY ASSESSMENT

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WHEATSTONE FOUNDATION PROJECT

AIR QUALITY ASSESSMENT

WS0-0000-HES-RPT-CPM-000-00002-000

Prepared for

Chevron Australia

Prepared by

Air Assessments

Final

August 2013

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Glossary

Term	***Definition***
%	percent
$\mu g/m^3$	micrograms per cubic metre
µm	micro metre
<	less than
>	greater than
^0C	degrees Celsius
AERMOD	United States EPA regulatory dispersion model
AGRU	Acid Gas Recovery Unit
BOG	Boil Off Gas
BoM	Bureau of Meteorology
BTEX	Benzene, toluene, ethyl- benzene and xylenes
Btu/scf	British Thermal Unit per standard cubic foot
CO	Carbon monoxide
CSIRO	Commonwealth Scientific Industrial Research Organisation
CTM	Chemical Transport Model
DEC	Department of Environment and Conservation
DLN	Dry Low NO_X burner
DOMGAS	Domestic Gas
e.g.	for example
EPA	Environmental Protection Authority (WA)
GRS	Generic Reaction Set
GT	Gas Turbine
GTG	Gas Turbine Generator
g/s	grams per second
IAH	Inlet Air Humidification
i.e.	that is
km	kilometre
LNG	Liquified Natural Gas
m	metre
M	million
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mg	milligram
Mt	million tonnes
Mtpa	million tonnes per annum
MW	Megawatt
Ne	Plume rise enhancement factor (number of effective stacks)
NEPM	National Environmental Protection Measure
No.	Number
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NPI	National Pollution Inventory
NRU	Nitrogen Removal Unit
O_3	Ozone

OLM	Ozone limiting method
PM	Particulate matter (fine dust)
$PM_{2.5}$ and PM_{10}	Particulate matter less than 2.5 or 10 microns, respectively
ppb	Parts per billion
ppm	Parts per million by volume
PS	Power Station
SO_2	sulphur dioxide
TAPM	The Air Pollution Model
TIBL	Thermal Internal Boundary Layer
tpa	tonnes per annum
tph	tonnes per hour
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
WA EPA	Western Australian Environmental Protection Authority

Executive Summary

Chevron Australia Pty Ltd (Chevron) will construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast, Western Australia (WA). The Foundation Project will consist of two LNG processing trains, each with a capacity of approximately 4.45 million tonnes per annum (Mtpa) and a Domgas plant. Environmental approval has been granted for a 25 Mtpa LNG plant and associated Domgas facilities to allow for the expected future expansions.

The air quality modelling for the 25 Mtpa environmental approval (SKM, 2010) was conducted using:

- The model TAPM, with concentrations predicted for the local region (<20 km) for nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter below 10 µm diameter (PM_{10}) and benzene, toluene, ethyl benzene and xylenes (BTEX);
- The model TAPM and the Generic Reaction Set (GRS) mechanism to model the regional ozone concentrations; and
- Preliminary generic emissions.

Notwithstanding that the 25 Mtpa plant was approved, Air Assessments (2010) noted a number of potential limitations with the air quality modelling, notably the:

- Smog modelling used a simplified, screening smog system with a smog reactivity that was likely to be too low;
- Not including fires in a cumulative smog assessment; and
- The major source of VOC from the project – emissions from condensate ship loading, though very infrequent in occurrence, was not assessed.

Therefore as detailed design information is now available, this report provides an updated assessment that also addresses the above potential limitations. This assessment utilises two models - AERMOD for predicting local impacts on a scale out to 13 km from the plant, and TAPM-CTM for predicting regional scale ozone and NO_2.

The results from the local AERMOD modelling, including the Foundation Project and the existing sources (the Macedon project and Onslow power station) indicate that:

- The predicted concentrations outside the lease boundaries are relatively low compared to their respective criteria, with the 1-hour NO_2 concentrations being closest, up to 21.5% of the relevant criterion, and all other pollutants contributing less than 5% of their respective criteria;
- For all the Wheatstone operating scenarios assessed, there is generally little variation in the predicted concentrations apart from the ship loading condensate scenario – case 5. That the emissions from the various flaring scenarios do not significantly change the predicted concentrations is a result of the very large amount of heat released and subsequent large plume rise from the flares. For the condensate loading case, though the concentrations do increase they

are still low, at most 3.6% of the annual average benzene criterion and 0.65% of the 24-hour xylenes criterion outside the lease boundary on land.

The results from the regional TAPM-CTM modelling for the modelled year (2009) indicate that:

- Maximum existing ozone concentrations at isolated areas in the Pilbara are relatively high, with the major contributor being emissions from bush fires. The maximum existing ozone concentrations predicted anywhere on the model grid are 87 and 95% of the 1-hour and 4-hour ozone standards respectively. Using what is considered the more appropriate second highest concentration when including natural sources, the predicted concentrations are 74 and 86% of the standard;
- With the addition of future industry and the Wheatstone Foundation Project, the maximum ozone concentrations predicted anywhere on the model grid remain essentially unchanged and, for some statistics and averaging periods, will even decrease. The minor impact or even reduction is due both to fires being the dominant source and the non linearity in the atmospheric chemical reactions, where additional NO_2 can (in some circumstances) reduce ozone concentrations;
- At residential locations, the predicted maximum 1-hour ozone concentrations for existing sources are between 43 to 60 ppb. With the addition of future industry (excluding the Wheatstone Foundation Project), these maximums are predicted to increase only marginally, typically less than 1 ppb. The exceptions to this are at Barrow Island where a large increase in ozone levels is predicted due to the Gorgon Project and for Mardie where there is a significant reduction in the maximum and second highest 1-hour ozone concentrations. This reduction at Mardie is due to the industrial sources impacting on a smog event due to fire emissions, where the additional NO_2 is predicted to reduce the ozone formation; and
- With the addition of the Wheatstone Foundation Project, under routine operations there is predicted to be negligible change in the concentrations at residential sites (including Onslow) apart from the Minderoo station with increases of no more than 1 ppb. For the non routine scenarios, the above result applies, except for the ship-loading condensate case where an increase of up to 3 ppb in the 1-hour concentrations at Minderoo station is predicted, though with the concentrations still being only 45% of the 1-hour NEPM standard. That the Wheatstone Foundation Project has such a minor impact on ozone concentrations is due to the emissions being relatively small, estimated to comprise only 0.13 to 4.9% of future anthropogenic emissions in the Pilbara. Therefore overall impacts on regional air quality from the Wheatstone Foundation Project are small.

1 Introduction

1.1 Background

Chevron Australia Pty Ltd (Chevron) will construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast, Western Australia (WA). The Wheatstone Foundation Project will process gas from various fields offshore in the West Carnarvon Basin. Ashburton North is the approved site for the LNG and Domgas production facility. The Foundation Project requires installation of gas gathering, export and processing facilities in Commonwealth and State waters and on land.

The Ashburton North site is approximately 12 km south-west of Onslow along the Pilbara coast within the Shire of Ashburton. The Foundation Project will consist of two LNG processing trains, each with a capacity of approximately 4.45 million tonnes per annum (Mtpa). The Domgas plant will be a separate, but co-located processing train and will form part of the Foundation Project.

Environmental approval for the project has been granted for a 25 Mtpa LNG plant and associated Domgas facilities to allow for the expected future expansions. The air quality modelling was conducted for a five train facility by SKM (2010) using:

- The model TAPM, with concentrations of nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter below 10 μm diameter (PM_{10}) and benzene, toluene, ethyl benzene and xylenes (BTEX) predicted on a 1 km pollution grid to assess local impacts; and
- The model TAPM and the Generic Reaction Set (GRS) mechanism to model the regional ozone concentrations on a 3 km pollution grid.

This report was reviewed by Air Assessments (2010a) which identified a number of areas where the modelling could be improved (see **Appendix A** for a fuller listing), notably:

- The smog (ozone) modelling chemical reaction equations used are intended only as a screening, conservative approach. Though in themselves they are likely to be conservative, the reactivity of the VOC emissions is considered to be understated, and as such the ozone levels from the project would also likely be under-predicted;
- The assessment included the LNG plant and most major emission sources at the time. The modelling did not however include emissions from fires which is the major source of precursors to ozone in the Pilbara and as such a cumulative assessment was not presented; and
- The major source of VOC from the project – emissions from condensate ship loading, though very infrequent in occurrence was not assessed.

Therefore, noting the potential limitations with the previous modelling and that Chevron have now more detailed emission estimates, Chevron have engaged Air Assessments to provide an updated air quality assessment of the Foundation Project (2 trains, 8.9 Mtpa LNG production).

1.2 Scope of Work

The following Scope of Work was agreed:

- Develop an updated emission inventory for the region incorporating all major industrial sources;
- Determine up to date background pollutant levels for the region and summarise this in the report;
- Undertake local modelling of NO_X, SO_2, CO, PM_{10}, $PM_{2.5}$, BTEX and H_2S for a total of six scenarios for the Foundation Project;
- Undertake regional modelling to predict concentrations of ozone and NO_2 incorporating emissions from fires. Fire emissions are to be incorporated using the methodology as used in the Gorgon Project developed by CSIRO with the modelling conducted using TAPM-CTM. This modelling system with the incorporation of emissions from fires and Pilbara industry was shown to provide very good agreement with the observations (see Pitts *et al*, 2011);
- Address the concerns raised in Air Assessments (2010a) and provide a comparison of the 2010 and updated 2013 emissions, as well as compare the 2010 and 2013 predicted concentrations; and
- Present the results in a stand alone report, detailing the methodology used and input data.

2 Atmospheric Emissions

2.1 Introduction

This section provides details on the atmospheric emissions of concern from the two train (8.9 Mtpa LNG) plant as well as the emissions from other sources in the region.

2.2 Wheatstone Gas Development Emissions

2.2.1 Sources

The primary emission sources from the Wheatstone Foundation Project include the:

- Twelve compressor gas turbines on the two LNG trains (six per LNG train). These GTs are General Electric LM6000PF aero-derivative gas turbines fitted with Inlet Air Humidification (IAH) and Dry Low Emissions (DLE) combustor systems. Emissions of concern are primarily NO_X;
- Four power station gas turbines generators (GTG). These are also General Electric LM6000PF aero-derivative gas turbines fitted with IAH and DLE. Emissions of concern are primarily NO_X;
- Two recuperative thermal oxidisers (RTO) used to combust the acid gas from the acid gas removal units (AGRU) from the two LNG trains, with one RTO for the Domgas plant acid gas stream. Emissions from the RTOs are primarily NO_X and SO_2 with residual emissions of BTEX due to incomplete destruction by the oxidiser;
- The regeneration gas process heater (one) and hot oil start up (two) process heaters. The emissions of concern are primarily NO_X;
- Flares. Under routine operation, the flares will operate with pilot and purge gas only and therefore will have low emissions. Under non routine conditions however, large quantities of gas are flared which will result in significant quantities of NO_X, CO, VOCs (including BTEX) being emitted. The flares include the main plant high pressure and low pressure flares (each handling wet and dry gas streams) and the marine flare for boil off gas (BOG).

As well as these sources from the LNG and Domgas plants, other significant emissions associated with the project include that have been included in the modelling are:

- VOC emissions from condensate ship loading. These occur as the VOC-rich vapour in the ships hold headspace is displaced during loading. This is a very infrequent operation, anticipated to occur with up to 12 condensate tankers per year with loading occurring for 13 hours each. That is, a total of 156 hours per year or 1.8% of the time; and
- Ship combustion sources from the LNG and condensate carriers and tugs. Major emissions are NO_X and also for the condensate carriers that use heavy fuel oil with high sulphur contents, SO_2.

Other sources, that are not included in this modelling assessment include:

- VOC emissions from fugitive releases from hydrocarbon storage tanks, valve packing, compressor seals, pump seals, flanges, and connectors. The proposed plant has been designed with best practice and fugitive emissions of VOCs are expected to be low;
- Relatively small and infrequent sources. These include:
  - Six diesel generators used during LNG plant trips cold-start procedures and for their intermittent periodic testing (total up to 25 hr/yr/generator);
  - Two fire water pumps for up to 52 hr/yr/unit; and
  - One submerged combustion vaporiser for generating natural gas when the Domgas plant is shut down for periodic maintenance (up to 240 hr/yr).
- Motor vehicles as these are a relatively small source in terms of emissions, though they can result in relatively high ground level concentrations immediately adjacent to highly trafficked roads under stable, light wind conditions; and
- Emissions during construction, such as particulate matter from construction activities and gaseous emissions such as from temporary power stations. The power stations do have sizeable NO_X emissions, but these will not operate during the LNG plant operation and have been addressed in their own modelling assessments.

2.2.2 Emission Scenarios Evaluated

For the assessment of the Wheatstone Foundation Project, Chevron reviewed the range of possible event scenarios with six scenarios selected to cover the range of likely events. These scenarios are listed in **Table 2-1** and are for:

1) Normal Operations;
2) Regenerative thermal oxidiser trip for one LNG train where the AGRUs vent gas is directed to the LP flare;
3) Blocked Nitrogen Rejection Unit (NRU) outlet vent. The gas stream emitted consists of concentrated N_2 with trace amount of methane (less than 1.5 mol %) which is vented directly to atmosphere;
4) Loss of BOG compressors, where the boil off gas from the LNG tankers will be routed to the marine flare;
5) Loading a condensate ship, where VOC rich vapours are displaced from the ships hold. This is estimated to occur for only 156 hours per year; and
6) Start-up of an LNG train with use of a start up oil heater and non routine flaring to the LP flare.

Table 2-1 Wheatstone Foundation Project (8.9 Mtpa) – Emission Scenarios Modelled

No.	Scenario Definition	Anticipated Frequency of Scenario	Comments
1	**Normal Operations** • Twelve LM6000 PF GTs operating. • Three LM6000PF GTGs are operating for 50% of the time (4,139 hr). • Four LM6000 PF GTGs operating for 50% of the time (4,139 hr). • LP and HP with three flare risers each (wet, dry and spare) operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating on pilots and purge gas, no non-routine flaring. • Two Acid gas TO for LNG plant and one for Domgas plant. • Domgas Regeneration Heater operating (3,621 hr/yr).	Up to 94.5% of the project uptime	• Two LNG trains operating at full load. • One Domgas plant operating at full load. • Although three GTGs running at full load will provide sufficient capacity to meet power demand under site conditions, the operating strategy is to have four GTGs running at partial load (>70 %) in an N+1 configuration to provide electrical power redundancy and stability. This ensures that sufficient power will be available to meet power demands even if one of the GTGs trips off-line. Peak emissions rates from considered scenarios are provided. • Domgas Plant Regeneration Gas Heater: Periodically heats a slipstream of processed gas to regenerate the Domgas Plant mol sieve dehydration units and will run continuously only during the heating phase of the regeneration cycle. • The spare flare will be isolated and not used during normal operations.
2	**Thermal Oxidizer Trip for One LNG Train** • Twelve LM6000 PF GTs operating. • Four LM6000 PF GTGs operating. • LP wet flare operating in non-routine mode. • LP dry and HP (dry and wet) flares operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating on pilots and purge gas, no non-routine flaring. • One Acid gas TO for LNG plant and one for Domgas plant. • Domgas Regeneration Heater operating (3,621 hr/yr).	1 event a year for a duration of 25 hours	• During this scenario, rest of the units and equipment will be operating including AGRU; however, the acid gas stream will be routed to the Wet Gas LP Flare. • Flow from the unit augmented with fuel gas to maintain heating value of 300 Btu/scf. Emissions are based on flowrate and composition for augmented condition.
3	**Blocked Outlet of NRU Vent (for one train)** • Twelve LM6000 PF GTs operating. • Four LM6000 PF GTGs operating. • LP dry flare operating in non-routine mode. • LP wet and HP (dry and wet) flares operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating on pilots and purge gas, no non-routine flaring. • Two Acid gas TO for LNG plant and one for Domgas plant. • Domgas Regeneration Heater operating (3,621 hrs/yr).	1 event a year, Duration of 22 hours	• NRU vent, with high nitrogen content, routed to the dry gas LP flare during valve failure. • Flow from the unit augmented with fuel gas to maintain heating value of 300 Btu/scf. • Emissions are based on flowrate and composition for augmented condition.
4	**Loss of BOG Compressors due to Partial Power Failure** • Twelve LM6000 PF GTs operating. • Four LM6000 PF GTGs operating. • LP and HP with three flare risers each (wet, dry and spare) operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating in non-routine mode. • Two Acid gas TO for LNG plant and one for Domgas plant. • Domgas Regeneration Heater operating (3,621 hr/yr).	2 events in a year, Duration of 12 hr per event	• During this scenario, rest of the Units and equipment will be operating; however, the LNG ship loading vapours will be routed to the Marine Flare.
5	**Condensate Ship Loading**	12 ships per	• 12 ships of 75,000m3 capacity per year for the

	• Twelve LM6000 PF GTs operating. • Four LM6000 PF GTGs operating. • LP and HP with three flare risers each (wet, dry and spare) operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating on pilots and purge gas, no non-routine flaring. • Two Acid gas TO for LNG plant and one for Domgas plant. • Domgas Regeneration Heater operating (3,621 hr/yr). • Condensate Ship Loading (156hr/yr).	year at 13 hrs of loading time per yr = 156hr/yr	Foundation Project have been assumed. • Total ship loading time of 13 hours at a loading rate of 5,769 m3/hr. • Emissions calculations are based on equation provided in U.S. EPA AP-42 Emission Factors.
6	**LNG Train 2 Start-up** • Six LM6000 PF GTs operating. • Two LM6000 PF GTGs operating. • Third LM6000 PF GTG operating at >50% load. • LP wet flare operating in non-routine mode. • LP dry and HP (dry and wet) flares operating on pilots and purge gas, no non-routine flaring. • One Marine flare operating on pilots and purge gas, no non-routine flaring. • One Acid gas TO for LNG plant and one for Domgas plant.	1 event for 25 days	• Peak emission rates have been provided for the modelling purpose.

The emission parameters from the normal operation scenario are presented in **Table 2-2** with **Table 2-3** presenting a summary of the sources that vary for the non routine operations and the resultant total emissions. A schematic of the plant layout is also provided in **Figure 2-1.**

Table 2-2 Wheatstone Foundation Project Stack Emissions Parameters - Normal Operations – Scenario 1

	Source	Easting GDA94 (m)	Northing GDA94 (m)	Stack Height (m)	Stack Tip Diam. (m)	Enh. Fact.[2]	Effect. Diam.[2] (m)	Exit Temp. (deg K)	Exit Velocity (m/s	PM (g/s)	NO_X as NO_2 (g/s)	CO (g/s)	SO_2 (g/s)	VOC (g/s)	Benzene (g/s)	Toluene (g/s)	Ethyl Benzene (g/s)	Xylene (g/s)	Formal-dehyde (g/s)
LNG Train 1																			
Acid Gas Therm Oxidizer-1	1H-1901	293,140	7,599,675	35	2.13	1	2.13	(670)[1]	13.5	0.026	1.401	2.132	0.732	1.247	0.157	0.579	0.054	0.374	-
Comp. Turb. Driver 1(P)(Bypass)	1W-3411	293,292	7,599,651	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 1(P)(WHRU)	1W-3411	293,289	7,599,640	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 2(P)(Bypass)	1W-3421	293,306	7,599,647	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 2(P)(WHRU)	1W-3421	293,303	7,599,637	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 3E(Bypass)	1W-3412	293,319	7,599,644	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 3E(WHRU)	1W-3412	293,316	7,599,633	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 4E (Bypass)	1W-3422	293,333	7,599,640	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 4E (WHRU)	1W-3422	293,330	7,599,629	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 5M (Bypass)	1W-3413	293,346	7,599,636	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 5M (WHRU)	1W-3413	293,343	7,599,626	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 6M (Bypass)	1W-3423	293,360	7,599,633	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 6M (WHRU)	1W-3423	293,357	7,599,622	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
LNG Train 2																			
Acid Gas Therm Oxidizer-2	2H-1901	293,078	7,599,441	35	2.13	1	2.13	(670)[1]	13.5	0.029	1.401	2.132	0.732	1.247	0.157	0.579	0.054	0.374	-
Comp. Turb. Driver 1(P)(Bypass)	2W-3411	293,230	7,599,417	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 1(P)(WHRU)	2W-3411	293,227	7,599,407	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 2(P)(Bypass)	2W-3421	293,243	7,599,413	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 2(P)(WHRU)	2W-3421	293,240	7,599,403	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 3E(Bypass)	2W-3412	293,257	7,599,410	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 3E(WHRU)	2W-3412	293,254	7,599,399	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 4E (Bypass)	2W-3422	293,270	7,599,406	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 4E (WHRU)	2W-3422	293,267	7,599,396	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 5M (Bypass)	2W-3413	293,284	7,599,403	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 5M (WHRU)	2W-3413	293,281	7,599,392	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
Comp. Turb. Driver 6M (Bypass)	2W-3423	293,297	7,599,399	50.7	3.6	1.29	5.27	741	2.4	0.026	0.316	0.538	0.001	0.008	1.99E-07	5.85E-09	6.25E-12	2.49E-11	0.002
Comp. Turb. Driver 6M (WHRU)	2W-3423	293,294	7,599,388	50.7	3.06	1.59	6.14	584	29.5	0.237	2.840	4.841	0.007	0.075	1.79E-06	5.27E-08	5.62E-11	2.24E-10	0.021
DomGas																			
Domgas Regen Gas Heater-1	1H-6532	293,618	7,599,725	39.7	1.19	1	1.19	467	3.3	0.108	0.221	0.112	0.0005	0.015	0.004	0.012	0.001	0.007	0.0002

Domgas Acid Gas Thermal Oxidizer-1	1H-6501	293,615	7,599,714	35	1.52	1	1.52	(806)[1]	10.8	0.005	0.503	0.765	0.117	0.394	0.047	0.155	0.015	0.10	-
Flares																			
HP Flare (Wet gas and dry gas pilot + purge)	0K-1901 + 0K-1902	292,645	7,599,324	96.6[3]	0.6[3]	1	0.6	1273	20	0.019	0.095	0.813	0.000	0.005	0.007	0.008	0.001	0.004	0.0
Marine flare-1	0K-1903	293,087	7,600,494	46.1[3]	0.35[3]	1	0.35	1273	20	0.006	0.032	0.271	0.0001	0.001	0.0	0.0	0.0	0.0	0.0
LP Flare (Wet gas and dry gas pilot + purge)	0K-1911 + 0K-1912	292,840	7,599,305	56.6[3]	1.72[3]	1	1.72	1273	20	0.157	0.774	6.639	0.002	0.038	0.060	0.061	0.006	0.032	0.0
Power Generation																			
GTG Turbine Driver-1	0TG-3101	292,985	7,599,375	35	3.28	1.22	4.42	737	27.7	0.219	3.569	6.083	0.007	0.063	1.50E-06	4.39E-08	4.69E-11	1.86E-10	0.017
GTG Turbine Driver-2	0TG-3102	292,970	7,599,320	35	3.28	1.22	4.42	737	27.7	0.219	3.569	6.083	0.007	0.063	1.50E-06	4.39E-08	4.69E-11	1.86E-10	0.017
GTG Turbine Driver-3	0TG-3103	292,955	7,599,265	35	3.28	1.22	4.42	737	27.7	0.219	3.569	6.083	0.007	0.063	1.50E-06	4.39E-08	4.69E-11	1.86E-10	0.017
GTG Turbine Driver-4	0TG-3104	292,941	7,599,210	35	3.28	1.22	4.42	737	27.7	0.219	3.569	6.083	0.007	0.063	1.50E-06	4.39E-08	4.69E-11	1.86E-10	0.017
Total										**4.39**	**56.6**	**101.7**	**1.71**	**4.21**	**0.433**	**1.394**	**0.130**	**0.890**	**0.346**

Notes:

1) Values in brackets used in modelling to account for heavier than air effects (See **Section 4.9**).
2) Ne is the plume rise enhancement factor see (**Section 4.7**) with the effective diameter is based on the diameter increased by the enhancement factor.
3) Flare parameters are the effective release height and diameter and exit temperature and velocity based on using the model AERMOD using the net heat release during flaring. The actual heights of the flares are; HP Flare (93.5 m), marine flare (44.3 m) and LP flare (44.2 m).
4) Emissions of H_2S not included above are 0.004 g/s from the LNG trains Thermal oxidizers each and 0.0006 g/s from the Domgas Thermal Oxidizer.

Table 2-3 Wheatstone Foundation Project Stack Emissions Parameters Summary – Scenario 1 to 6

Scenario	Source	Stack Height (m)	Stack Tip Diam. (m)	Exit Temp. (deg K)	Exit Velocity (m/s	PM (g/s)	NO_X as NO_2 (g/s)	CO (g/s)	SO_2 (g/s)	VOC (g/s)	Benzene (g/s)	Toluene (g/s)	Ethyl Benzene (g/s)	Xylene (g/s)	Formal-dehyde (g/s)	H_2S (g/s)
Scenario 1 – Routine Ops - Total						**4.39**	**56.6**	**101.7**	**1.71**	**4.21**	**0.433**	**1.394**	**0.130**	**0.890**	**0.346**	**0.009**
Scenario 2 -Thermal Oxidiser Trip																
Acid Gas Therm Oxidizer-1 (offline)	1H-1901	35	2.13	0	0	0	0	0	0	0	0	0	0	0	0	0
LP Flare	0K-1911 + 0K-1912	64.8	4.42	1273	20	1.035	5.10	43.75	1.34	0.261	0.639	2.16	0.201	1.40	0.0	0.006
Total						**5.24**	**59.5**	**136.7**	**2.32**	**3.18**	**0.855**	**2.92**	**0.271**	**1.88**	**0.346**	**0.011**
Scenario 3 - Blocked NRU Outlet																
LP Flare	0K-1911 + 0K-1912	71.9	6.01	1273	20	1.93	9.51	81.5	0.081	1.16	0.190	0.569	0.059	0.298	0.0	0.0
Total						**6.16**	**65.3**	**176.6**	**1.79**	**5.32**	**0.562**	**1.90**	**0.183**	**1.156**	**0.346**	**0.009**
Scenario 4 - Loss of BOG Compressor																
Marine Flare	0K-1903	94	11.1	1273	20	6.57	32.4	278	0.0003	0.400	0.0	0.0	0.0	0.0	0.0	0.0
Total						**10.95**	**88.9**	**379**	**1.71**	**4.60**	**0.433**	**1.39**	**0.130**	**0.890**	**0.346**	**0.009**
Scenario 5 - Condensate Ship Loading																
Condensate Ship Loading						0	0	0	0	532	1.43	2.49	0.205	1.03	0.0	0.0
Total						**4.39**	**56.6**	**101.7**	**1.71**	**537**	**1.87**	**3.89**	**0.336**	**1.92**	**0.346**	**0.009**
Scenario 6 – Plant Start Up One train and TO offline																
LP Flare	0K-1911 + 0K-1912	79.0	7.62	1273	20	3.11	16.3	89.7	0.044	14.7	0.142	0.276	0.028	0.158	0.000	0.001
Total						**5.74**	**51.7**	**150.4**	**0.969**	**17.2**	**0.358**	**1.03**	**0.099**	**0.642**	**0.208**	**0.005**

Notes: Sources listed are those that vary from Scenario 1

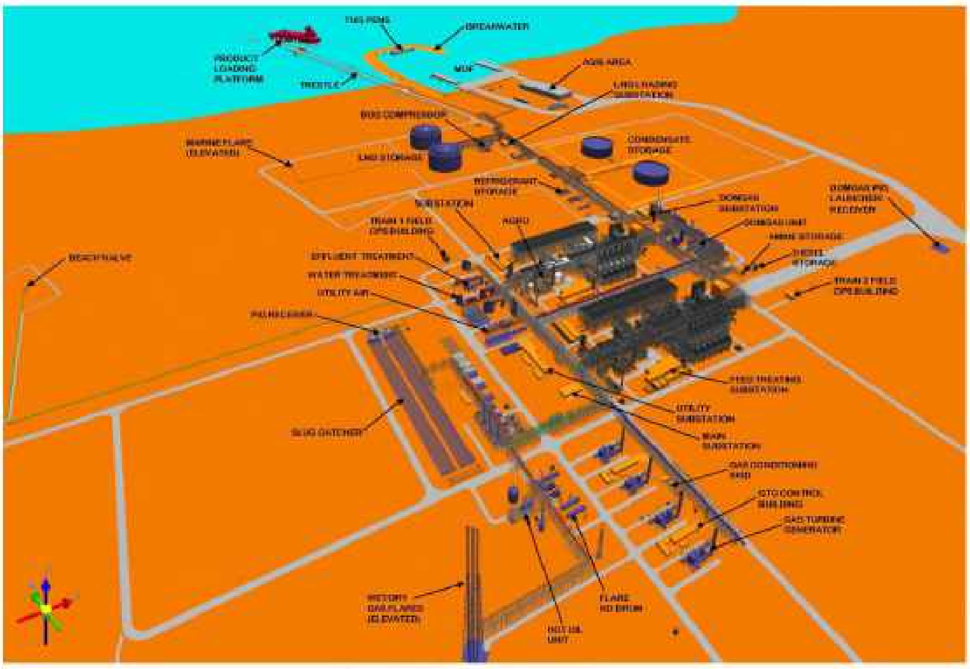

Figure 2-1 Wheatstone Foundation Project

Table 2-2 and **Table 2-3** indicate that:

- Total emissions from the routine case (scenario 1) will be 56.6 g/s of NO_X and 4.2 g/s of VOC including 0.433 g/s of benzene;
- For scenario 2 (the thermal oxidiser trip for one LNG train), the emissions increase from the routine case due to the AGRU acid gas stream being routed to the LP flare. Under this case, there is a slight increase in NO_X with a more significant increase in BTEX, including benzene emissions increasing to 0.855 g/s;
- For scenario 3 (blocked outlet of NRU vent), the emissions are the same as per scenario one, except with the LP flare flaring at a much greater rate. This results in only a slight increase in most emissions;
- For scenario 4 (loss of a BOG compressor), there is large flaring of BOG gas to the marine flare with significant increase of NO_X and CO emissions to 88.9 and 379 g/s respectively, but with no change to the facility's BTEX emissions as this gas stream contains negligible BTEX;
- For scenario 5 with condensate loading occurring there is a significant increase in the VOC emissions with emissions of 1.87 g/s of benzene, the highest for any scenario; and
- For scenario 6 (start up of an LNG train), the emissions increase for PM, VOC and CO, but are lower for the other species, due to one train being offline.

2.2.3 Other Sources in the Immediate Region

Macedon Project

Emission data for the Macedon Project are provided in URS (2010) and the works approval documentation. The 2010 assessment was however, only a preliminary screening level assessment and the data is considered incomplete as, no power generation sources were given and the emissions from the sales gas compressors were too high (based on comparison to the actual equipment specification sheets). Further data was sought from the Macedon Project, but this was not available. As such, in this assessment, to provide more accurate data, emissions from their equipment specification data sheets were used for:

- The three sales gas compressors (Taurus 70 GTs, each rated 7.5 MW[1] at 15 deg C) with two to be in operation at any one time using DLE combustors (<25ppm NO_X);
- The three wet gas compressors (Mars100 GTs, each rated at 11.4 MW at 15 deg C) with two to be in operation at any one time using DLE combustors; and
- The four Saturn 20 GTs for electricity generation with three GTs taken to operate at any one time. These have no NO_X control as these are not available for these small GTs.

All emission parameters were obtained at 30 deg C (typical ambient temperature).

Onslow Power Station

The present power station consist of gas engines with a total capacity of 3.6 MW with 3 MW of emergency diesel generators that are located on the Dampier Salt lease (WAPC, 2011). The gas

[1] The GT sizes quoted in the works approval appear to be quoted at very high temperatures at around 45 deg C.

[2] There is a more recent version of AERMOD Version 12345 (year 2012, day 345) or released on 12 October 2012. This is the

engines comprise six 600 kW MWM TBG616 reciprocating gas engines. As data was not available for these engines, the exhaust parameters were scaled off a 900 kW caterpillar engine. Emission rates of NO_X were derived from the average annual value in the NPI of 1.6 g/s with the emissions split between two units.

Table 2-4 Summary of Emission Parameters for Nearby Sources

Source	Easting (m)	Northing (m)	Release Height (m)	Exit Temp (deg C)	Internal Diameter (m)	Exit Velocity (m/s)	NO_X (g/s)	CO (g/s)	SO_2 (g/s)	PM (g/s)
Macedon Project										
Sales Gas 1 (Taurus 70) Pollutant Emissions for 2 GTs	291,090	7,595,440	15	498	1.88	20	2	3.4	0	0.2
Wet Gas 1 (Mars 100) Pollutant Emissions for 2 GTs	291,165	7,595,446	20.8	498	2.34	20	2.96	5.03	0	0.3
Power Gen GT (Saturn 20) Pollutant emissions for 3 GTs	291,199	7,595,470	15	445	0.95	20	2.52	4.28	0	0.25
Onslow Power Station										
Unit 1	303,300	7,603,800	8	450	0.32	25	0.78	0.50	0.0007	0.00007
Unit 2	303,300	7,603,830	8	450	0.32	25	0.78	0.50	0.0007	0.00007

Note: Emission parameters for the Macedon GTs given for a single GT, though the pollutant emissions are for the total of either two or three sale gas, wet gas or power generation GTs.

It is understood that there are plans to construct a new 9 MW power station at Onslow (WAPC, 2011). Details of this are not available as yet.

2.2.4 Condensate Ship-loading Emissions

During loading of the third party condensate carriers with condensate, the VOC-rich vapour within the ship's hold is displaced and is released to air through a mast riser situated at least 6 m above the ship's deck or by a pressure release valve that ensures an exit velocity of at least 30 m/s. Estimates of the VOC emission rates and their frequency for the Wheatstone Foundation Project are summarised in **Table 2-5** along with estimates from other condensate loading operations as provided in Air Assessments (2012).

Table 2-5 Estimates of VOC Emissions from Condensate Ship Loading

Parameter	Units	Gorgon	Wheatstone 2 Train	WA Oil BWI Operations	Karratha Gas Plant	Pluto 2 Trains
LNG Production	(Mtpa)	20	8.9	Oil	16.3	11.9
Frequency of Operations	Frequency	One every 14 days	1 per month	Eight per year	Once every 5.6 days	Once every 24 days
Modelled Frequency per month		2	1	1	6	2
Loading Rate	(m^3/hr)	5000	5768	2000	-	-
Time of loading	(hours)	25	13	20	-	-
NMVOC	(g/s)	1200	532	77	300	300
Benzene	(g/s)	26.6	1.43	1.6	2.4	2.4
Toluene	(g/s)	18.2	2.49	1.0	3.2	3.2
Xylenes	(g/s)	6.6	1.03	0.3	0.44	0.44
Ethyl benzene	(g/s)	0.8	0.21	0.04	Negl	Negl

Notes:

1) Wheatstone emissions are based on 12 ships of 75,000m^3 capacity per year for the Foundation Project. Total ship loading time of 13 hours at a loading rate of 5,769 m^3/hr. Emissions calculations are based on equation provided in U.S. EPA "AP-42, Fifth Edition, Volume I, Chapter 5.

2) Other source emissions from Air Assessments (2012).

Shipping combustion emissions for the Wheatstone Foundation Project were estimated based on the following:

- Ship and Tugs. LNG ships were estimated at 3 per week, which was scaled from the 7 estimated for the 25 Mtpa facility (Chevron, 2010). The number of condensate ship per month were estimated at one based on the 3 per month provided for the 25 Mtpa plant in Chevron (2010);
- Both condensate and LNG ships were assumed at berth for 24-hours, though ship loading times would be less than this;
- Time in the shipping channel was based on an average speed of 10 knots (accounting for slow down near berth;
- Tug operations were based on two tugs accompanying the ships to half way along the shipping channel at the above speed. Four tugs were assumed in berthing which was assumed to take half an hour; and
- Ship and tug emissions were as per Air Assessments (2012) for the Gorgon Project.

2.2.5 Other Regional Industrial Sources in 2013

A summary of existing and approved industrial emissions in the region is summarised in Table 2-6. This has been developed from the list in Air Assessments (2012), but updated with recent projects.

Table 2-6 Summary of Major Anthropogenic Sources (g/s) of Atmospheric Emissions in the Modelling Region for Future when the Wheatstone Foundation Project is Operating

Source Group / Source	Reference	NO_X	CO	SO_2	PM	Benzene	Xylenes	Toluene
Existing								
Karratha Gas Plant	SKM (2006) and AA (2012)	412	147	23.4	21.4	6.3	4.3	9.4
Burrup Fertilisers	AA (2012)	8	20	0.4	0.3	0.0	0.0	0.0
Yurralyi Maya PS	SKM (2008a)	30	18	1.3	1.4	0.0	0.0	0.1
West Pilbara PS – Karratha	PAE (2008)	10	6	0.4	0.7	0.0	0.0	0.0
Pluto LNG (only 1 train installed, modelled as 2 LNG Trains)	AA (2012)	89	138	9.7	3.4	0.42	0.02	0.02
Other small operations in Cape Lambert Dampier area	NPI	6	2	0.1	0.0	0.0	0.0	0.0
WA Oil - Barrow Island	AA (2012)	9	20	0.0	0.1	0.0	0.0	0.0
Other Over-water Sources	NPI	186	163	17.8	6.4	0.3	0.8	2.1
Other Overland Sources	NPI	961	370	9.0	39.8	2.4	2.4	2.1
Total	NPI	**1705**	**883**	**41**	**75**	**9.4**	**7.6**	**13.8**
Existing Other Sources Increased to 2020 Estimates								
Pilbara Towns	AA (2012)	84	462	12.0	7.4	2.5	8.1	9.2
Shipping - Ports and Channels	AA (2012)	177	20	94.7	16.9	0.9	0.2	0.2
Condensate Ship Loading	AA (2012)	0	0	0.0	0.0	2.5	0.6	2.2
Total		**261**	**483**	**97**	**24**	**5.9**	**8.8**	**11.3**
Future Industry								
Gorgon LNG (4 Train) 1 AGRU venting continuously	AA (2012)	177	74	0.1	9.5	25.5	19.2	60.5
Wheatstone LNG (2 Train)	This Study	57	102	1.7	4.4	0.08	0.13	0.11
Cape Lambert PS (New)	AA (2012)	15	2	0.0	0.4	0.0	0.0	0.0
Sino Iron Project PS (commissioning)	AA (2008)	38	46	2.2	0.0	0.0	0.0	0.1
Sino Iron Project approved Pellet Plants	AA (2008)	283	192	45.2	57.5	0.0	0.2	0.5
Balmoral South PS and Pellet Plants	AA (2008)	307	196	48.4	54.0	0.0	0.2	0.6
Devils Creek Gas Project	SKM (2008b)	5	2	11.0	0.0	0.0	0.0	0.0
Anketell Point PS	ENVIRON (2010)	30	21	3.5	0.0	0.0	0.0	0.0
Macedon Domestic Gas	This Study	7	13	0.0	0.0	0.0	0.0	0.0
Dampier Nitrogen	GHD (2010)	15	2	0.1	0.6	0.0	0.0	0.0
Burrup Nitrates - (TANPF)	BNPL (2010)	4	1	0.0	1.6	0.0	0.0	0.0
Sino Iron Project- Mine Vehicles	AA (2008)	40	17	1.0	2.3	0.1	0.1	0.1
Balmoral South - Mine Vehicles	AA (2008)	79	34	2.0	4.7	0.2	0.2	0.1
Cape Lambert Port B - Mine Vehicles	AA (2012)	3	1	0.0	0.2	0.0	0.0	0.0
Anketell Port – Vehicles	AA (2012)	3	1	0.0	0.2	0.0	0.0	0.0
Varanus including the Expansion	Apache (2012)	2	3.4	0.0	0.2	0.0	0.0	0.0
Future Total (g/s)		**1064**	**721**	**115**	**137**	**26.2**	**20.2**	**62**
Total from All Source Groups (g/s)		**3,030**	**2,086**	**253**	**237**	**41**	**37**	**87**
Total from all source groups incl. Wheatstone Foundation Project (tpa)		**95,542**	**65,791**	**7,978**	**7,459**	**1,302**	**1,155**	**2,759**
Wheatstone Foundation Project contribution to Total (%)		**1.9**	**4.9**	**0.7**	**1.9**	**0.2**	**0.4**	**0.13**

Notes:

1) NPI refers to data obtained from the NPI website.
2) PM refers to combustion particulate only and neglects particulate from crustal sources.
3) Condensate ship-loading includes that from Karratha Gas Plant, Gorgon, Wheatstone, and Pluto LNG plants and also includes WA Oil BWI Operations. Therefore the plant emissions for these facilities exclude this.

The emissions in **Table 2-6** have been obtained from the referenced sources in the second column, with the following specific comments made for major sources:

- Karratha Gas Plant with 5 LNG trains. The emission parameters were based on the emission estimates provided in the 2006 Pluto modelling assessment (SKM, 2006). Emissions of CO, PM and VOC species such as formaldehyde that were not provided were filled in based on NPI emission factors for gas turbines and flares. BTEX emissions from the AGRUs were based on the NPI emission estimates for 2009/2010 and added to the KT1430 vent emissions based on the percentage of Rsmog values from these sources in SKM (2006). The SO_2 emissions in SKM (2006) were reduced by a factor of 5 to be consistent with the latest NPI figures as it is understood that the earlier SO_2 emissions were overstated. Emissions from fugitive sources (primarily seals) were taken from the NPI reporting for fugitive (non point sources) and assigned a near surface source as per SKM (2006). The resultant emissions were compared to the latest reported NPI emissions and found to be consistent;
- Pluto LNG Project. Emissions were as per (SKM, 2006) with CO and VOC that were not provided filled in based on NPI emission factors for gas turbines and flares. A two train development was modelled, though only one train has been built to date;
- Dampier Power Station. This has closed and is replaced by the Yurallayi Maya power station. Therefore it has not been included in the future modelling;
- Old Cape Lambert power station. The old gas fired boiler power station at Cape Lambert with three 35 MW boilers was not modelled as this has now closed, being replaced by a new combined cycle power station;
- New Cape Lambert Power Station. This consists of two 40 to 45 MW GE LM6000 PF Sprint GTs with dry low emissions that can run in combined cycle mode (PAE, 2011). Emissions were sourced from the modelling assessment;
- Yurallayi Maya Power station, near the Dampier Salt facilities, with four open cycle 46 MW LM6000 gas turbines constructed with another two units approved. For modelling, the six units with total power generation of 276 MW was modelled;
- West Pilbara Power Station (Atco Power) with two 46 MW open cycle gas turbines near the Karratha light industrial area;
- Varanus Island. Emission estimates for the present facilities were derived from the NPI estimates. Data for the new, approved upgrade, including two Solar Mars 100 gas turbine compressor units and one centaur 40 gas turbine powered generator unit (Apache 2012) were not available and were therefore derived from the equipment specifications for these units;
- Thevenard Island. This is to be closed in 2014 and therefore has been omitted from the future case modelling;
- Regional Power Karratha. This consists of one 20 MW GE TM2500 open cycle turbine that can operate on either gas or diesel. This is a small emission source that is intended for only 5 years and therefore has been omitted;
- Anketell Port was modelled as the worst case presented in the impact assessment, with 6 gas units and one diesel unit operating. Note in Air Assessments (2012) this was incorrectly modelled with 6 gas units and 4 diesel units which is the emergency case;

- Proposed Sino Iron Project (stage 1) and Balmoral South operations with Pellet Plants and power stations. Note that stages 3, 4 and 5 with further mines and further Pellet Plants have not been included in this modelling as the Pellet plants with total production of 28 Mtpa of pellets are considered very unlikely to proceed; and
- Onslow town for the future was assumed a population of 2,200 with town and support emissions scaled to this from the estimates for Karratha (see Air Assessments, 2012).

Comparison of the total regional anthropogenic emissions in **Table 2-6** indicate total future emissions of 3,030 g/s of NO_X and 253 g/s of SO_2 with the Wheatstone Foundation Project comprising between 0.2 to 5% of the Pilbara emissions.

3 Impact Assessment Criteria

3.1 Ambient Air Quality Criteria

For assessing ambient ground level concentrations, the WA EPA does not have state-wide standards, but are in the process of implementing a Statewide Environmental Policy (SEP) with a draft policy released for public comment in June 2009 (EPA, 2009a). The policy objective is to meet environmental quality criteria with these being the:

- Approved National Environmental Protection Measure (NEPM) standards; and
- Standards or guidelines for Local Pollutants that are not part of an approved air related NEPM and are published as guidelines by the Chief Executive Officer of the Department of Environment and Conservation. At present there are no Local Pollutants defined.

These criteria are to apply to the whole of Western Australia, excepting for the following:

- Where an Ambient Air SEP pollutant is covered by an Environmental Protection Policy (EPP). There are currently two existing EPPs; the Kwinana EPP which cover SO_2 and total suspended particulate and the Goldfields Residential Areas EPP which covers SO_2;
- Within the boundary of industrial premises;
- Within defined industrial buffer areas. These are to be recognised resident-free buffer area which are secured by the planning system. Examples of residence free buffers are the Kemerton, Oakajee and Boodarie Resource Processing estates;
- Within the boundary of a road; and
- In an area where there are no sensitive receptors as determined by the Chief Executive Officer of the Department Environment and Conservation (EPA, 2009a).

> *If an industrial premises exists in a remote area where there is a reasonable likelihood that no sensitive receptors will be present, other than on a temporary basis, it may be determined that there is no need for the environmental quality criteria to be achieved at the premises boundary. There is an expectation however, that the environmental quality criteria will be achieved at the nearest sensitive receptor.*
>
> *It is important to remember the term 'sensitive receptor' extends beyond a location where humans are likely to reside and includes areas of cultural or environmental significance, including environmentally sensitive areas declared under the act.*
>
> *It is also expected that industry adopt and achieve best practice management of its operation and emissions control, which may require emission limits to be set and monitoring at the source.*

The NEPM standards are listed in **Table 3-1**and **Table 3-2** these being for:

- Ambient Air Quality NEPM Standards (1998) covering 6 criteria pollutants with the goal to achieve these standards by 8 July 2008;

- Ambient Air Quality NEPM Advisory Reporting standard (2005) for $PM_{2.5}$ with a goal to gather sufficient data nationally to facilitate a review; and
- Air Toxics NEPM (2004) with a goal to gather sufficient data nationally to facilitate development of standards for air toxics.

For gaseous pollutants these criteria are given in parts per million (ppm) or parts per billion (ppb) as the in this form the concentrations are invariant with temperature and pressure. **Table 3-1** and **Table 3-2** also provide these in terms of mass per volume of air. These have been converted as per the NSW guidelines for the criteria pollutants at standard conditions of 0 deg C and 101.3 kPa and for the air toxics at 25 deg C and 101.3 kPa.

Table 3-1 National Environmental Protection Measure - Air Quality Standards and Goals

Pollutant	Averaging Period	Maximum Concentration (ppm)	Maximum Concentration ($\mu g/m^3$)	Goal
				Maximum allowable exceedances within 10 years
Carbon Monoxide	8-hour	9.0	*11,240*	1 day a year
Nitrogen Dioxide	1-hour 1-year	0.12 0.03	*246* *62*	1 day a year None
Photochemical Oxidants (as ozone)	1-hour 4-hours	0.10 0.08	*214* *171*	1 day a year 1 day a year
Sulphur Dioxide	1-hour 1-day 1-year	0.20 0.08 0.02	*570* *228* *60*	1 day a year 1 day a year None
Lead	1-year	-	0.5	None
Particles as PM_{10}	1-day	-	50	5 days a year
Advisory Reporting Standards and Goal				
Particles as $PM_{2.5}$	1-day 1-year	- -	25 $\mu g/m^3$ 8 $\mu g/m^3$	Goal is to gather sufficient data nationally to facilitate a review of the advisory Reporting standard as part of the review of this Measure scheduled to commence in 2005

Note: Concentrations of gaseous pollutants in italics have been converted from the NEPM standard quoted at 0 deg C and 101.3kPa as per the NSW Guidelines (DEC NSW, 2005).

Table 3-2 National Environmental Protection Measure (Air Toxic) Monitoring Investigation Levels

Pollutant	Averaging Period	Monitoring Investigation Level (ppb)	Equivalent Concentration at 101.3 kPa and 25 deg C ($\mu g/m^3$)
Benzene	Annual Average	3 ppb	9.6
Benzo (a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons	Annual Average	0.3 ng/m^3	NA
Formaldehyde	24 hours	40 ppb	49
Toluene	24 hours Annual Average	1000 ppb 100 ppb	3,770 377
Xylenes (as total of ortho, meta and para isomers)	24 hours Annual Average	250 ppb 200 ppb	1,085 868

Note: The 8-year goal (date 2012) of the air toxics NEPM is to gather sufficient data nationally to facilitate development of a standard.

In modelling assessments the DEC requires that the NEPM criteria be compared to the predicted maximum for that averaging period. That is, the predicted maximum 1-hour ozone level is to be compared to the standard and not the predicted 2nd highest hour. The DEC modelling guidance (DoE, 2006) also requires that modelling be presented for existing concentrations, the proposed facility alone and cumulative (existing and proposed facility).

Of the above standards and investigation levels it is noted that for benzene lower international standards have subsequently been introduced, with the new European Union regulation (commenced 1st January 2010) specifying an annual mean of 5 µg/m³. This is being adopted for England from 31st December 2010 whilst a lower value of 3.25 µg/m³ is to apply for Scotland, Northern Island and Wales based also on a stricter rolling annual average (DEFRA, 2007). This value of 3.25 µg/m³ (approximately 1ppb) is about 3 times lower than the Air Toxic NEPM investigation level. For this study the new European Union value or English value of 5 µg/m³ has been adopted.

For the other NEPM air toxics pollutants, some assessments have used other Australian guidelines to determine the acceptability of impacts. For example the Pluto LNG and Gorgon assessment used the NSW Guidelines (Victoria Govt Gazette 2001, DEC NSW, 2005) for toluene, ethyl benzene and xylenes. It is however considered that these may be overly conservative as based on health criteria which have been converted by the application of large, uncertainty correction factors. For example the NSW benzene guideline (9th highest 1-hour level of 29 µg/m³) is significantly below the acute reference exposure level of 1300 µg/m³ for 6-hours derived by the Californian Office of Environmental Health Hazard Assessments (OEHHA). This Californian acute value is based on the no observed effect level for reproductive/developmental toxicity in rats and reduced for application for humans using an uncertainty factor of 100. The Californian acute criteria has been used in many studies within Australia (instead of the NSW guidelines) including the Worsley Alumina refinery expansion (Toxikos, 2005) and Manjimup biomass power station assessment (Toxikos, 2008). As such, it is considered more appropriate for toluene, xylenes and formaldehyde to use the NEPM air toxics investigation levels as they have been more rigorously derived. These were also used in the 2010 Wheatstone assessment approved by the EPA.

For hydrogen sulphide the criteria recommended for the Browse LNG by the WA EPA has been adopted as reflective of the DECs current position. The EPA report recommended with regards to future Browse Precinct odour assessments (EPA, 2012, page 145). This is for a

> *1 hour average 99.9th percentile concentration limit of 1.6 ou (C99.9,1hr=1.6 ou) at sensitive receptors such as the accommodation zone.*

The above criterion is understood to be based on a proposed new DEC odour criteria, which has not been formally released to the public for review and comment. This criterion of 1.6 ou is understood to apply only for elevated stack sources based on a 8.0 ou criterion for a surface area or significantly wake affected emission of 1-hour average 8.0 ou, 99.9th percentile, by dividing the odour concentration by a factor of 5. The factor of 5 is based on the ratio of the tall stack to area (or wake affected) source criteria used in the Queensland odour regulations (Queensland Govt, 2009).

For hydrogen sulphide the DEC and EPA recommended a hydrogen sulphide odour detection threshold of 0.5 ppb that was based primarily on a study by McGinley and McGinley (2010).[2] Therefore a hydrogen sulphide odour criterion would be 1 hour average 99.9th percentile 0.8 ppb. As 1 ppb H_2S is equal to 1.39 µg/m^3 (at 25 deg C and 101.3 kPa), in mass per volume the criteria is equal to 1.11 µg/m^3 of H_2S at 25 degrees C.

4 Atmospheric Dispersion Modelling

4.1 Introduction

This section provides a summary of the important atmospheric dispersion processes that need to be modelled and the rationale for selection of the models and the model set ups.

4.2 Sources to be Modelled

The major sources and pollutants from the Wheatstone Foundation Project (see **Section 2.2.1**) are:

- Compressor gas turbines with stack heights of 50 m emitting buoyant plumes that will typically rise 75 to 250 m above ground level, with the emission of most concern being NO_X;
- The Thermal Oxidizers with buoyant plumes that will rise typically to 75 to 250 m with NO_X and BTEX and SO_2;
- Stack flares with very variable emissions with pollutants of concern being NO_X, PM and VOCs. For the large flaring events, the very large amount of heat released will result in a very buoyant plume that will rise hundreds to a thousand metres above ground level;
- Ships engine emissions. These are less buoyant and under stronger winds will be subject to plume downwash due to the airflow around the superstructure of the ships. Emissions from ships at berth and in the shipping channel near the island have been considered; and
- Vapour emissions from ship loading. This occurs when the VOC rich air in the headspace in the tankers holds is displaced during ship-loading. This vapour is heavier than air and will have a tendency to descend to ground level under light winds.

Besides the Wheatstone sources, other sources including the Macedon Project and Onslow Power station sources which have smaller buoyant point sources also need to be included.

4.3 Important Dispersion Processes to be Modelled

The relevant dispersion processes are dependent on the type of source, the topography, land use variations and general wind patterns. For the sources considered above in a coastal environment in a sub-tropical region, the following meteorology and dispersion processes are important:

Plume Rise above the Stable Boundary Layer

Generally the buoyant plumes such as from the gas turbines will penetrate any low inversion and remain above the inversion. As such, at night when there are low winds, the ground level concentrations should be negligible.

Morning Fumigation

This occurs in the morning when the morning mixed layer grows to the plume height and the plumes can be mixed rapidly to the ground. In modelling by Hurley et al (2003) for the Karratha Gas Plant, this phenomenon was considered to lead to the highest concentrations for distances greater than 5 to 10 km from the sources.

Onshore Winds and the Thermal Internal Boundary Layer

For onshore winds the temperature of the sea is often cooler than on the land during the day. In such cases, the onshore flow is relatively stable and plumes emitted into this air flow will disperse relatively slowly. When this air passes over the hotter land surface a growing region of thermal dispersion occurs (termed the Thermal Internal Boundary Layer, TIBL). The TIBL is important for dispersion near the coast and for tall stacks and/or very buoyant plumes as it can lead to fumigation of the plume to the ground at distances of several to ten kilometres downwind, leading to higher concentrations than would otherwise occur (see **Figure 4-1**).

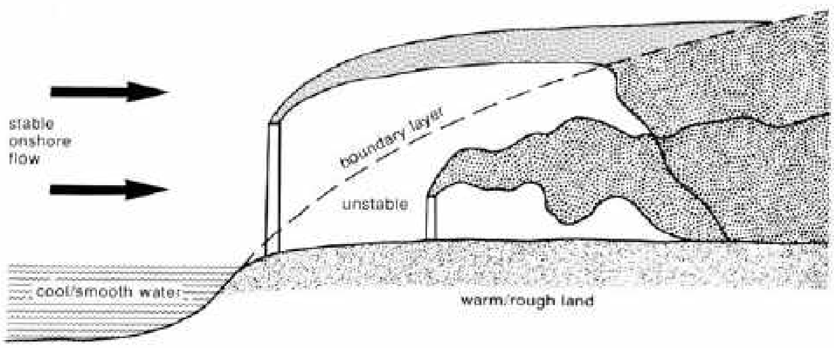

Figure 4-1 The fumigation process due to the presence of a thermal internal boundary layer (from DCE, 1982). Note the plume from the tall stack on the coast is undergoing fumigation, whilst the shorter stack inland is just trapped.

Alternatively for short stacks and less buoyant plumes, the plumes will stay below the TIBL, with the TIBL acting to restrict the vertical dispersion of plumes therefore acting to increase somewhat the ground level concentrations further down wind. For the sources here, 2 to 3 km from the coast, with generally short stacks (excepting the stack flares which are 3 km from the coast), the plumes will tend to be trapped within the TIBL as per the smaller stack to the right in **Figure 4-1**.

Plume Merging with Nearby Plumes

Plumes that are sufficiently close together may, in the process of rising, start to merge, resulting in an overall greater plume rise for each plume than would otherwise occur. This process is especially important when there are many, closely spaced plumes such as at power stations.

Plume Downwash due to Nearby Structures

Downwash occurs when plumes are mixed by the turbulent eddies that develop when air flows over and around buildings. This process will lead to plume being mixed to the ground more quickly and closer to the stack, resulting in higher ground level concentrations. This is especially important for the emissions from the ships with stacks just above their superstructures.

Modelling Heavier than Air Releases

The vapour emissions displaced from the ships hold when loading condensate are heavier than air due to the high molecular weight of the vapours. They will therefore have a tendency to descend hence the initial plume path and dispersion cannot be modelled by normal regulatory air pollution models.

Convective Dispersion

During the day time, the heated earth's surface will generate convective cells of rising and descending air which can bring any plume to the ground within several hundred metres of the source.

Terrain Effects on Airflow

The topography in the local modelling domain is reasonably flat with no rises above 20 m within 10 km. Therefore topography affects will have minimal impact on dispersion for the sources to be modelled.

Modelling Photochemistry

Of the pollutants emitted, NO_X will react with VOCs in the presence of sunlight and create ozone and other secondary pollutants. Therefore, given the significant emissions of NO_X in the region, modelling of chemical transformation is required. As maximum ozone concentrations occur two to five hours after release, the modelling must be on a regional basis and not just for the local area. With the location of the Wheatstone LNG plant 210 km SW of the Burrup Peninsula, it is considered that the Wheatstone Foundation Project may contribute to an increase in existing pollutant levels there. As there have been concerns raised regarding potential air pollution impacts on the Burrup Peninsula, it is considered that modelling should predict this Project's contribution at the Burrup. Therefore predicting the winds, wind fields and pollutant transport in the larger Pilbara region is important.

Inclusion of Existing Concentrations – Cumulative Assessment

Where there are significant background levels or other nearby significant sources, a cumulative impact assessment is required. If predicting crustal particulates, as in the case of mining studies, the background particulate concentrations are simply added to the predicted particulate levels. For pollutants such as NO_X, ozone and CO however, the resultant concentrations depend on chemical reactions of the emissions with the background concentrations in a complex manner. Therefore, cumulative predictions for these pollutants require models that predict the chemical reactions.

4.4 Previous Modelling for the Wheatstone LNG Project

Modelling for the Draft Environmental Impact Statement (SKM, 2010) was conducted using TAPM for the local modelling and TAPM with the generic reaction set (GRS) mechanism for the photochemical modelling.

For the local modelling, TAPM was selected for it's ability to model convective dispersion, the affect of TIBLs and the influence of buildings and structures. For modelling regional ozone, TAPM with the GRS scheme was used as had been used for a number of LNG plant assessments from the 2000 onwards in the Pilbara. In a review of this modelling (see **Appendix A**), a number of minor concerns were raised with local modelling, as well as a number of other limitations including the derivation of Rsmog which is an important component of smog formation and the section of other model options found. These are detailed more fully in **Appendix A** with it now being considered that the use of the

GRS scheme, the simplifications it uses and the need to include emissions from fires precludes its use for more accurate assessments.

4.5 Models Selected for this Study – AERMOD, TAPM and TAPM-CTM

For the important processes described in **Section 4.3** and the sources and pollutants to be modelled in this study (NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$, BTEX and ozone), the models AERMOD and TAPM-CTM have been selected.

4.5.1 Local Modelling - AERMOD

For the range of dispersion processes to be modelled in **Section 4.3**, the model AERMOD has been selected for modelling all local modelling scenarios, except the condensate loading scenario. Other possible models considered were TAPM, ADMS, CALPUFF and AUSPLUME. Of these:

- AUSPLUME was discounted as it can not model convective processes for stacks less than 100 m tall;
- CALPUFF does not have regulatory approval for near field modelling (except on a case by case basis for complex meteorology) and there are concerns with predictions from taller stacks (see Rayner, 2009);
- ADMS the UK regulatory model does model all the dispersion processes, but to our knowledge has not been used for a public assessment in Australia and the regulators have little or no experience with this model;
- TAPM as used in the last assessment has for the latest versions shown issues with significant over-prediction on occasions from taller stacks as shown by Rayner (2011). There were also a number of technical issues raised in terms of;
    - The change-over from Lagrangian to Eulerian dispersion,
    - Under-predicts the wind speed for stronger winds at the surface, though it models well the winds higher up (above 50 m); and
    - For short releases, TAPM over-predicts concentrations as shown by Luhar (2011). This occurs as TAPM estimates the ground level concentration as the average over the lowest 17.5 m. If a plume centreline is less than this it may be incorrectly assumed to be mixed to ground near to the source for night time stable conditions.

  The advantages of this model however, is that it does model the full range of dispersion processes (except heavier than air releases).

Therefore AERMOD, the US EPA near field or local dispersion model, has been used. This can model all the dispersion processes except, it does not have an explicit treatment for the effect of the TIBL and is not appropriate to model the heavier than air emissions and dispersion over water of the VOC emissions from ship loading condensate. For the affect of the TIBL as described in **Section 4.3**, the plumes to be trapped. To account for this trapping, the mixing heights have been modified within the meteorological files as described in **Section 4.6.1**.

4.5.2 Local Modelling – VOC Emissions from Condensate Ship Loading - TAPM

For modelling the vapours emitted during ship loading, the important processes to be modelled are the heavier than air releases, dispersion induced by the ship structure and over water dispersion. For modelling this special case, the model TAPM has been used as it can model the latter two effects, with it considered that the induced turbulence from the ship structures for most wind conditions will dominate over the slight plume slumping effects. TAPM importantly has also been used to model the same condensate tanker filling operations at another LNG facility and found to predict reasonably well the 1-hour and annual average concentrations 1 to 6 km downwind.

4.5.3 Regional Modelling – TAPM-CTM

For regional modelling, TAPM-CTM was selected. TAPM-CTM utilises the meteorology predicted by TAPM but instead of the normal dispersion options available within TAPM, TAPM-CTM predicts the dispersion and photochemistry using the Chemical Transport Model.

TAPM-CTM has been used as:

- TAPM can generate the regional wind fields required for CTM. Other alternatives are to use another prognostic model or use a diagnostic model. A diagnostic method was not considered due to lack of upper air data in the region;
- CTM was selected as it has one of the best photochemistry schemes available. CTM uses the Carbon Bond 2005 (CB05) reaction mechanism which is a state of the art chemical transformation mechanism which has recently been released by the US EPA (Yarwood et al, 2005). In the modelling here, 62 gaseous and 28 aerosol species were modelled. Organic species are lumped according to their carbon-carbon bonding type. Organic species treated in CB05 include alkanes, ethene, terminal and internal-bonded alkenes, toluene, xylene, formaldehyde, higher aldehydes, isoprene and terpenes.
- TAPM-CTM does not require the estimation of Rsmog as in GRS which is highly uncertain;
- TAPM-CTM has been shown to provide very good agreement for modelling Pilbara sources (Pitts et al, 2011) where it was shown to be superior to TAPM with the GRS scheme. The validation study found very good agreement with the observations at Karratha and Dampier with the comparison of ozone concentrations at Dampier in 1999 presented in **Figure 4-2**.

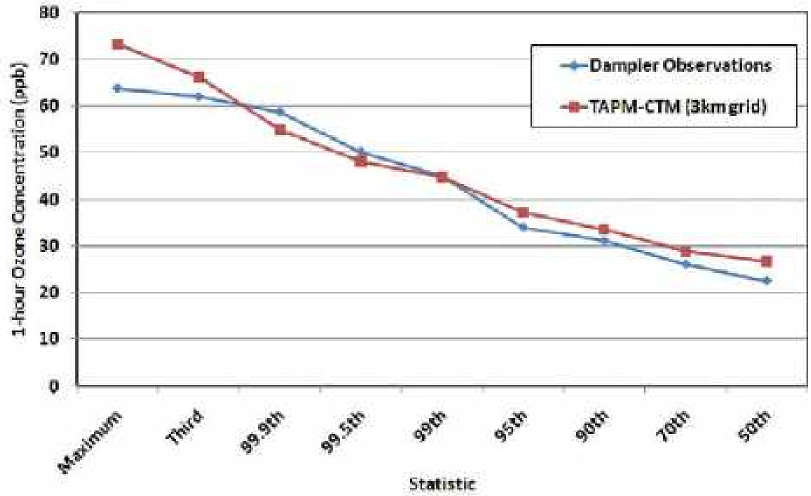

Figure 4-2 Observed and predicted ozone concentrations at Dampier North for 1999 (from Pitts *et al*, 2011)

- TAPM-CTM can include the emissions from fires as developed by CSIRO and therefore allow a true cumulative assessment to be conducted; and
- It has been successfully used to model other LNG developments such as the Browse and Gorgon projects (Air Assessment, 2010b and 2012).

4.6 Models Setup

4.6.1 AERMOD setup – Local Modelling

To model local pollution, AERMOD (version 11353)[2] was used with the following:

- A meteorological file developed from Wheatstone meteorological measurements for 2010 (see **Section 5.2**);
- Inclusion of terrain, though essentially for modelling purposes the terrain is flat;
- No building down wash affects for modelling the LNG and Domgas sources. No solid structures were identified as significant for inclusion in modelling the LNG and Domgas sources based on the data supplied by Chevron. The top of the fin fan coolers (top of the LNG train is 24.5 m) with the stacks along the LNG train at 50 m high. According to modelling guidance "rules of thumb", downwash should be considered when nearby structures are more than 40% of the stack height, which is just the case here. However the LNG trains, particularly near the top of the train structures are reasonably open, allowing air to pass through it and are not solid bodies upon which the empirical down wash formula within the PRIME algorithms used within AERMOD were based.

  Additionally, the PRIME algorithms are not considered appropriate when the building width and widths to height ratios are > 3 to 4.4 (see Petersen, 2008 and Schulman and Scire, 2012) as for the LNG train structures as they can provide quite incorrect predictions. Incorporation of circular tanks is also very problematic as the air tends to flow around these under stable conditions, and they do not have the sharp corners that cause the flow separation as per cubes, especially tanks with domes. Therefore at LNG plants there are significant limitations in applying PRIME building down wash algorithms as many of the structures are outside the applicable range of the PRIME formulation. For example in model validation studies at the KGP, modelling using PRIME and the actual dimensions of the LNG trains (assuming a solid building), with length to heights of around 10 predicts very high concentrations, much higher than the observed concentrations. Hurley et al (2003) in their evaluation instead found that building downwash was not important and could be excluded for the above reasons when predicting offsite concentrations.

  Further, there is another confounding issue in modelling in that the hot air from the fin fan coolers results in a large area of rising air, with cooler air being pulled into the area. This is not

[2] There is a more recent version of AERMOD Version 12345 (year 2012, day 345) or released on 12 October 2012. This is the current version and includes changes to distinguish between vector or scalar wind speeds and non regulatory options for the treatment of dispersion under very low wind speeds. Model runs for NO_2 (the pollutant closest to their respective criteria), indicates negligible change (<0.2%) to the predicted concentrations.

accounted for in simple dispersion models such as AERMOD or TAPM, with computational fluid dynamic modelling needed to resolve the complex interactions. Such assessments have been conducted for the Gorgon and Browse LNG projects where this plume rise has resulted in plume merging between the GT driver exhausts and the fin fan cooler air.

Therefore, it is considered that there are many difficulties in applying the simplistic PRIME algorithms to LNG structures, with the available validation studies indicating that even for the KGP with shorter stacks, building downwash is not significant.

Though not included for the LNG and Domgas plant, building affects were included for the combustion emissions from ships and VOC emissions from ship loading, with typical ship dimensions included;

- Model pollution grids of:
  - A 500 m covering an area of 20 by 17 km; and
  - A finer grid for the area around the Wheatstone and Macedon of 250 m over a 5 by 8.75 km grid to better resolve the maximum impacts close in.
- Modification for the effect of the TIBL. As the ocean is only 2 to 3 km distant to the north and 6 km distant to the west, the assumption that AERMET (the meteorological pre-processor to AERMOD) uses of negligible warm or cold advection does not hold. That is, the boundary layer cannot be assumed to grow continuously from an initial profile in the morning, with the mixing extending throughout the day based on this morning profile. Instead the boundary layer is predominantly affected by the new incoming temperature profile at the coast and the growth of the TIBL. This results in the boundary layer typically only growing to several hundred metres throughout the day and not the several thousands of metres that would occur if the site was well inland. To account for this, the convective mixing heights and temperature gradient above this height was replaced with that predicted from TAPM at the point of most interest, the centre of the LNG facility. For the mechanical mixing height, the AERMET prediction was retained. For periods where the convective mixing height was changed, the convective velocity scale was recalculated.

  For hours where TAPM sometimes predicted a negative heat flux and therefore no convective mixing height was available, but AERMET predicted a positive heat flux, an adjustment was required. These events occurred at the start and end of daylight hours where the AERMET-estimated heat fluxes were typically very small, below 10 W/m^2. When this occurred for the first hour of daylight, the mixing height was set to 200 m which was typical of the predictions after it, whilst for the hour just prior to sunset it was set equal to the previous hour. The temperature lapse rate for these hours was set to 0.01 K/m - a typical value. This approximation should have negligible effect as these occurrences are for very weak heat flux and neutral conditions where the capping inversion should have no effect on plume dispersion.

4.6.2 TAPM-Ship loading Modelling setup – Case 5

For modelling the VOC emissions from condensate ship loading (case 5), the following set-up options within TAPM were used:

- Use of TAPM v4.05 with new surface schemes;
- Default options for turbulence and land use schemes for version 4;
- Modelling was undertaken for the year 2010 to be consistent with the local AERMOD modelling;
- Sea surface temperatures were obtained from the TAPM databases;
- 25 vertical levels;
- Four nested meteorological grids of sizes 30, 10, 3 and 1 km each of 35 by 35 grid points;
- Soils assigned to a silty clay loan (classification 14) with land use assigned to shrub-land low sparse (classification 14) to provide a low surface roughness;
- Deep soil moisture specified as 0.1 for the year;
- Two spin up days for each model run to allow the meteorological fields to stabilise;
- No data assimilation of surface observations to nudge the model predictions. Data assimilation is considered to lead to sharp wind shears in the vertical at night when the winds above the number of layers used to define surface layer return to that derived by TAPM; and
- Pollutant predicted on a 500 m grid over the model domain.

4.6.3 TAPM-CTM setup

The following set-up options within TAPM were used for the TAPM-CTM pollution modelling:

- Use of TAPM v4.04 (the version available within TAPM-CTM), with new surface schemes;
- Where possible, the model set ups as used in the model validation study of Pitts *et al* (2011), with the major exception being the grid size and domain, which was selected to better cover the area of interest;
- A larger meteorological grid with 22, 10 and 5 km with 68 by 49 grid points see **Figure 4-3**.

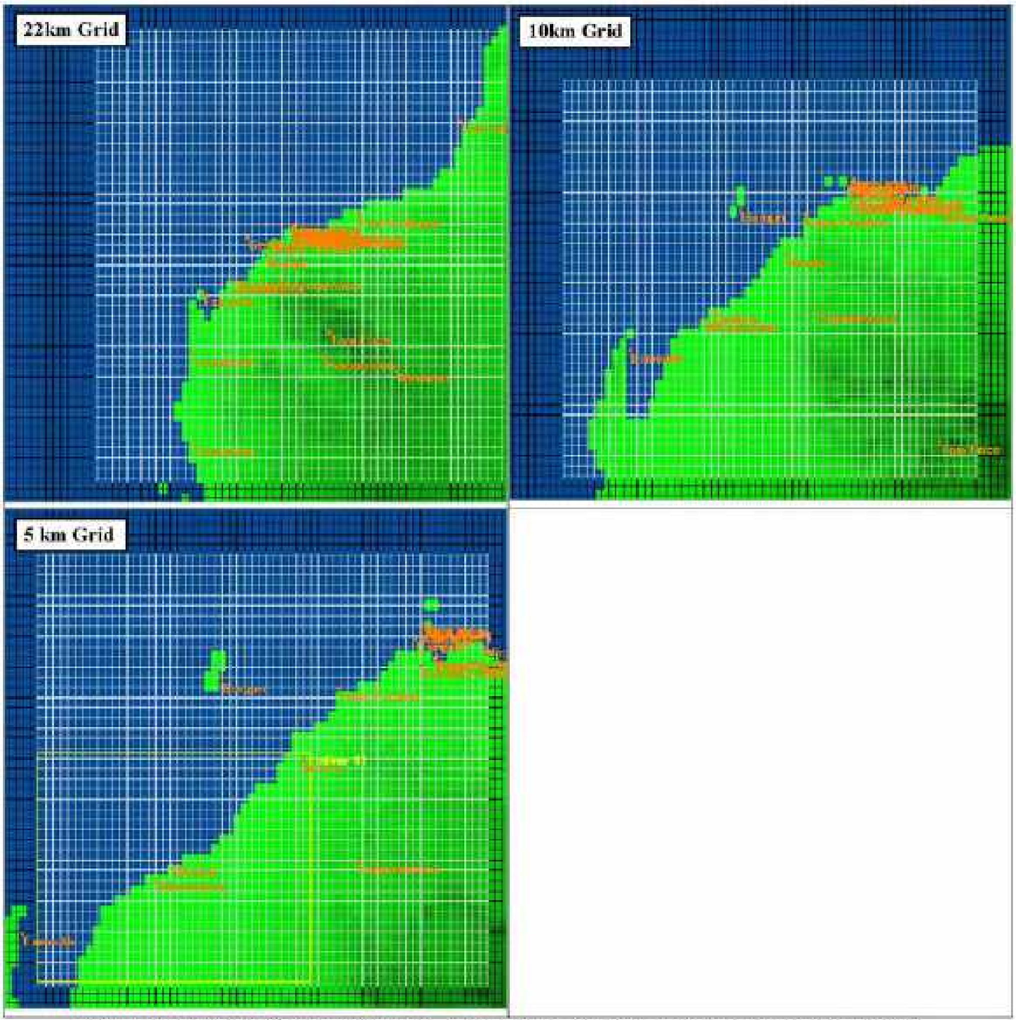

Figure 4-3 TAPM-CTM model grids. The black and white grids are the meteorological and pollution grids. The yellow box marks the extent of the inner 2.5 km pollution grid.

This size was selected such that the inner pollution grid of 2.5 km (marked as the yellow box), would cover the area needed to capture the region near Onslow, whilst the 5 km pollution grid would cover the area out to the Dampier/Karratha area and also out to Exmouth. The outer grid was set to encompass a large area of fire emissions and extended from the Dampier Peninsula near Broome to near Carnarvon. The pollution grid was selected to be also slightly in from the boundary of the meteorological grid boundary to minimise boundary effects on the pollution predictions;

- Default options for turbulence and land use schemes for version 4;
- Modelling was undertaken for the year 2009 to match the 2009 fire emission data base. At the time of modelling, no later annual fire databases after 2009 were available to allow a period that corresponded to the good quality wind measurements recorded at the site (see Table 5-1). In

terms of the representativeness of the fire emissions, 2009 is considered typical as shown by the area burnt for the Pilbara in Figure 4-4. There are years with significantly greater fire emissions, such as 2000 and 2006 which had resultant higher ozone levels (see Pitts *et al*, 2011).

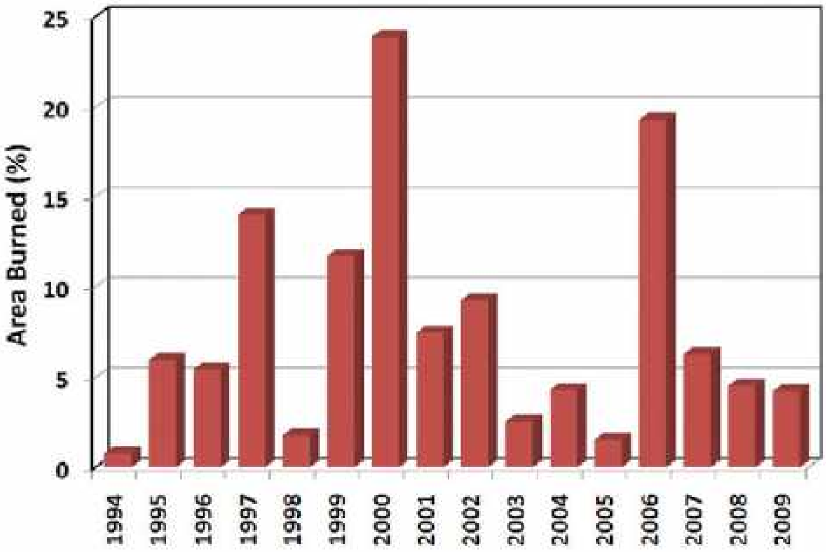

Figure 4-4 Land Area Burnt for the 1994 to 2009 (from Pitts *et al*, 2011)

Though different years are used in the local and regional modelling, this is not considered to affect the outcomes of the report as they are two stand alone modelling assessments;

- Sea surface temperatures were obtained from the TAPM databases;
- 25 vertical levels;
- Soils assigned to a silty clay loan (classification 14) with land use assigned to shrub-land low sparse (classification 14) to provide a low surface roughness;
- Two spin up days for each model run to allow the meteorological fields to stabilise;
- No data assimilation of surface observations to nudge the model predictions;
- All sources were modelled as point sources including ships;
- Emissions from fires were entered separately for each pollution grid. For the outer 22 km pollution grid, a 8 km emission grid was used. For the 10 km grid a 5 km emission file was used, whilst for the 5 and 2.5 km grids, emissions were resolved onto a 1 km grid. Setting the fire emission fire resolution to generally no more than half the grid size was done as a balance between adequately resolving the fire (not spreading it over too wide a region), but also limiting the number of fire sources that had to be modelled. If the same 1 km emission file was used for the large 25 km outer domain, a very large number of fire sources would be required;
- For modelling the pollution within TAPM-CTM, a Eulerian dispersion scheme is used;
- 12 vertical levels for modelling pollution;
- Use of the Carbon Bond 5 mechanism;

- Emissions from biogenic sources and soils and fires are as described in Air Assessments (2012); and
- Initial and Boundary VOC levels developed through a literature review of available measurements including those from the Burrup rock art study and background aerosol measurements for Australian sites (Galbally et al., 2009 and references therein; Gillett and Cope 2009, Cainey et al., 2007). All species except ozone were set constant for the year with lower initial conditions as summarised in **Table 4-1**.

Table 4-1 Initial and Boundary Concentrations used in TAPM-CTM Modelling

Substance	Average Concentration (ppb)	Substance	Average Concentration (ppb)
Gaseous Species			
Benzene	0.015	Ethane	0.03
NO	0.1	Olefins	0.02
NO_2	0.6	Toluene	0.02
CO	65	Xylenes	0.01
SO_2	0.1	MEK	0.001
Formaldehyde	0.3	PAN	0.0
Aldehyde	0.0	Methane	1700
Paraffins	0.6 (0.06 ≥450m)	NH_3	0.3
Particulate Species			
Elemental Carbon < 2.5 µm	0.1 (0.001 ≥800m)	Sea Salt < 2.5 µm	0.6 (0.3 ≥600m)
Elemental Carbon 2.5 to 10 µm	0.1 (0.001 ≥800m)	Sea Salt 2.5 to 10 µm	2.0 (1.0 ≥600m)
Organic Carbon < 2.5 µm	0.1 (0.001 ≥800m)	Miscellaneous PM < 2.5 µm	0.1
Organic Carbon 2.5 to 10 µm	0.1 (0.001 ≥800m)	Miscellaneous PM 2.5 to 10 µm	0.1

Boundary conditions of ozone were varied by month as the upwind ozone levels are considered to change more than the other parameters and as ozone is an important boundary condition. The monthly values are listed in **Table 4-2**. Low values from the west are specified as this is generally very clean air. High values from the east, especially in October to November occur with the large fires to the east at this time, with higher values to the south in May to August from burn-offs to the southwest.

Table 4-2 Initial and Boundary Ozone Concentrations used in TAPM-CTM Modelling

Month	North (ppb)	East (ppb)	South (ppb)	West (ppb)
January	20 (30)	22 (30)	20 (25)	17 (25)
February	20 (30)	22 (30)	20 (25)	17 (25)
March	20 (25)	20 (25)	18 (25)	15 (22)
April	20 (25)	20 (25)	18 (25)	15 (22)
May	20 (28)	22 (30)	22 (28)	17 (25)
June	20 (28)	23 (30)	23 (30)	17 (28)
July	20 (28)	23 (30)	23 (30)	17 (28)
August	20 (28)	23 (30)	23 (30)	17 (28)
September	20 (30)	22 (32)	20 (28)	17 (25)
October	20 (30)	22 (32)	20 (28)	17 (25)
November	20 (32)	22 (32)	20 (28)	17 (25)
December	20 (30)	22 (30)	20 (25)	17 (25)

Note: Values in brackets are the 4 top levels from 1 km to 3 km.

4.7 Plume Merging and Plume Rise Enhancement

Combined plume rise or plume rise enhancement is often used to account for the effect that nearby plumes will tend to merge and increase the overall plume rise of each individual plume. Plume rise enhancement was used in the model validations for the Karratha Gas Plant by Physick and Blockley (2001) who argued it was required to explain the observed concentrations, and also in the later model validation by Pitts *et al* (2011). These assessments used the method of Briggs (1974) (as generally used within Australia) that defines the effective number of stacks (*Ne*) as:

$$Ne = \left[\frac{n+S}{1+S}\right] \qquad \textbf{Equation 4.1}$$

where n is the physical number of stacks, and S is a dimensionless separation factor:

$$S = 6 \cdot \left[\frac{(n-1)\cdot \Delta s}{n^{1/3} \cdot \Delta z}\right]^{3/2} \qquad \textbf{Equation 4.2}$$

where Δs is the stack separation and Δz is the plume rise for an individual plume. The rise enhancement factor E_N is then:

$$E_N = Ne^{1/3} \qquad \textbf{Equation 4.3}$$

with the enhanced plume rise Δz_E

$$\Delta z_E = E_N \cdot \Delta z \qquad \textbf{Equation 4.4}$$

Assuming buoyancy is the dominant cause of plume rise a diameter enhancement factor can be derived as:

$$D_F = Ne^{1/2} \qquad \textbf{Equation 4.5}$$

For this study, the enhancement factors for the Wheatstone stacks that are considered to possibly merge have been calculated in **Table 4-3** using the average plume rise calculated from the model TAPM for the first 6 months of the year.

Table 4-3 Estimates of Plume Enhancement

Source	Number in Row Operating	Stack Separation (m)	Diameter (m)	Average Plume Rise[1] (m)	Ne	En	D_F	Equiv. Diam[2] (m)
Train Compressors (WHRU)	6	14	3.06	169	4.02	1.59	2.00	6.14
Train Compressors (Bypass)	6	14	3.6	56	2.14	1.29	1.46	5.27
GTG Turbine Driver	4	57	3.28	185	1.82	1.22	1.35	4.42

Notes:

1) Average plume rise derived from six months of TAPM modelling (January to June 2010).
2) For modelling, the equivalent diameter was used for those stacks that the plume enhancement was calculated, with the given exit temperature and velocity.

Besides plume merging from the LNG GTs, there is a large amount of hot air released from cooling fans such as on the top of the LNG trains. This has been shown using computational fluid mechanics modelling to merge with the plumes from gas turbines, particularly during lighter winds, but will require more verification work before it can be used in modelling.

4.8 Estimating the NO_2 Fraction within NO_X for Local Modelling

To estimate the proportion of NO_X in the form of NO_2 for the local modelling, the ozone limiting method (OLM) as incorporated in AERMOD was used. The NO_2/NO_X emission ratios used are summarised in **Table 4-4**.

Table 4-4 NO_2/NO_X Ratio used at Emission

Source	NO_2/NO_X Ratio	Reference
Gas Turbines with DLN Wheatstone and Macedon sales and GTs	0.2	From Air Assessments (2012)
Flares	0.1	Default assumption
Boilers and TOs	0.1	Default assumption
Reciprocating gas engines Onslow Power Station	0.2	From Air Assessments (2012) as based on data for gas engines on Barrow Island
Small Power GTs at Macedon without DLN	0.1	Default

Background ozone values used in the OLM were specified to vary by hour of day based on the 75th percentile value of measurements at Barrow Island, the nearest available monitor. The resultant hourly values ranged from 20 ppb at 1am to 31 ppb in the mid afternoon (2 to 4 pm). These values are similar to that measured at the DEC Dampier site from 1998 to 2001 with 75th percentiles ranging from 21 ppb at 7am to 29 ppb at 1 pm. Note the 75th percentile was used to add some conservatism. In modelling OLM groups were used within AERMOD, with separate OLM groups assigned for the three separate sites, Wheatstone, Macedon and Onslow PS.

4.9 Modelling Gaseous Emissions with High Molecular Weights

Emissions from the Thermal Oxidizers and condensate loading from ships have higher molecular weights than from normal combustion sources. Normal combustion sources have a similar molecular weight to that of ambient air and as such the molecular weight of the exhaust gas is neglected in the plume rise calculations of regulatory models such as AUSPLUME, AERMOD and TAPM.

To model the high molecular weight sources in this study, the following was undertaken:

- Thermal Oxidizers. As the TOs have high exit temperature, they were modelled conventionally within TAPM and TAPM-CTM, but with the temperature of release adjusted to a lower "apparent" temperature as shown in **Table 4-5**.

Table 4-5 Emissions Parameters for High Molecular Weight Releases

Source	Stack Tip Exit Temp (deg K)	Molecular Weight (g/mol)	Apparent Temp (deg k)	Apparent Temp (deg C)
Acid Gas TO	858	37.15	670	397
Domgas Acid Gas TO	1033	37.15	806	533
Condensate Loading Vent Riser	41	40	-45	Not Modelled

  The apparent temperature is the temperature that would result in the same buoyancy as the gas stream at its actual temperature after taking into account the higher molecular weight of the emission. The correction is made by multiplying the emission temperature in Kelvin by the ratio of the molecular weight of ambient air and exhaust air (approximated as 29g/mole) to that of the gas stream. The use of the apparent temperature will therefore decrease the buoyancy and momentum of the plume as regulatory models use the plume temperature in both calculations. In reality the momentum of the plume should increase with higher molecular weight and therefore the above approximation will understate the momentum plume rise. For the TO plumes, the buoyancy term is, however, the dominant term and the approximation is reasonable if slightly conservative;

- Ship-loading condensate emissions. This source due to the high molecular weight and low temperature will have some tendency to slump if released from the older style vent riser, though this may be minimised if released through the new style relief valve with exit velocity greater than 30 m/s. In either case, it is considered that for the moderate to stronger winds, the dispersion will be more influenced by the airflow distortion around the ships structure with it considered that the plume will generally be down-washed into the lee of the ship. As such though important, it is considered more important to account in the local modelling for the ship plume structure.

Therefore in the local TAPM modelling of BTEX, the plume release was approximated with a vent of height 17 m above sea level, diameter of 0.4 m, exit velocity of 7.1 m/s and temperature of 25 deg C, with inclusion of ships hold structure of height 15 m. These parameters were used in a previous model validation study using TAPM for condensate emissions and found to provide good agreement with down wind concentrations.

For the TAPM-CTM regional modelling, which does not model building effects, the sources was approximated as a release at vent height (approximately 17m) with no plume rise. For regional predictions where the plume is initially mixed within the 2.5 by 2.5 km Eulerian grid cell, this approximation is considered adequate.

4.10 Modelling the Non Routine Scenarios

In modelling the non routine scenarios (2, 3, 4 and 6), the emissions were modelled continuously for the entire year. This is a slightly conservative assumption for predicting short period maximums (1-hour and 24-hour concentrations), as with these scenarios only occurring for a low number of hours per year, it is unlikely that the emissions will occur for the worst case dispersive conditions. For modelling annual average concentrations this approach will be very conservative and therefore will overstate the predicted concentrations.

For the condensate loading scenario 5, the modelling has instead endeavoured to use more realistic estimates.

In the local modelling, the VOC emissions from condensate loading were modelled emitting continuously using TAPM. Annual average concentrations were then determined by multiplying the concentrations by the probability that these emissions would occur. In this case they were modelled as occurring once in 30 days and therefore multiplied by 0.033. This therefore provides a realistic estimate of the annual average concentrations, which are used for instance to evaluate the annual benzene concentrations. Maximum 24-hour concentrations, used for the less important xylene and toluene 24-hour predictions were determined by assuming the emissions were continuous for the whole year. Therefore the 24-hour predictions should provide an estimate of the worst case impacts as it is unlikely that the emissions will occur on the period with worst case dispersive conditions.

For the regional modelling, predictions of 1-hour and 4-hour ozone concentrations are of most importance. To provide likely worst case predictions, the Wheatstone condensate emissions were modelled continuously such that a prediction of the maximum concentrations that could occur if condensate loading occurred at the worst case dispersive hours was made. For the other condensate sources in **Table 2-5** the condensate loading VOC emissions were assumed to occur for a 24 hour period (midnight to midnight) at the frequency determined by the number of ships required per year. That is 2, 1, 6 and 2 condensate ships for the Gorgon, existing WA Oil BWI Operations, Karratha Gas Plant and Pluto LNG plants respectively. These were assumed to occur on set days for each month.

4.11 Conversion from Mass by Volume to ppb and Particle Size Distributions Assumed

In modelling gaseous pollutants, the predicted AERMOD concentrations in $\mu g/m^3$ have been converted to ppb, assuming conditions of 0 deg Celsius and 1 atmosphere. This results in the following conversions:

- NO_2 1 ppb = 2.056 $\mu g/m^3$;

- SO_2 1 ppb = 2.86 μg/m³;and
- CO, 1 ppb = 1.25 μg/m³.

In modelling particulate, $PM_{2.5}$ have been conservatively assumed equivalent to PM_{10} as the emission sources are primarily gas fired gas turbines, boilers and reciprocating engines where the particulate is predominantly less than 2.5 μm.

4.12 Modelling Using One Year of Data

The WA DEC modelling guidance document states, "If using a conventional model, the proponent will need to obtain at least one (preferably two or more) year's data on the meteorology of the area". The AERMOD modelling in this assessment falls into the category of a conventional model and as such more than one year's data would be preferable. However, it is considered that the multiple year preference is only necessary when the predicted levels are close to the criteria, with one year's data being adequate whenever predicted levels are well below the criteria. It is additionally noted in practice in air quality assessments in WA, one year of meteorological data is generally only used.

4.13 Background Concentrations Used in Modelling

Wheatstone monitoring to date has been conducted using passive samplers for the measurement of monthly average NO_2, SO_2 and by the use of OSIRIS particle monitors to measure hourly particulate concentration data as $PM_{2.5}$ and PM_{10}. This background data is generally not considered of high quality (especially for the OSIRIS) and is not considered adequate to define the background levels. Therefore for this assessment in lieu of no acceptable measurements, data from Barrow Island and at Dampier have been used and are presented in **Table 4-6**.

Table 4-6 Expected Background Concentrations in the Onslow Region

Pollutant	Ave. Period	Units	Average	75th Percentile	Maximum	Source
Nitrogen Dioxide	1-hour 1-year	(ppb) (ppb)	- 2 (0.5)	2 (1.5) -	32 -	2010 Barrow Island [1,4] (Dampier brackets) [2]
Sulphur Dioxide	1 hour 24-hour Annual	(ppb) (ppb) (ppb)	- - Negl	Negl - -	Negl - -	Dampier Measurements [2,4]
Ozone	1-hour	(ppb)	21 (20-25)	26 (25)	48 (62)	2010 Barrow Island (Dampier brackets)
Carbon Monoxide	8-hour Annual	(ppb) (ppb)	- 65	100 -	300 - 1000 -	Dampier Measurements
Benzene	1-hour Annual	(ppb) (ppb)	- 0.02	0.02 -		Dampier Measurements
Toluene	1-hour 24-hour Annual	(ppb) (ppb) (ppb)	- - 0.05	0.05 0.05 -		Dampier Measurements
Xylenes	24-hour Annual	(ppb) (ppb)	- 0.015	0.05 -		Dampier Measurements
Formaldehyde	1-hour 34-hour	(ppb) (ppb)		0.55 0.55	5	Modelling using background sources. Note fires and are significant sources of formaldehyde
H_2S	1-hour	(ppb)	negl	negl	negl	-
PM_{10}	24-hour Annual	($\mu g/m^3$) ($\mu g/m^3$)	- 23	27 -	>50 Bushfire smoke	Pilbara measurements [3]
$PM_{2.5}$	24-hour Annual	($\mu g/m^3$) ($\mu g/m^3$)	- 5	6 -	>25 Bushfire smoke	Pilbara measurements [3]

Notes:

1) Values at Barrow Island as summarised in Air Assessments (2012).
2) Dampier NO_2, SO, CO and Ozone results from DoE monitoring (DoE, 2005) with BTEX measurements from Gillett (2008).
3) Pilbara measurements from Pitt (2011) and are for Pilbara townsite values. Non townsite values away from man made sources will be somewhat lower.
4) For comparison, the Wheatstone annual average NO_2 and SO_2 levels were very low, less than 0.3 ppb for NO_2 and 0.15 ppb for SO_2 in line with those reported above.

Table 4-6 indicates that pollutant levels are generally low, apart from occasional high particulate levels due to bushfire smoke or dust storms. Dust storms such as recorded photographically at Onslow on the 9th January 2013[3] occur all along the Pilbara such as at Dampier and Karratha, Wickham and Port Hedland. For background concentrations for inclusion with the modelling, the 75th percentile background concentration has been used. This percentile is based on the Victorian EPA (Victoria Government Gazette, 2001) who recommends the use of the 70th percentile measured concentration as the background value. **Table 4-6** therefore presents the 75th concentrations, with the values used in modelling taken as the highest value, excepting for the annual NO_x concentration where a mid value of 1 ppb was used as the average value from Barrow Island is considered high due to local sources there.

[3] See for example http://au.news.yahoo.com/thewest/a/-/breaking/15803849/storm-delivers-onslow-a-red-dust-sunset/

5 Meteorology and Dispersion File Development

5.1 Available Meteorological Data

Meteorological data with wind measurements that are available from the Onslow area are summarised in **Table 5-1**.

Table 5-1 Meteorological Monitoring in the Onslow Region

Monitoring Site	Easting [1] GDA94 (m)	Northing [1] GDA94 (m)	Elevation (m ahd)	Averaging Period	Comments	Parameters Measured	Period
Onslow Town	304,570	7,606,239	4	3 hourly spot measurements	Not Air Quality Grade. Poor siting	WS and WD at 10m, AT, RH, BP, Rainfall	1886 to July 2012
Onslow Airport	304,364	7,602,632	10	10 min every 30 minutes	Robust wind sensors but not Air Quality Grade	WS and WD at 10m, AT, RH, BP, Rainfall	From 1997 to present
Onslow Jetty	303,490	7,606,006	4	1 minute	100m from ocean at Jetty	WS and WD at 10m,	Unknown
Wheatstone Site	292,935	7,598,680	6	10 min	Air Quality Grade Wind Sensors	WS and WD at 10m, AT at 1.4 and 10m, RH, BP, SR, Rainfall	16 Dec 2009 to 5 Oct 2012 [3]

Notes:

1) Co-ordinates Zone 50.
2) WS-wind speed; WD-wind direction; AT-air temperature; RH-relative humidity; BP-barometric pressure; SR-solar radiation.
3) Wheatstone meteorological station was decommissioned in October 2012.

Of these, the most suitable are the Wheatstone site measurements as they are located at the site of interest and importantly are based on air quality grade wind sensors. The sensors used were Evirondata WS45 wind speed sensors, with start-up threshold of 0.3 m/s and stalling threshold of 0.2 m/s and WD42 wind direction sensors, with a threshold of 0.3 m/s. A photo of the site is presented in **Figure 5-1**.

Figure 5-1 Photograph of Wheatstone weather station located at the site of the LNG plant

The other sites in Table 5-1 are located further away, with:

- The Onslow town site recording only 3-hourly manual observations;
- The Onslow airport measurements measured by the Bureau of Meteorology using an automatic weather station that was installed in 1997. Of most importance for air quality, the surface (10m) wind data is collected using a Synchrotac 706 wind sensor, which though appropriate for measuring typical and strong winds has a reasonably high stalling speed of 0.7 to 1.0 m/s. Therefore, the sensor overstates the frequency of calm winds. The wind measurements at the site do however, provide data over a long period which can be used to assess the annual variation of winds; and
- The Onslow Salt measurements at the land end of Onslow Jetty. As this site is about 100 m from the ocean, onshore winds (here NE through north to SW), will be more representative of winds over the ocean and therefore tend to overstate the winds that will occur at the site.

5.2 Data Processing for AERMET

For the Wheatstone monitoring site data, the data capture was relatively high. During 2010 there were only nine hours of missing data, whilst for 2011, for all sensors (except solar radiation) there were only eighteen hours of missing data. Data return from solar radiation for 2011 was low due to instrument failure which resulted in a period of 127 days data loss (see Table 5-2).

Table 5-2 Data Return (%) from the Wheatstone Meteorological Station for 2010 and 2011

Year	Wind Speed and Direction (10m)	Air Temperature	Rainfall	Solar Radiation	Relative Humidity	Atmospheric Pressure
2010	99.9	99.9	99.9	99.9	99.9	99.9
2011	99.8	99.8	99.8	64.9	99.8	99.8

The meteorological data from this site was processed using AERMET, the meteorological processor to AERMOD with the following corrections to the data or assumptions:

- Use of the 2010 data as this had the highest data return. The data used included the wind speed and direction, surface temperature and humidity, rainfall and solar radiation;
- The 9 hours of missing data, which occurred as isolated 1 or 2 hours gaps, was filled in by interpolation from the surrounding data.
- The solar radiation data for 2010 was found to have under-read and was corrected (scaled) according to comparison to TAPM predictions for clear sky days;
- A surface roughness value of 5 cm estimated for the meteorological station site which consists of typical Spinifex grasses (see **Figure 5-1**);
- Annual average albedo of 0.28;
- Bowen ratio of 2.5 (representative of a reasonably dry area);
- Assumption that the above are constant throughout the year for all wind directions;
- Sensible heat fluxes were estimated using the standard method using the latitude, time of day, Bowen ratio and cloud cover estimates; and
- Other parameters required, the opaque cloud cover estimates and twice daily temperature profiles, were estimated from the model TAPM for the site.

5.3 Resultant AERMOD Meteorological File

The annual wind rose for 2010 is presented in **Figure 5-2** indicating that the winds at the Wheatstone site are predominantly south westerly and west to WNW with a low frequency of calm winds (less than 0.5 m/s) of 0.46%, with an annual average wind speed of 4.2 m/s.

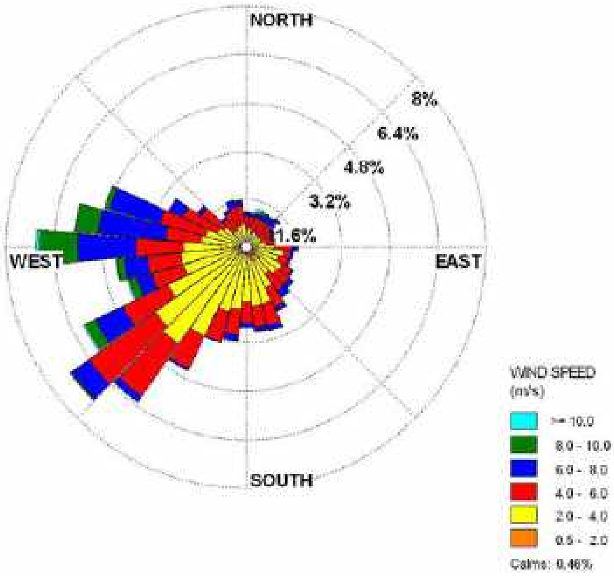

Figure 5-2 Annual windrose from the Wheatstone Foundation Project site for 2010

Annual stability class distribution derived from the Monin Obhukov length and the surface roughness length using Golders monogram are presented in **Table 5-3**. These are not used within AERMOD, but are presented here as a useful summary of the stability class summary at the site.

Table 5-3 Distribution of Stability Classes (%) for the Wheatstone Site - 2010

Stability Class	A	B	C	D	E	F
Percentage (%)	5.7	10.0	17.4	19.3	24.9	22.7

Note: Stability classes range from A, highly dispersive conditions that occur for low wind speeds with strong solar insolation, to neutral conditions (D class) which occur for overcast and/or cloudy conditions to F class which corresponds to very low dispersion rates (stable atmosphere). These conditions occur for nights with clear skies and low wind speeds.

5.4 Wind Variation by Season and Time of Day

The variation of the winds with season and time of day are presented in **Figure 5-3** to **Figure 5-5**.

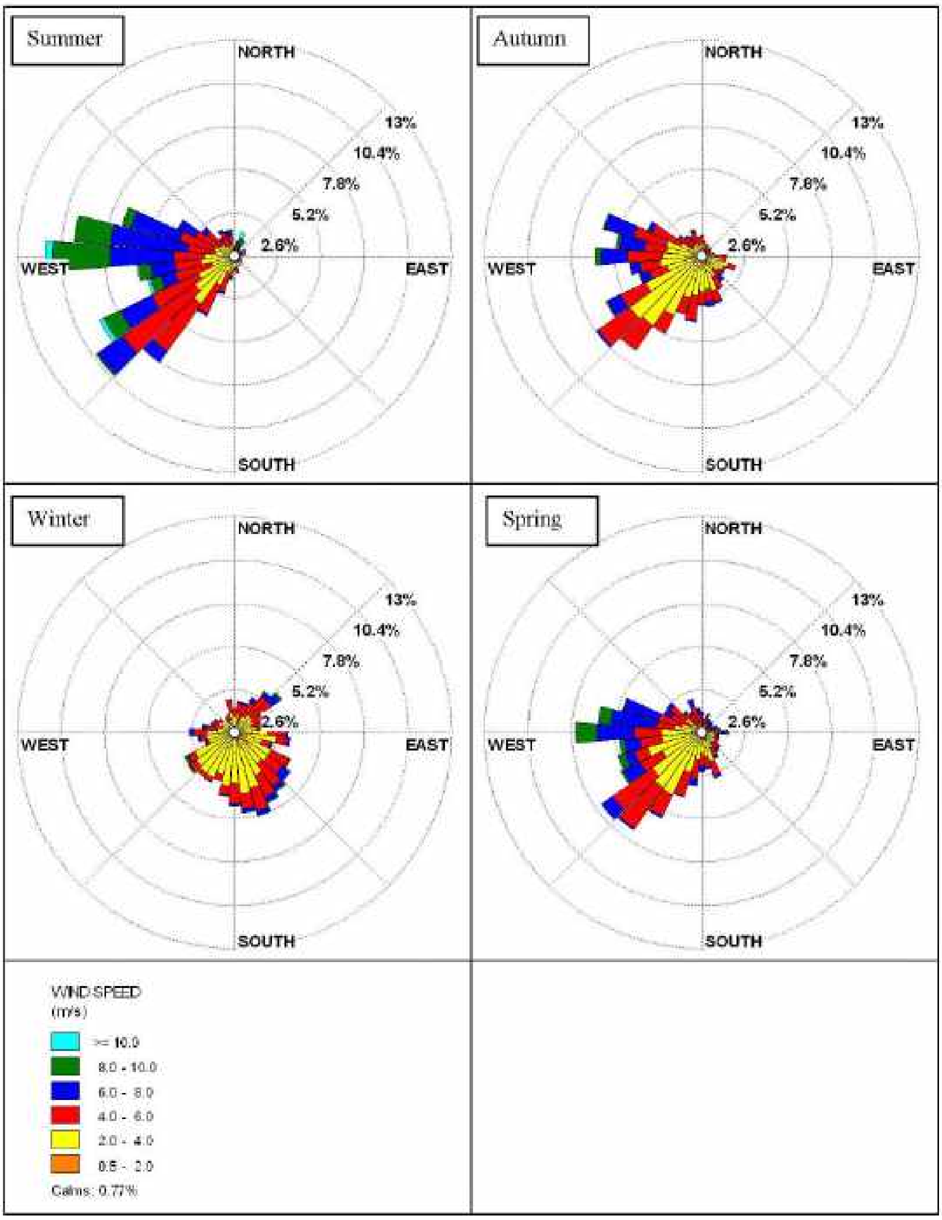

Figure 5-3 Seasonal windroses from the Wheatstone Foundation Project site for 2010

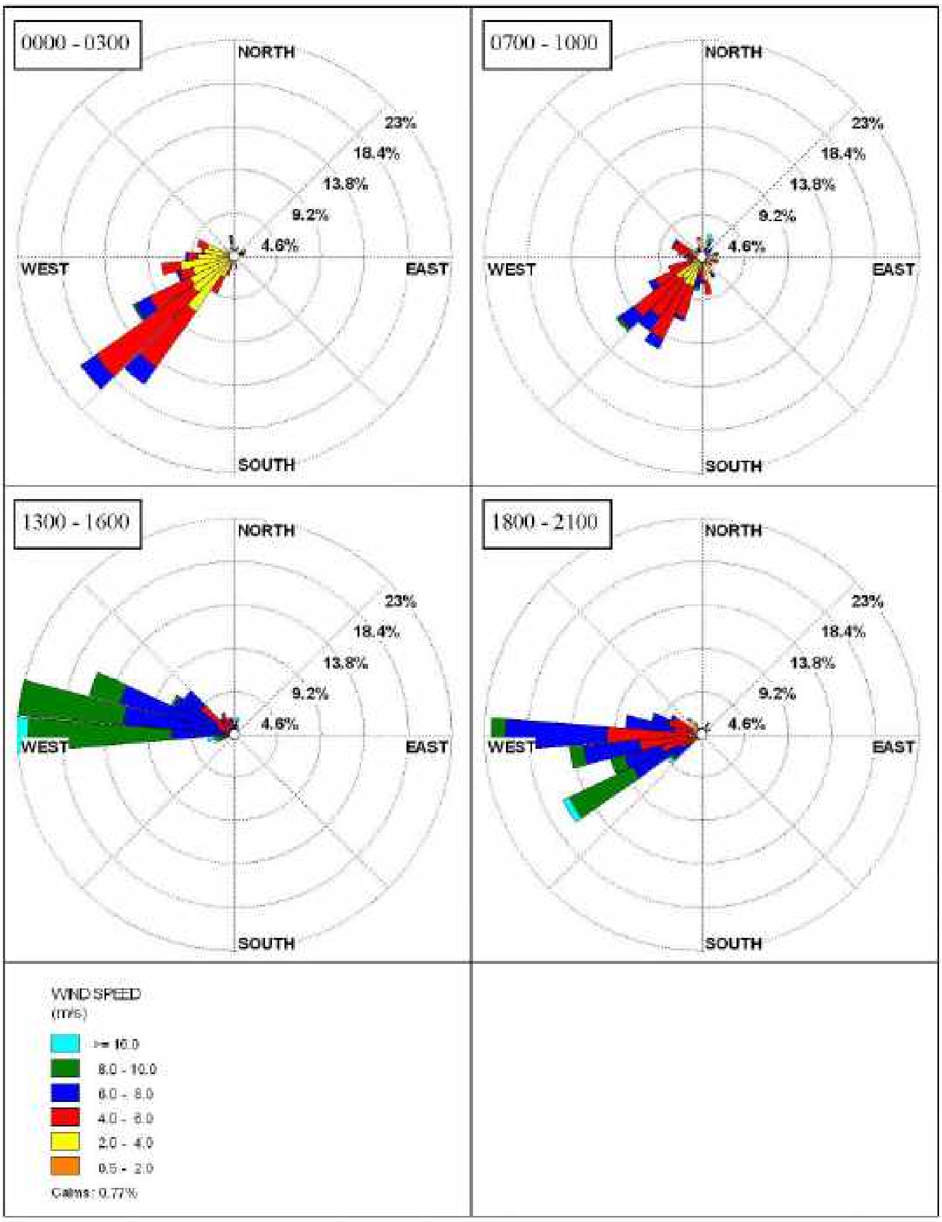

Figure 5-4 Summer windroses from the Wheatstone Foundation Project Site for 2010 by time of day

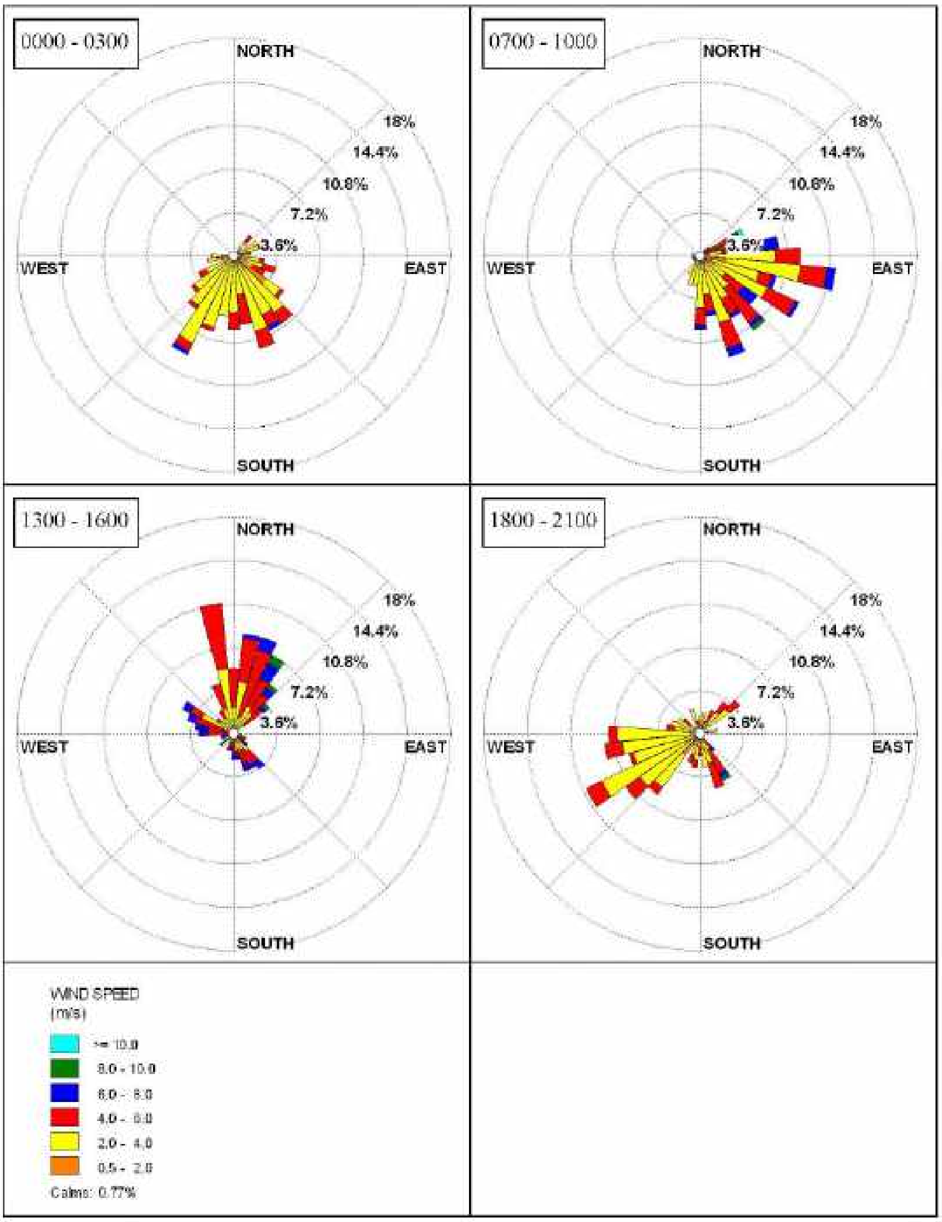

Figure 5-5 Winter windroses from the Wheatstone Foundation Project Site for 2010 by time of day

Figure 5-3 to **Figure 5-5** indicate that at the Wheatstone site:

- Winds have a seasonal nature with an overall predominance of W to WNW and SE winds. Therefore locations to the ENE and NW of any pollutant source will be expected to have relatively more frequent plume impacts;
- The summer winds are essentially from two directions and are very consistent. The winds overnight and in the morning are from the SW (land breeze) or parallel to the coast and from around noon to early evening, a stronger west to WNW sea breeze occurs; and
- Winter winds show more southerly winds at night, turning SE in the morning with a northerly sea breeze occurring in the afternoon before swinging west to WSW in the early evening.

5.5 Comparison of TAPM Predictions for 2010

As TAPM-CTM is used for predicting regional pollutant levels, a comparison of the TAPM predictions of the meteorology is made. As a full year of onsite data is not available for 2009 (the year modelled by TAPM-CTM due to the availability of fire emissions for that year), the comparison of the meteorology has been conducted for 2010. The predicted wind rose at 10 m for 2010 from TAPM at the Wheatstone monitoring site is presented in **Figure 5-6** for comparison to the observed wind rose in **Figure 5-2**.

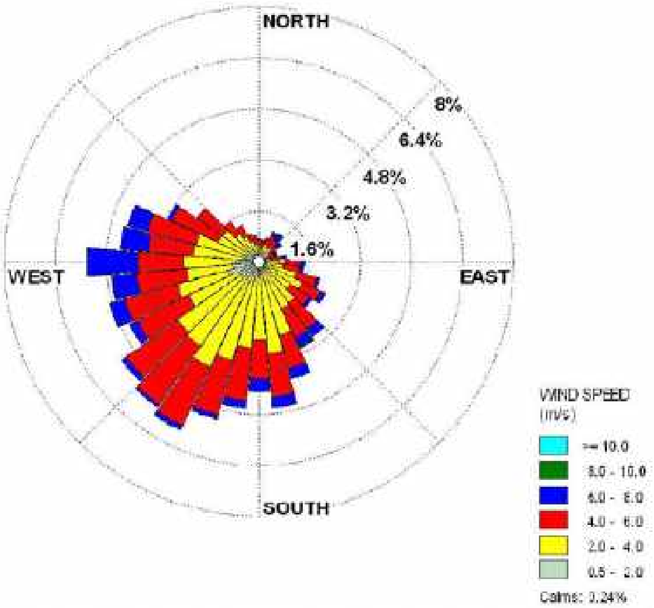

Figure 5-6 Annual (1 Jan to 21 Dec 2010) Wind Rose Predicted by TAPM for the Wheatstone Site

Figure 5-2 and **Figure 5-6** show overall good agreement in the wind directions, though TAPM under-predicts the strength of the winds at this site at 10 m. This is further illustrated in **Figure 5-7**.

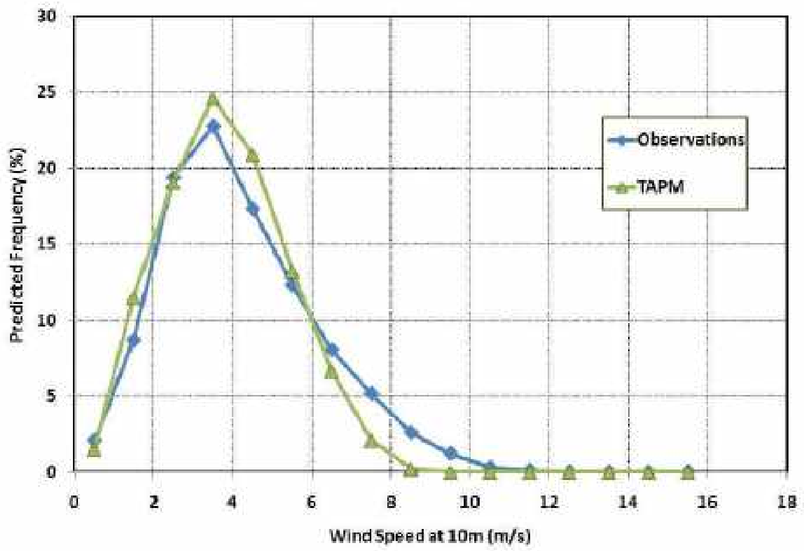

Figure 5-7 Annual wind speed histogram observed and predicted at the Wheatstone site for 2010

Ambient air temperatures which are less important in terms of dispersion from the very buoyant plumes are reasonably well predicted by TAPM as indicated by the temperature scatter plot in **Figure 5-8**.

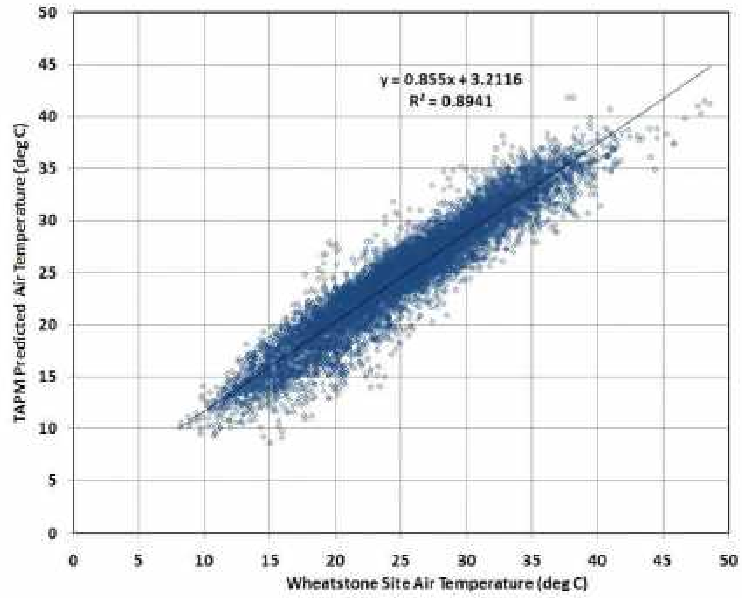

Figure 5-8 Observed and predicted air temperatures at 1.2m at the Wheatstone Site for 2010

The under-prediction of the stronger winds at the surface is a common feature of TAPM for areas with low surface roughness. TAPM does however, predict better the winds at greater height above ground level where the plumes from the LNG plant will be primarily advected and dispersed. A comparison of the wind speeds at the "Karratha" DEC monitoring site which had a wind sounding system (SODAR) was conducted in Air Assessments (2012). This showed similar reductions at the surface, though at 50 and 100 m the winds were predicted well. Therefore it is considered that TAPM has a tendency to under-predict the surface winds for areas of low surface roughness, but performs reasonably well at higher heights, which are important for the sources modelled in this study.

6 Predicted Local Concentrations

6.1 Introduction

The following sections present the predicted local concentrations of NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$ BTEX, formaldehyde and H_2S using the model AERMOD and local measured meteorological data. In this report, "local" is defined as within 13 km of the plant where the maximum concentrations of these pollutants occur. Concentrations of ozone are presented in **Section 7** using TAPM-CTM to predict concentrations on the regional scale to include the interaction with regional sources, as the peak concentrations may occur up to 100 km away from the source.

For the local concentrations predictions the following are excluded as detailed in **Section 2.2.1**;

- Emissions from relatively small and infrequent sources including motor vehicle emissions;
- VOC emissions from fugitive releases from hydrocarbon storage tanks, valve packing, compressor seals, pump seals, flanges, and connectors as the emissions are expected to be low;
- Predictions of ethyl benzene as the concentrations are relatively low compared to criteria and found not an issue and are not included in the air toxics NEPM. That is, benzene, toluene and xylenes are sufficient indicators of issues with BTEX concentrations; and
- Emissions from ship and tug combustions as they are considered uncertain due to issues in estimating emissions, modelling the impact of ships superstructure and modelling over-water dispersion and therefore are not presented in this section. For comparison however, predictions for the routine case with ship combustion sources have been included in **Appendix C**.

6.2 Summary of Maximum Predicted Concentrations – Without Background

Predicted maximum concentrations at any location and outside the lease boundaries are presented in **Table 6-1** and **Table 6-2** with the concentrations as a percentage of the ambient criteria outside the lease boundary presented in **Table 6-3**.

Table 6-1 Predicted Maximum Concentrations from the Wheatstone Foundation Project Anywhere on the Model Grid

Pollutant	Ave. Period	Conc. Statistic	Criteria Value	Units	Back-ground	Routine Case 1	Non Routine				
							TO Trip Case 2	Blocked NRU Vent Case 3	BOG Comp. Trip Case 4	Conden-sate Loading Case 5	Start Up Case 6
CO	8-hour	Max	9000	ppb	100	50	53	55	53	50	50
NO_2	1-hour	Max	120	ppb	2	38	38	38	38	38	38
	1-year	Ave	30	ppb	1	4.0	4.0	4.0	4.0	4.0	4.0
SO_2	1-hour	Max	200	ppb	0	1.4	0.9	1.4	1.4	1.4	0.9
	1-day	Max	80	ppb	0	0.7	0.4	0.7	0.7	0.7	0.4
	1-year	Ave	20	ppb	0	0.095	0.067	0.095	0.095	0.095	0.056
PM_{10}	1-day	Max	50	$\mu g/m^3$	27	2.1	2.1	2.1	2.1	2.1	2.1
$PM_{2.5}$	1-day	Max	25	$\mu g/m^3$	6	2.1	2.1	2.1	2.1	2.1	2.1
	1-year	Ave	8	$\mu g/m^3$	5	0.32	0.33	0.33	0.32	0.32	0.32
Benzene	Annual	Ave	5	$\mu g/m^3$	0.06	0.065	0.054	0.063	0.065	0.87	0.038
Toluene	24-hour	Max	1000	ppb	0.05	0.4	0.32	0.4	0.4	34	0.4
	Annual	Ave	100	ppb	0.05	0.06	0.05	0.06	0.06	0.52	0.06
Xylenes	24-hour	Max	250	ppb	0.05	0.22	0.18	0.22	0.22	16	0.15
	Annual	Ave	200	ppb	0.015	0.03	0.03	0.03	0.03	0.23	0.02
Formaldehyde	24-hour	Max	40	ppb	0.55	0.11	0.11	0.11	0.11	0.11	0.06
H_2S	1-hour	99.9th	1.11	$\mu g/m^3$	0	0.02	0.02	0.02	0.02	0.02	0.02

Note: Includes the Macedon Project and Onslow power station, but excludes background concentrations as defined in **Section 4.13.**

Table 6-2 Predicted Maximum Concentrations from the Wheatstone Foundation Project Outside the Lease Boundary on Land due to Wheatstone

Pollutant	Ave. Period	Conc. Statistic	Criteria Value	Units	Back-ground	Routine Case 1	Non Routine				
							TO Trip Case 2	Blocked NRU Vent Case 3	BOG Comp. Trip Case 4	Conden-sate Loading Case 5	Start Up Case 6
CO	8-hour	Max	9000	ppb	100	40	40	40	42	40	34
NO_2	1-hour	Max	120	ppb	2	26	26	26	26	26	26
	1-year	Ave	30	ppb	1	1.4	1.4	1.4	1.4	1.4	1.4
SO_2	1-hour	Max	200	ppb	0	0.9	0.6	0.9	0.9	0.9	0.5
	1-day	Max	80	ppb	0	0.28	0.23	0.28	0.28	0.28	0.17
	1-year	Ave	20	ppb	0	0.046	0.035	0.046	0.046	0.046	0.028
PM_{10}	1-day	Max	50	$\mu g/m^3$	27	1.2	1.2	1.2	1.45	1.2	0.83
$PM_{2.5}$	1-day	Max	25	$\mu g/m^3$	6	1.2	1.2	1.2	1.45	1.2	0.83
	1-year	Ave	8	$\mu g/m^3$	5	0.24	0.24	0.25	0.25	0.24	0.18
Benzene	Annual	Ave	5	$\mu g/m^3$	0.06	0.04	0.03	0.034	0.04	0.18	0.027
Toluene	24-hour	Max	1000	ppb	0.05	0.22	0.15	0.22	0.22	4.0	0.12
	Annual	Ave	100	ppb	0.05	0.03	0.03	0.03	0.03	0.16	0.02
Xylenes	24-hour	Max	250	ppb	0.05	0.10	0.09	0.10	0.10	1.6	0.07
	Annual	Ave	200	ppb	0.015	0.02	0.02	0.02	0.02	0.09	0.01
Formaldehyde	24-hour	Max	40	ppb	0.55	0.07	0.07	0.07	0.07	0.07	0.04
H_2S	1-hour	99.9th	1.11	$\mu g/m^3$	0	0.012	0.012	0.012	0.012	0.012	0.008

Note: Includes the Macedon Project and Onslow power station, but excludes background concentrations as defined in **Section 4.13.**

Table 6-3 Predicted Maximum Concentrations (as a percent of Criteria) from the Wheatstone Foundation Project outside the Lease Boundary due to Wheatstone

Pollutant	Ave. Period	Conc. Statistic	Criteria Value	Units	Back-ground	Routine Case 1	Non Routine				
							TO Trip Case 2	Blocked NRU Vent Case 3	BOG Comp. Trip Case 4	Conden-sate Loading Case 5	Start Up Case 6
CO	8-hour	Max	9000	ppb	100	0.4	0.4	0.4	0.5	0.4	0.4
NO_2	1-hour	Max	120	ppb	2	21.5	21.5	21.5	21.5	21.5	14.2
	1-year	Ave	30	ppb	1	4.7	4.7	4.7	4.7	4.7	4.9
SO_2	1-hour	Max	200	ppb	0	0.5	0.3	0.5	0.5	0.5	0.3
	1-day	Max	80	ppb	0	0.4	0.2	0.4	0.4	0.4	0.2
	1-year	Ave	20	ppb	0	0.2	0.2	0.2	0.2	0.2	0.1
PM_{10}	1-day	Max	50	µg/m³	27	2.4	2.4	2.4	2.9	2.4	1.7
$PM_{2.5}$	1-day	Max	25	µg/m³	6	4.8	4.8	4.8	4.8	4.8	3.3
	1-year	Ave	8	µg/m³	5	3.0	3.0	3.1	3.1	3.0	2.3
Benzene	Annual	Ave	5	µg/m³	0.06	0.8	0.6	0.7	0.8	3.6	0.5
Toluene	24-hour	Max	1000	ppb	0.05	0.02	0.02	0.02	0.02	0.40	0.01
	Annual	Ave	100	ppb	0.05	0.03	0.03	0.03	0.03	0.16	0.02
Xylenes	24-hour	Max	250	ppb	0.05	0.04	0.04	0.04	0.04	0.65	0.03
	Annual	Ave	200	ppb	0.015	0.01	0.01	0.01	0.01	0.05	0.01
Formaldehyde	24-hour	Max	40	ppb	0.55	0.2	0.2	0.2	0.2	0.2	0.1
H_2S	1-hour	99th	1.11	µg/m³	0	1.0	0.6	1.0	1.0	1.0	0.7

Note: Includes the Macedon Project and Onslow power station, but excludes background concentrations as defined in **Section 4.13.**

Table 6-1 to **Table 6-3** indicate that:

- The predicted concentrations outside the lease boundaries are generally low compared to their respective criteria, with the 1-hour NO_2 concentrations being closest - up to 21.5% of the criteria, with all other pollutants contributing less than 5% of their respective criteria. Concentrations at nearby sensitive receptors are even lower and are listed in **Appendix B**; and
- For all scenarios there is generally little variation in the predicted concentrations apart form higher concentrations of benzene, toluene and xylenes from the ship loading scenario – case 5.

Further details of the concentrations are provided in the following sections along with plots of the concentration contours when the Wheatstone Foundation Project contributes more than approximately 1% of their respective criteria.

6.3 Contour Plots and Descriptions

6.3.1 Routine Operation – Case 1

Predicted maximum concentrations from routine operations are listed in **Table 6-1** with **Figure 6-1** to **Figure 6-6** presenting the pollutants closest to their criteria, NO_2, PM (representing both PM_{10} and $PM_{2.5}$, benzene, formaldehyde and H_2S.

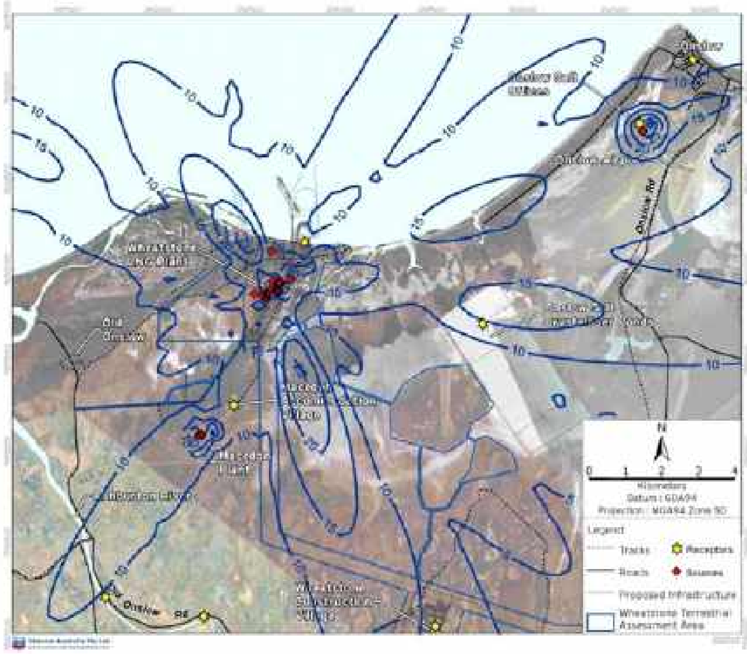

Figure 6-1 Predicted maximum 1-hour NO_2 concentrations (ppb) from normal operation

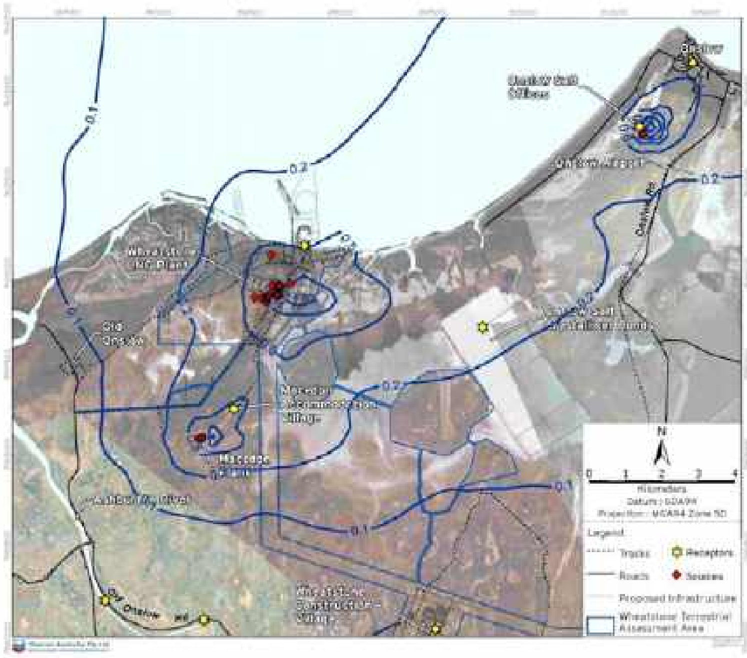

Figure 6-2 Predicted annual average NO_2 concentrations (ppb) from normal operation

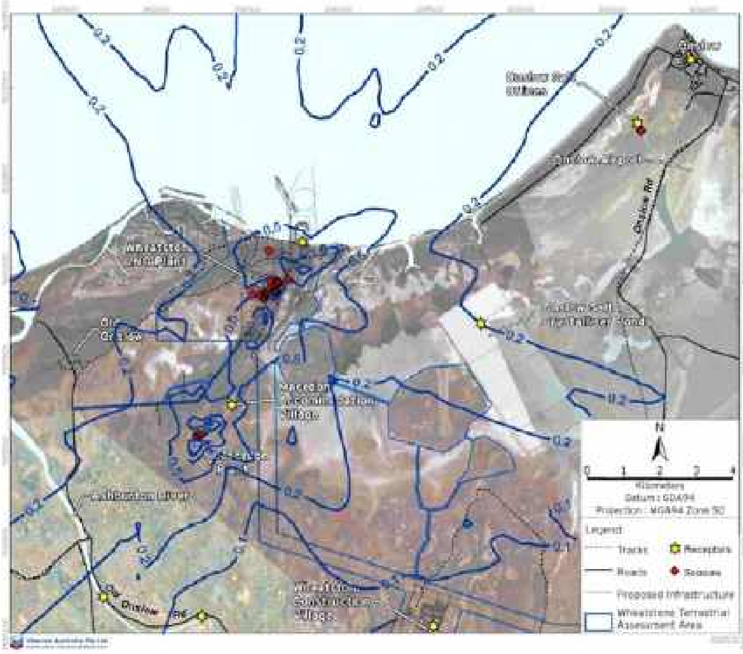

Figure 6-3 Predicted maximum 24-hour average $PM_{2.5}$ (or PM_{10}) concentrations ($\mu g/m^3$) from normal operation

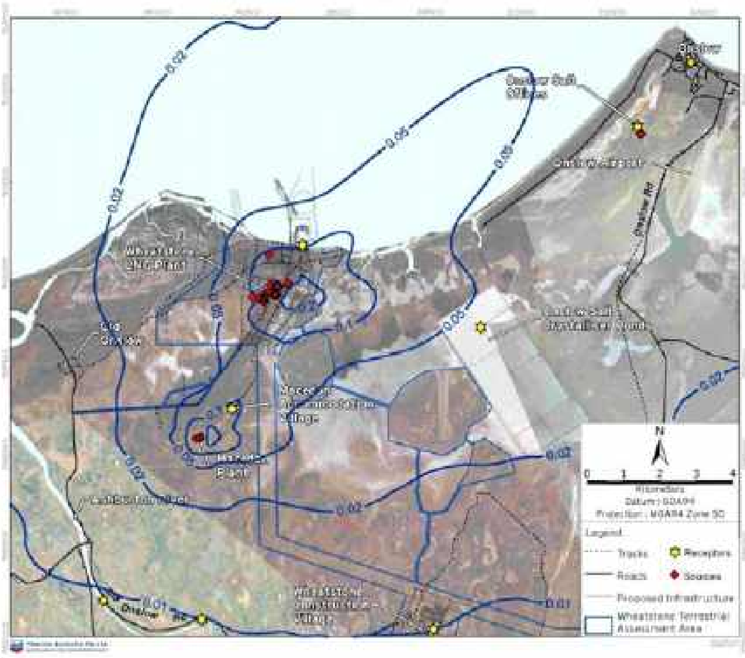

Figure 6-4 Predicted annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) from normal operation

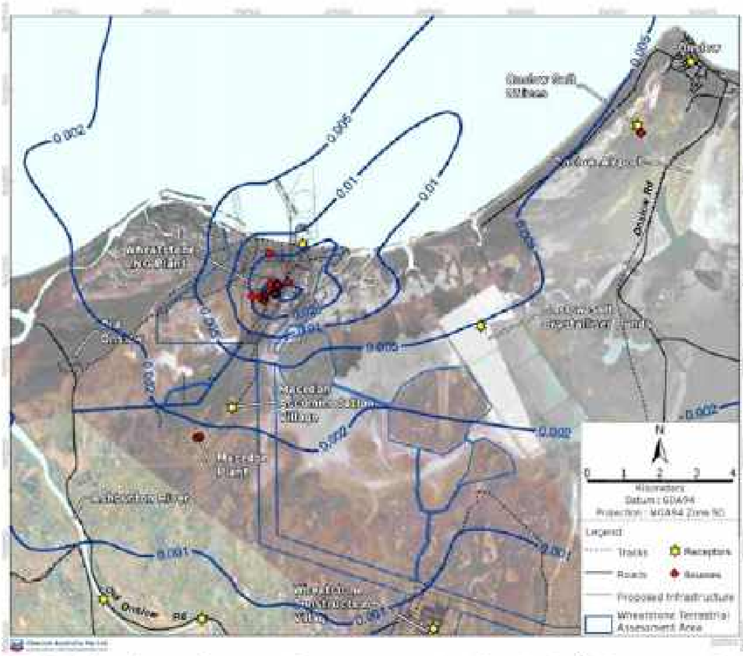

Figure 6-5 Predicted annual average benzene concentrations ($\mu g/m^3$) from normal operation

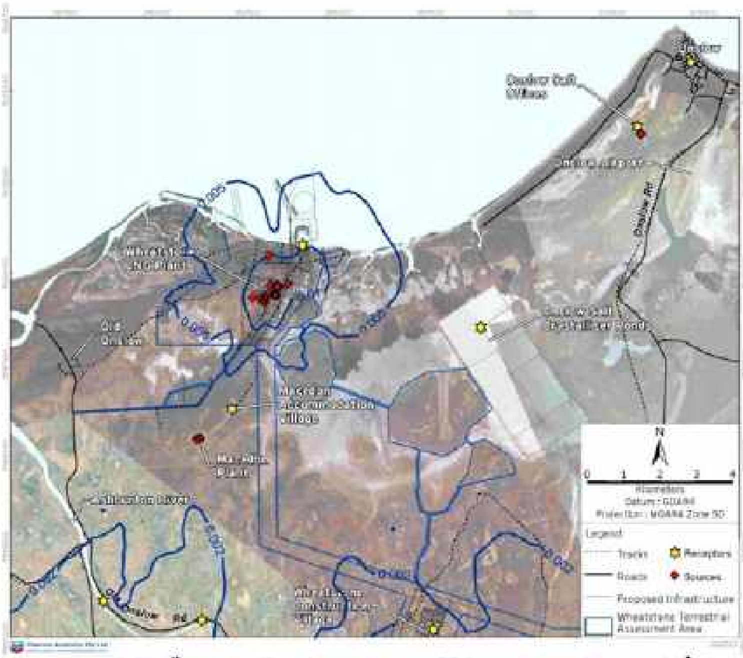

Figure 6-6 Predicted 99.9[th] percentile 1-hour average H_2S concentrations ($\mu g/m^3$) from normal operation

Table 6-1 and **Figure 6-1** to **Figure 6-6** indicate that for routine operations:

- Airborne concentrations of all pollutants are low;
- The highest concentration outside the plant lease boundary relative to the criteria is 1-hour NO_2 concentrations at 21.5% of the criterion; and
- Predicted concentrations of NO_2 are actually higher from the Onslow power station and the Macedon Project, due to their shorter stacks and less buoyant sources, though the regions of high concentrations from these projects are very localised to their respective sites.

6.3.2 Scenarios 2, 3, 4 and 6

For scenarios 2, 3 and 4 there is very little increase in the predicted concentrations from the routine case and therefore will not be discussed in detail. This minimal change occurs as the increase in emissions occurs from the non-routine flaring, with the emissions from this flaring predicted to make little impact on local concentrations due to the large heat release and therefore plume rise.

For case 6, one LNG train is offline and though there are increased emissions from flaring, this does not counter balance the reduced emissions from the LNG train. Therefore concentrations are lower than from the routine case and therefore are not an issue.

6.3.3 Ship Loading Condensate – Case 5

Table 6-1 and **Figure 6-7** to **Figure 6-8** indicate that ship loading of condensate will increase the concentrations of benzene, toluene and xylenes, though with the maximum concentrations occurring near the condensate berths but with the concentrations decreasing rapidly with distance. At any location on land (but outside the lease boundary), the highest predicted concentrations are at most 3.6% of the annual average benzene criterion and 0.65% of the 24-hour xylenes criterion.

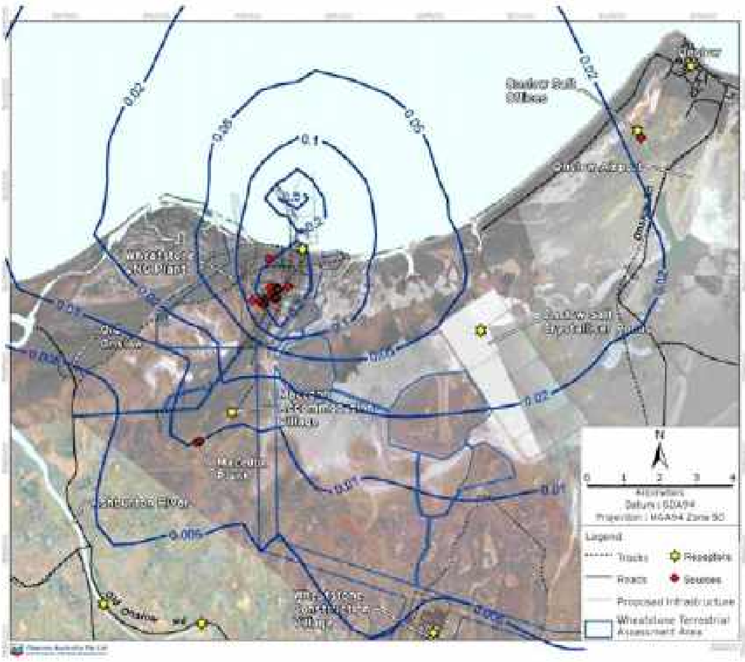

Figure 6-7 Predicted annual average benzene concentrations ($\mu g/m^3$) from Case 5 (from TAPM)

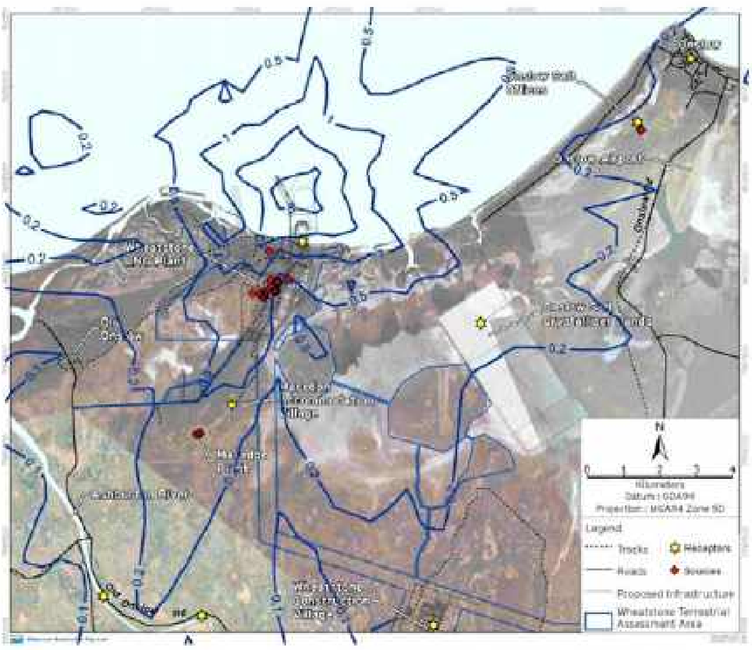

Figure 6-8 Predicted maximum 24-hour xylenes concentrations (ppb) from Case 5 (from TAPM)

6.4 Summary of Maximum Predicted Concentrations – Including Background Concentrations

The predicted maximum concentrations outside the lease boundary including background concentrations as a percentage of the criteria are presented in **Table 6-4**. The background concentrations as generally low and make little contribution to the levels, with all background levels apart from PM_{10} and $PM_{2.5}$ being below 4% of the criteria. For PM_{10} and $PM_{2.5}$, background levels make up a significant fraction of the criteria, but for these the contribution from the Wheatstone Foundation Project is small and the predicted cumulative concentrations remain below the criteria. Therefore, the consideration of background concentrations does not change the conclusions in **Section 6.2** and **Section 6.3**.

Table 6-4 Predicted Maximum Concentrations (as a percent of Criteria) from the Wheatstone Foundation Project Outside the Lease Boundary Due to Wheatstone – Background Levels Included

Pollutant	Ave. Period	Conc. Statistic	Criteria Value	Units	Back-ground (%)	Routine Case 1 (%)	Non Routine				
							TO Trip Case 2 (%)	Blocked NRU Vent Case 3 (%)	BOG Comp. Trip Case 4 (%)	Conden-sate Loading Case 5 (%)	Start Up Case 6 (%)
CO	8-hour	Max	9000	ppb	1.1	1.6	1.6	1.6	1.6	1.6	1.5
NO_2	1-hour	Max	120	ppb	1.7	23.2	23.2	23.2	23.2	23.2	15.9
	1-year	Ave	30	ppb	3.3	8.0	8.0	8.0	8.0	8.0	8.2
SO_2	1-hour	Max	200	ppb	0.0	0.5	0.3	0.5	0.5	0.5	0.3
	1-day	Max	80	ppb	0.0	0.4	0.2	0.4	0.4	0.4	0.2
	1-year	Ave	20	ppb	0.0	0.2	0.2	0.2	0.2	0.2	0.1
PM_{10}	1-day	Max	50	µg/m³	54	56	56	56	57	56	56
$PM_{2.5}$	1-day	Max	25	µg/m³	24	29	29	29	29	29	27
	1-year	Ave	8	µg/m³	62.5	66	66	66	66	66	65
Benzene	Annual	Ave	5	µg/m³	0.6	2.1	1.9	2.0	2.1	4.9	1.8
Toluene	24-hour	Max	1000	ppb	0.05	0.03	0.02	0.03	0.03	0.40	0.02
	Annual	Ave	100	ppb	0.05	0.08	0.08	0.08	0.08	0.21	0.07
Xylenes	24-hour	Max	250	ppb	0.05	0.06	0.06	0.06	0.06	0.67	0.05
	Annual	Ave	200	ppb	0.015	0.02	0.02	0.02	0.02	0.05	0.01
Formaldehyde	24-hour	Max	40	ppb	0.55	1.6	1.6	1.6	1.6	1.6	1.5
H_2S	1-hour	99th	1.11	µg/m³	0.0	1.0	0.6	1.0	1.0	1.0	0.7

Note: Includes background concentrations as defined in **Section 4.13** and other existing and approved sources.

7 Predicted Regional Concentrations

7.1 Introduction and Summary

The following section presents the predicted regional concentrations of ozone and NO_2 from the various scenarios before and with the Wheatstone Foundation Project. These concentrations have been predicted using the model TAPM-CTM as it has been shown to provide good agreement with observations in the Pilbara (see Pitts *et al*, 2011) and allows for all sources (including bush fires) to be modelled, such that a true cumulative assessment can be conducted.

A summary of the predicted concentrations is presented in **Table 7-1** and as a percentage of the adopted criteria **Table 7-2**. The following sections provide details of descriptions and contour plots.

Table 7-1 Predicted Maximum Concentrations (ppb) of Ozone and NO_2 Anywhere on the Model Grid

Pollutant	Ave. Period	Statistic Used	Criteria Value (ppb)	Existing 2009 (ppb)	Future without Wheatstone (ppb)	Future with the Wheatstone Foundation Project					
						Routine Case 1 (ppb)	TO Trip Case 2 (ppb)	Blocked NRU Vent Case 3 (ppb)	BOG Trip Case 4 (ppb)	Condensate Loading Case 5 (ppb)	Start Up Case 6 (ppb)
Nitrogen Dioxide	1-hour	Max	120 (1)	75.1	75.6	75.6	75.6	75.6	75.7	75.6	75.1
	1-hour	2^{nd}	120	45	45	45	45	45	45	45	45
	1-year	Ave	30	9.2	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Ozone	1-hour	Max	100 (1)	87	86	86	86	86	86	86	86
	1-hour	2^{nd}	100	74	67	67	67	67	67	68	67
	4-hour	Max	80 (1)	76	75	75	75	75	75	75	75
	4-hour	2^{nd}	80	69	63.5	63.5	63.5	63.5	63.5	64.2	63.5

Note: (1) The NEPM 1-hour goal allows for 1 day of exceedances per year with the modelling including natural sources. As such with natural sources included, compliance is if the 2^{nd} highest predicted concentration is less than the criterion concentration.

Table 7-2 Predicted Maximum Concentrations of Ozone and NO_2 Anywhere on the Model Grid as a Percentage of their Criteria (%)

Pollutant	Ave. Period	Statistic Used	Criteria Value (ppb)	Existing 2009 (%)	Future without Wheatstone (%)	Future with the Wheatstone Foundation Project					
						Routine Case 1 (%)	TO Trip Case 2 (%)	Blocked NRU Vent Case 3 (%)	BOG Trip Case 4 (%)	Condensate Loading Case 5 (%)	Start Up Case 6 (%)
Nitrogen Dioxide	1-hour	Max	120 (1)	63	63	63	63	63	63	63	63
	1-hour	2^{nd}	120	38	38	38	38	38	38	38	38
	1-year	Ave	30	31	31	31	31	31	31	31	31
Ozone	1-hour	Max	100 (1)	87	86	86	86	86	86	86	86
	1-hour	2^{nd}	100	74	67	67	67	67	67	68	67
	4-hour	Max	80 (1)	95	94	94	94	94	94	94	94
	4-hour	2^{nd}	80	86	79	79	79	79	79	80	79

Note: (1) The NEPM 1-hour goal allows for 1 day of exceedances per year with the modelling including natural sources. As such with natural sources compliance is if less than 2 days of exceedances are measured.

7.2 Contour Plots

7.2.1 Existing Sources as at 2009

The predicted maximum ozone and NO_2 concentrations from natural and existing sources as at 2009 are listed in **Table 7-1 and Table 7-2** with concentration plots presented in **Figure 7-1** to **Figure 7-7**

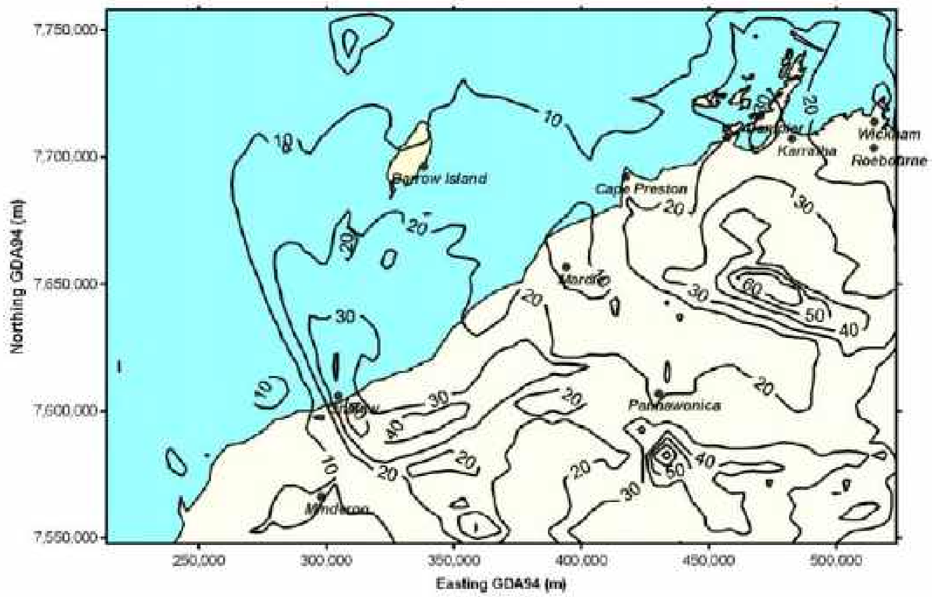

Figure 7-1 Predicted maximum 1-hour NO_2 concentrations (ppb) from existing (2009) sources

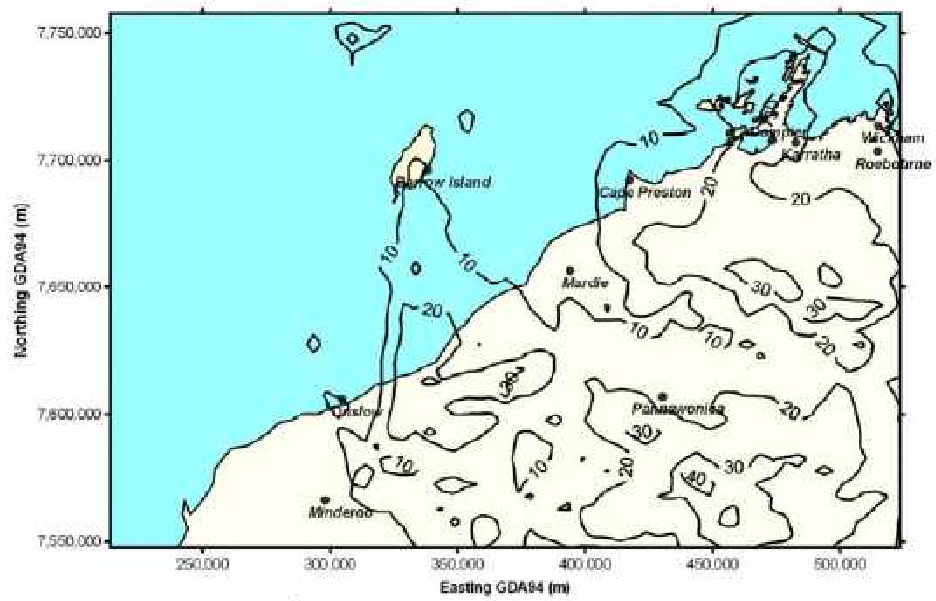

Figure 7-2 Predicted 2nd highest 1-hour NO_2 concentrations (ppb) from existing (2009) sources

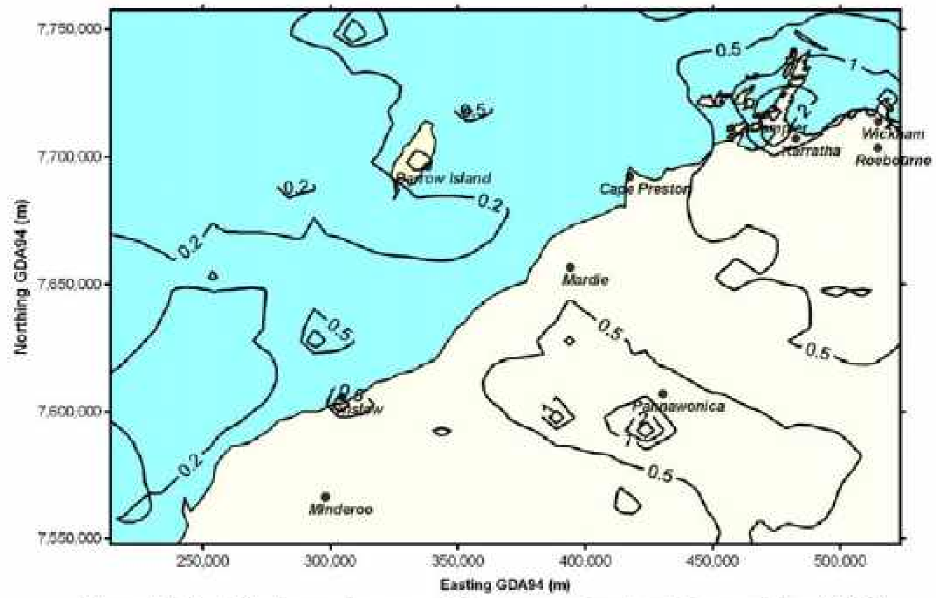

Figure 7-3 Predicted annual average NO_2 concentrations (ppb) from existing (2009) sources

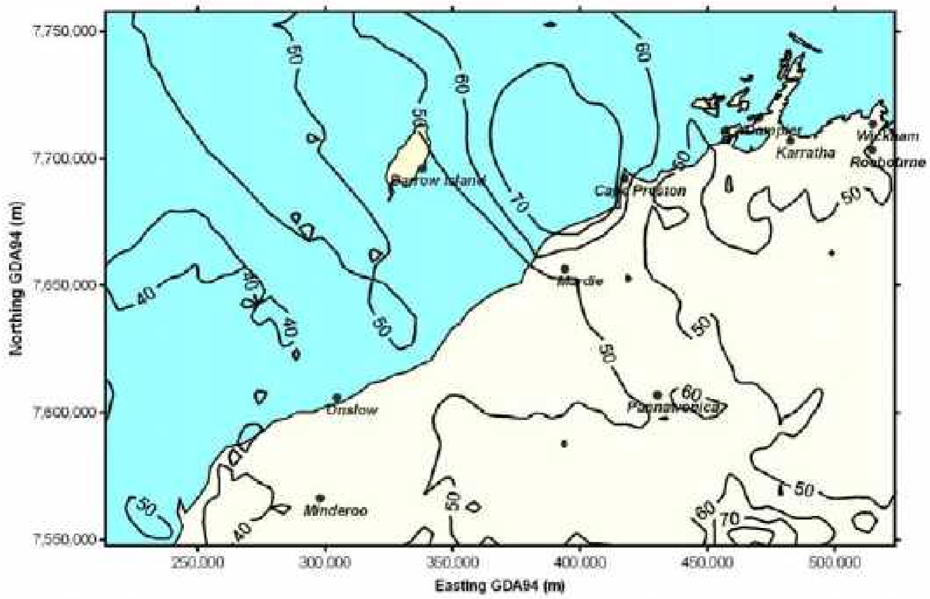

Figure 7-4 Predicted maximum 1-hour ozone concentrations (ppb) from existing (2009) sources

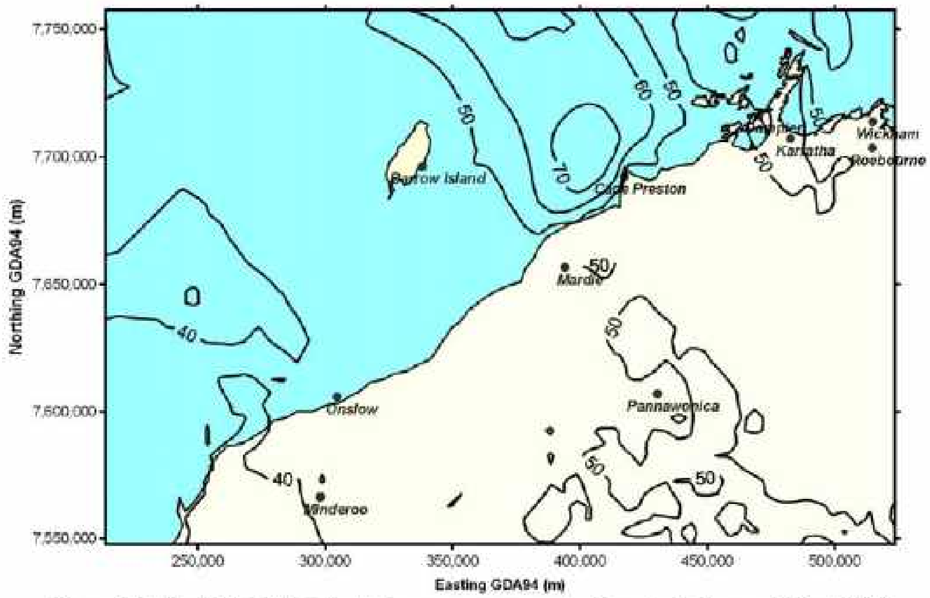

Figure 7-5 Predicted 2nd highest 1-hour ozone concentrations (ppb) from existing (2009) sources

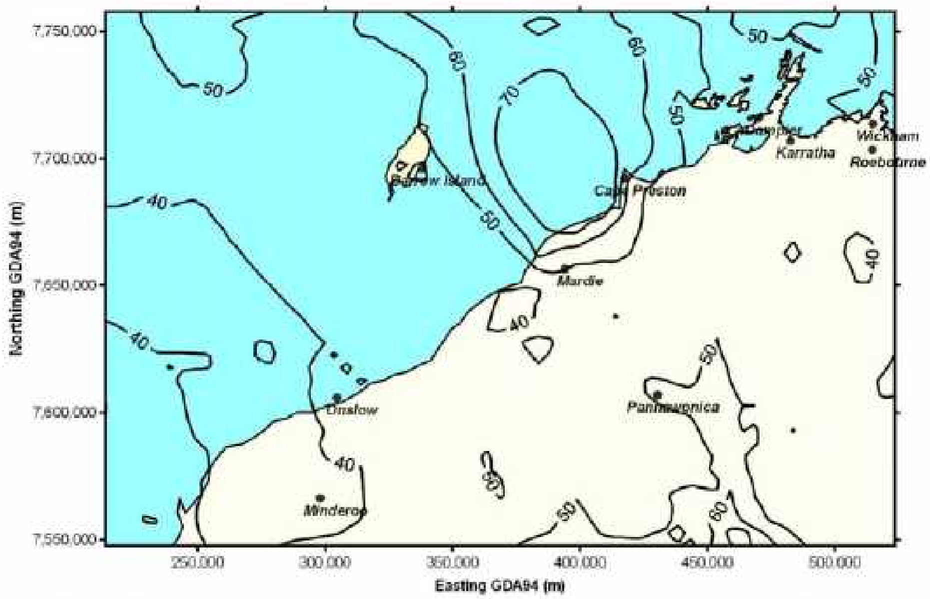

Figure 7-6 Predicted maximum 4-hour ozone concentrations (ppb) from existing (2009) sources

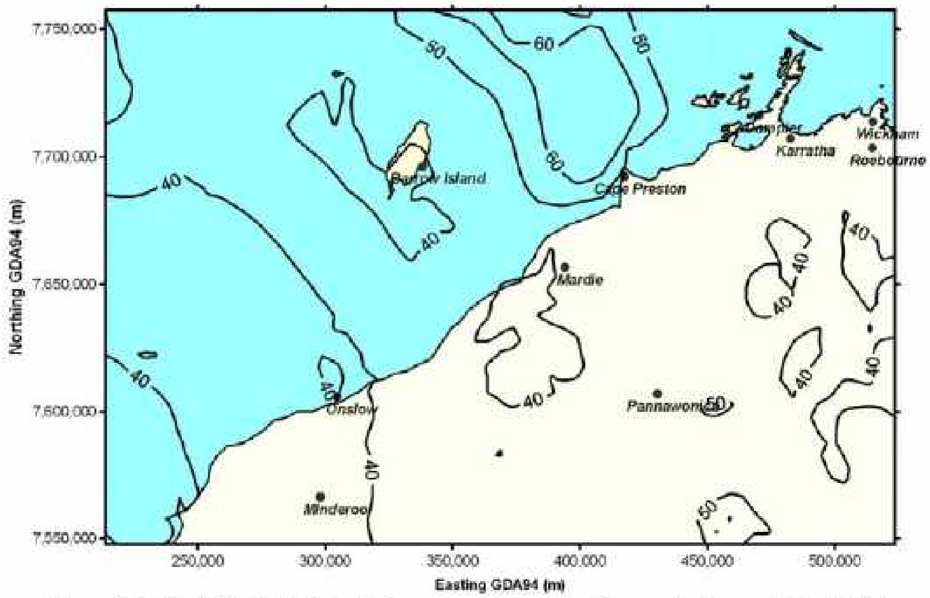

Figure 7-7 Predicted 2nd highest 4-hour ozone concentrations (ppb) from existing (2009) sources

Table 7-1 and Table 7-2 and Figure 7-1 to Figure 7-7 indicate that:

- Maximum NO_2 concentrations occur inland near the fires and to a lesser extent close to the industrial sources such as on the Burrup peninsula. In comparison to the NEPM standards, the concentrations using the highest concentration (requested by the DEC when assessing industry only impacts) are up to 63% of the 1-hour NO_2 standard. Using what is considered the more appropriate second highest concentration when natural sources such as fires are included in the modelling, as is here, the predicted concentrations are 38% of the standard;
- Maximum ozone concentrations are predicted to occur over inland areas and to a lesser extent over the ocean. These peaks inland are due to the large fires for that year (see Pitts *et al*, 2011). The levels over the ocean were due to a fire to the south of Onslow that was blown out to sea under a southerly wind and then the next day, back into the Cape Preston area (see **Section 7.3**). In comparison to the NEPM standards, the maximum ozone concentrations predicted anywhere on the model grid are 87 and 95% of the 1-hour and 4-hour ozone standards respectively. Using what is considered the more appropriate second highest concentration when including natural sources, the predicted concentrations are 74 and 86% of the standard; and
- Therefore at any location the concentrations are predicted to comply with the NEPM standards with fires being the largest source.

7.2.2 Predicted Future Concentrations without the Wheatstone Foundation Project

The predicted maximum ozone and NO_2 concentrations from future sources (under construction and approved), excluding the Wheatstone Foundation Project are listed in **Table 7-1** and **Table 7-2** with concentration plots presented in **Figure 7-8** to **Figure 7-14**.

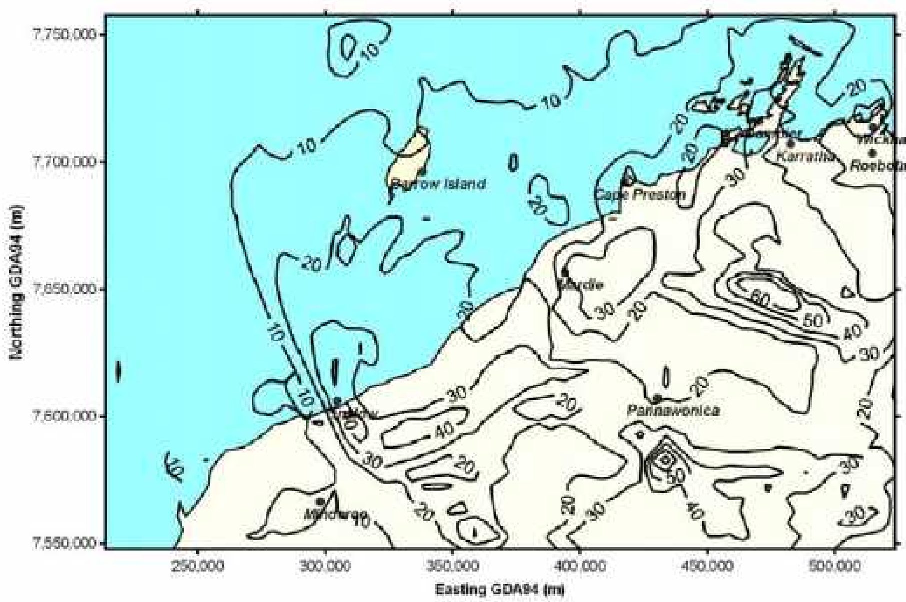

Figure 7-8 Predicted maximum 1-hour NO_2 concentrations (ppb) from future sources without the Wheatstone Foundation Project

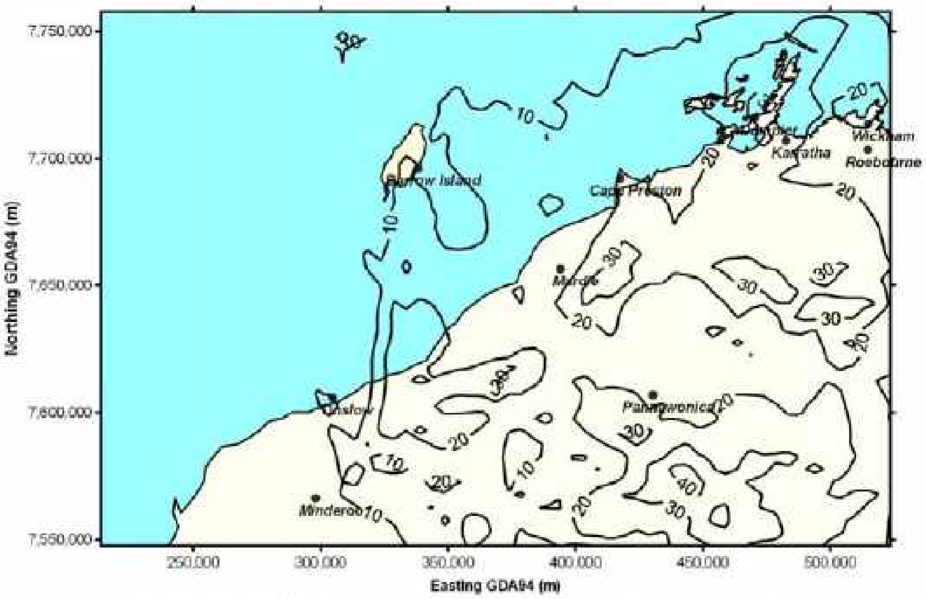

Figure 7-9 Predicted 2[nd] highest 1-hour NO_2 concentrations (ppb) from future sources without the Wheatstone Foundation Project

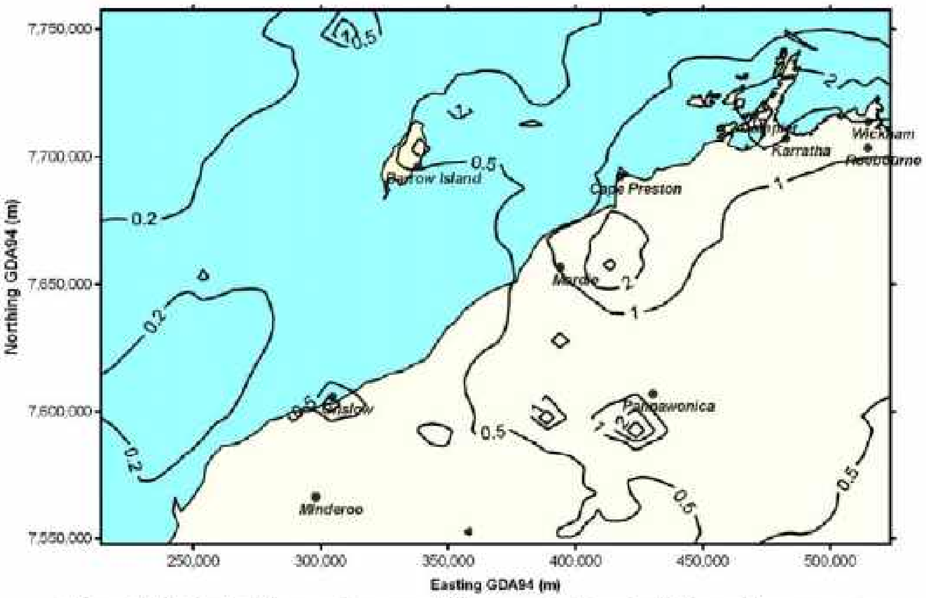

Figure 7-10 Predicted annual average NO_2 concentrations (ppb) from future sources without the Wheatstone Foundation Project

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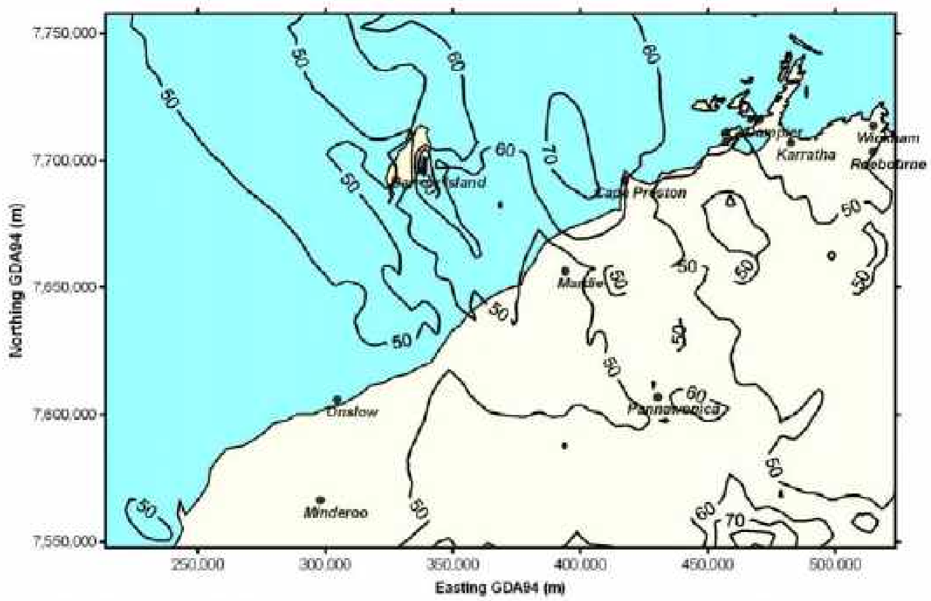

Figure 7-11 Predicted maximum 1-hour ozone concentrations (ppb) from future sources without the Wheatstone Foundation Project

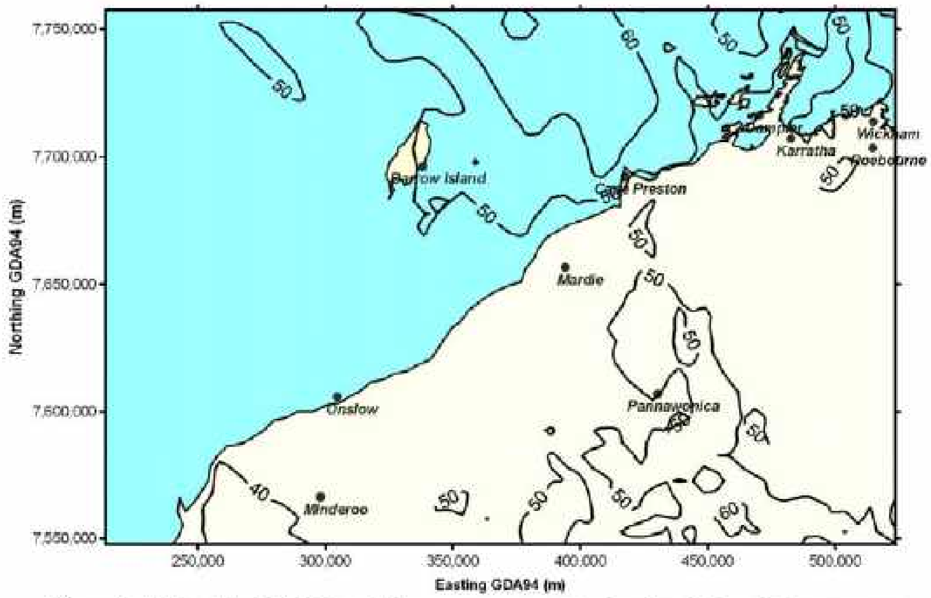

Figure 7-12 Predicted 2nd highest 1-hour ozone concentrations (ppb) from future sources without the Wheatstone Foundation Project

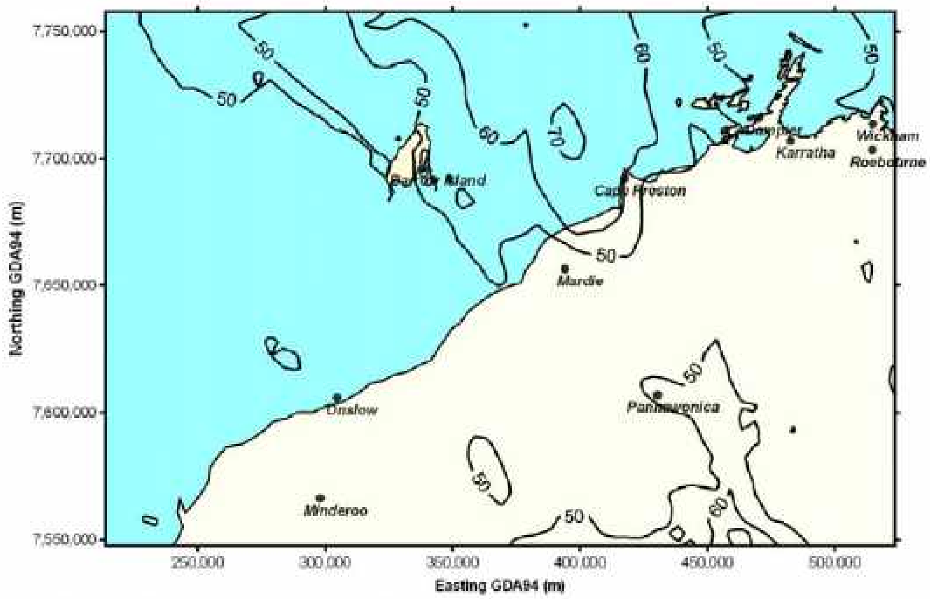

Figure 7-13 Predicted maximum 4-hour ozone concentrations (ppb) from future sources without the Wheatstone Foundation Project

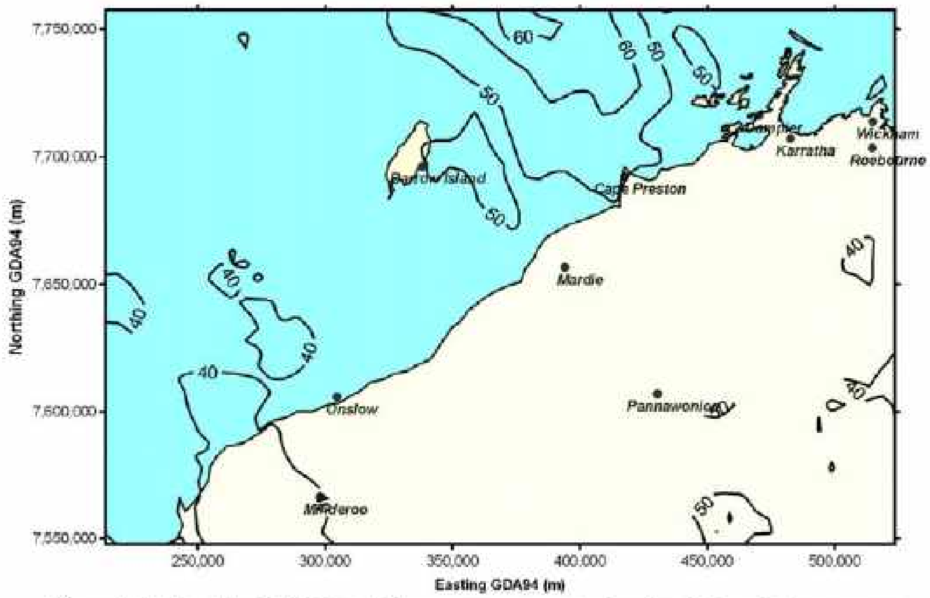

Figure 7-14 Predicted 2nd highest 4-hour ozone concentrations (ppb) from future sources without the Wheatstone Foundation Project

Table 7-1 and **Table 7-2** and **Figure 7-8** to **Figure 7-14** show:

- Negligible changes in the maximum concentrations as fires are predicted to be the dominant source with contributions from industrial emissions being smaller. There is a small decrease in the maximum 1-hour ozone levels which is considered due to the non linear reactions with the additional NO_X on the day with the peak emissions reducing the peak 1-hour ozone levels. In any case the change is very small and NO_2 and ozone will remain below the NEPM standard;
- There is an increase in NO_x in some areas such as near the Cape Preston area and Barrow Island, but these are well below the maximums predicted from fires;
- There are relatively high ozone concentrations predicted near Barrow Island due to the Gorgon project, with this maximum being slightly less than the maximum predicted on the grid;
- The broad area of high ozone levels predicted over the ocean to the northwest of Cape Preston is predicted to decrease slightly. This decrease is due to the non linear reactions in ozone formation. In this case, the additional NO_X from the Barrow Island and Cape Preston region emitted into this broad plume of pollutants from the fire is predicted to reduce the ozone levels. This is considered to occur as ozone formation in the Pilbara is generally determined by the availability of VOC, with additional NO_X not necessarily leading to additional ozone. Additional ozone is formed when VOCs are added to the air.

The actual event above where the ozone concentrations decrease was predicted to occur on 7th August 2009. The ozone concentrations for the existing 2009 case are shown in **Figure 7-15** and for the future case in **Figure 7-16**. In **Figure 7-15** and **Figure 7-16** the plume path from the emissions from the fire south of Onslow can be seen as it trails from south of Onslow out north of Barrow island and back to the north of Cape Preston. **Figure 7-16** shows that with the addition of industry emissions, the ozone levels are actually reduced.

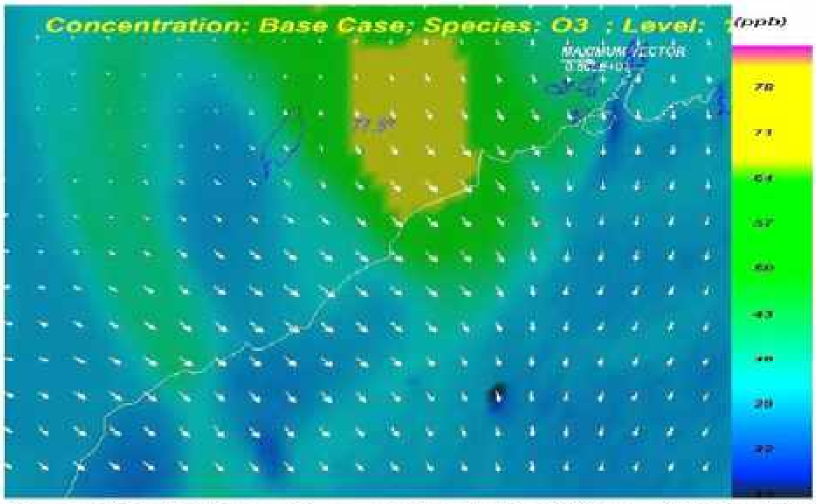

Figure 7-15 Predicted 1-hour O_3 concentrations (ppb) at 1700 7 Aug 2009 from 2009 Sources

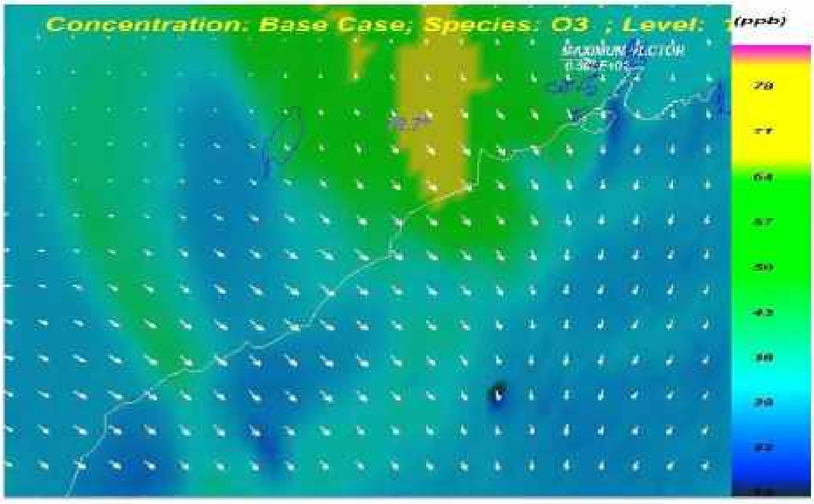

Figure 7-16 Predicted 1-hour O_3 concentrations (ppb) at 1700 7 Aug 2009 from future sources

This reduction in some of the peak events but general increase in lower concentration events is further discussed in **Section 7.3**.

7.2.3 Future Sources with the Wheatstone Foundation Project (Routine Operations and Non Routine Scenarios 2, 3, 4 and 6)

The predicted maximum ozone and NO_2 concentrations from future sources with the Wheatstone Foundation Project for the routine operations (case 1) and the non routine scenarios are listed in **Table 7-1** and **Table 7-2**. For the routine case and non routine scenarios 2, 3, 4 and 6 there is negligible change to the maximum concentrations on the model grid. The contour plots for the routine case are presented in **Figure 7-17** to **Figure 7-23**. The non routine scenarios 2, 3, 4 and 6 are not plotted as they almost identical.

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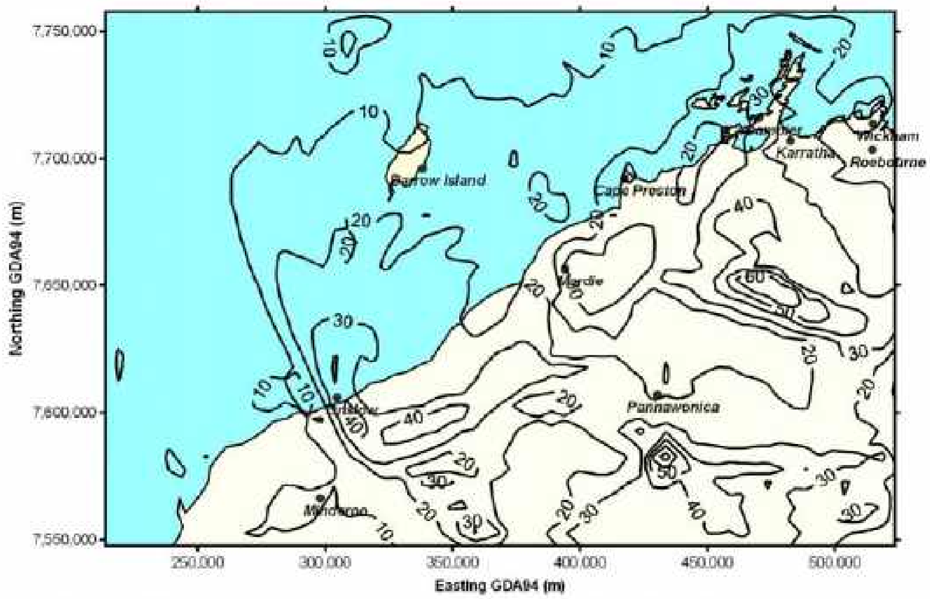

Figure 7-17 Predicted maximum 1-hour NO_2 concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

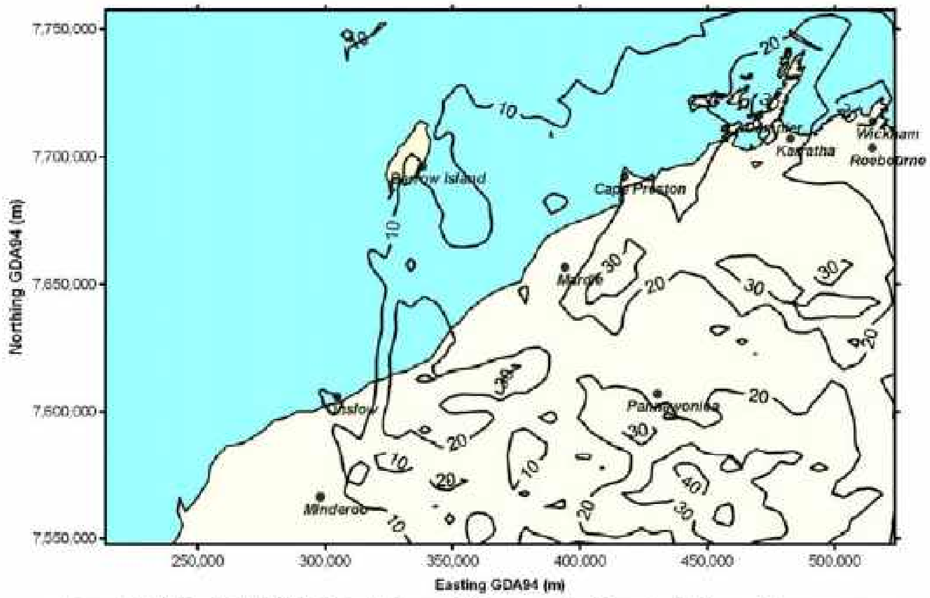

Figure 7-18 Predicted 2nd highest 1-hour NO_2 concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

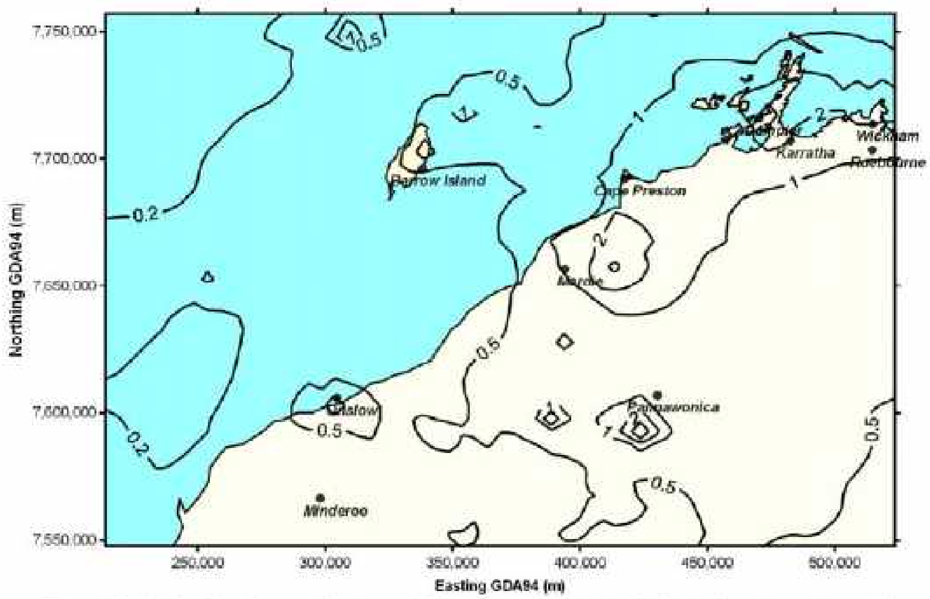

Figure 7-19 Predicted annual average NO_2 concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

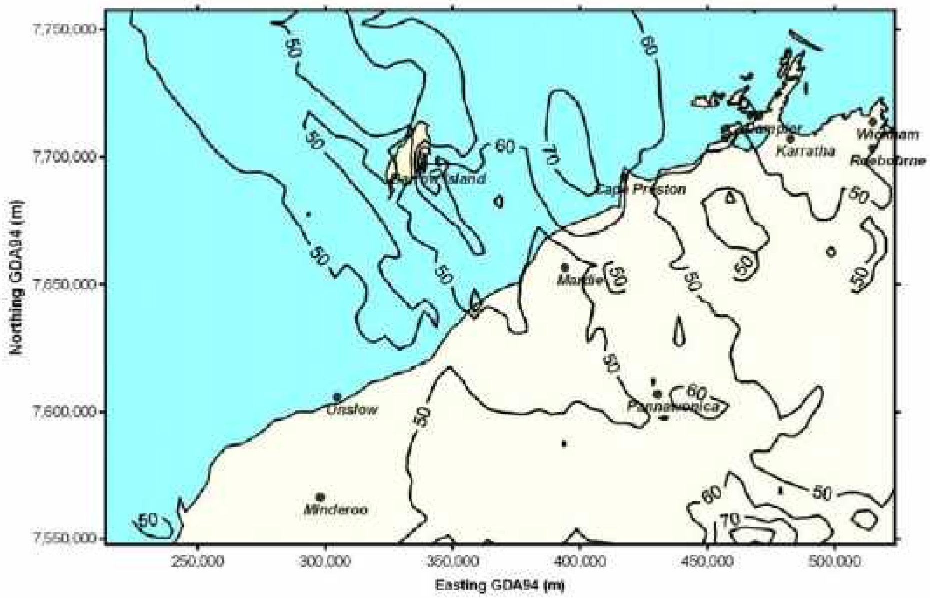

Figure 7-20 Predicted maximum 1-hour ozone concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

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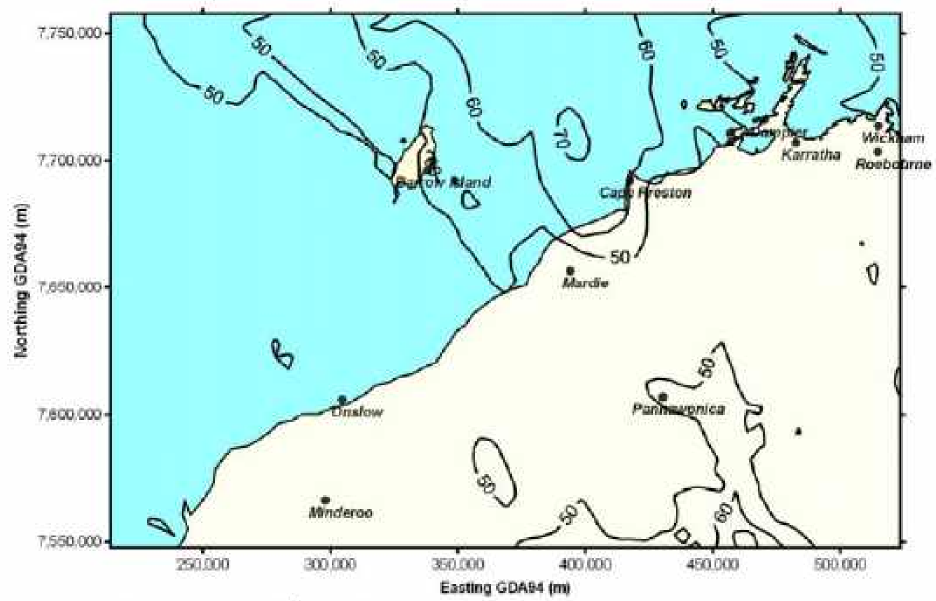

Figure 7-21 Predicted 2nd highest 1-hour ozone concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

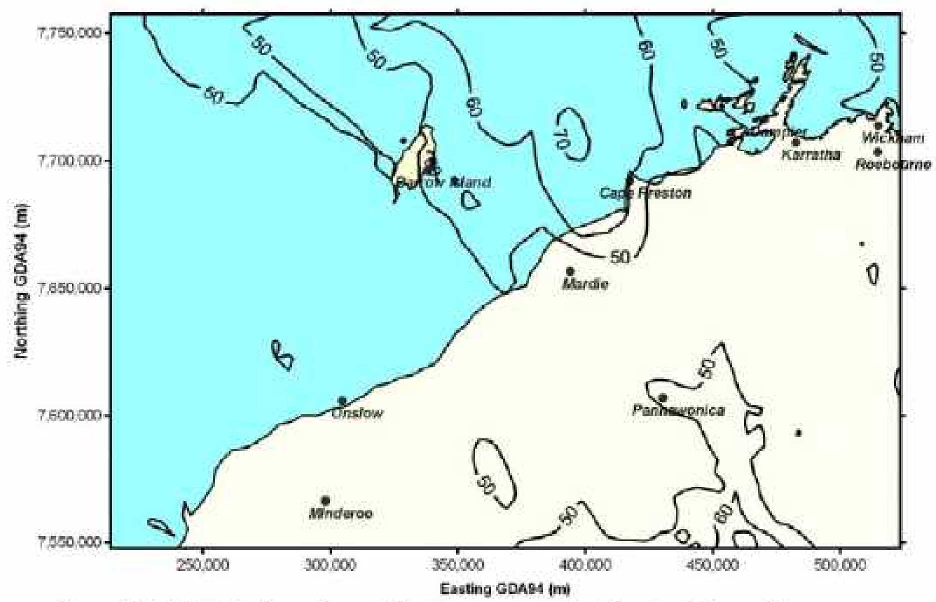

Figure 7-22 Predicted maximum 4-hour ozone concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

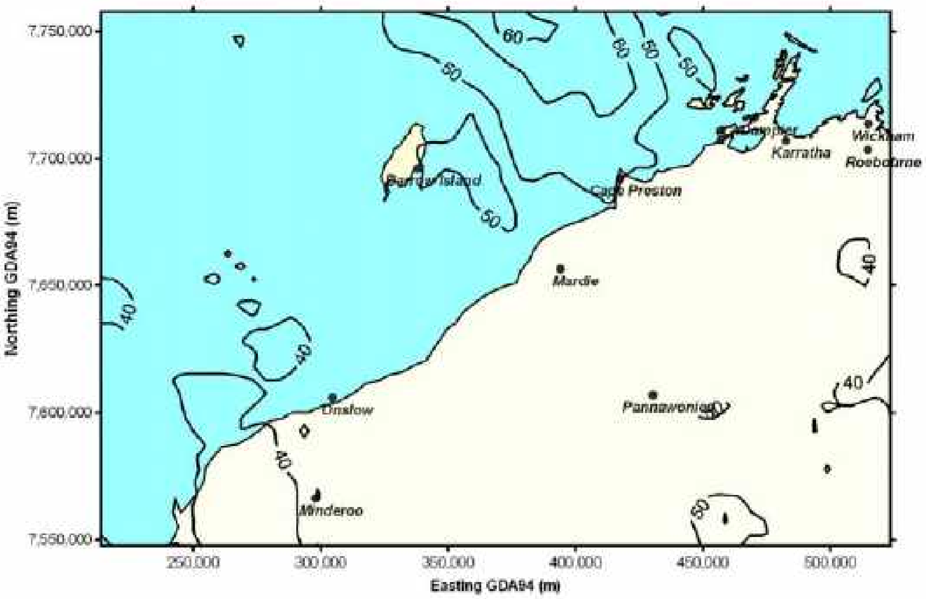

Figure 7-23 Predicted 2nd highest 4-hour ozone concentrations (ppb) from future sources with the Wheatstone Foundation Project – routine operations

Figure 7-17 to **Figure 7-23** indicate a slight increase in the annual average concentrations in the Onslow area with only minor changes in other areas as the maximum impacts are due to the existing sources (e.g. fires) or larger industrial sources. That the Wheatstone Foundation Project is a minor source is seen by comparing the emissions from the Wheatstone Foundation Project to other sources as listed in **Table 2-6**. This shows that the Wheatstone Foundation Project will emit only 57 g/s of NO_X compared to projects under construction or approved at Cape Preston of 590 g/s and the Gorgon Project at 177 g/s. Therefore on a regional scale, the Wheatstone Foundation Project's impacts on ozone formation are small.

7.3 Predicted Concentrations at Select Receptors

To further illustrate the change in ozone concentrations for the various modelled scenarios, concentration statistics at various residential areas shown in **Figure 7-1 to Figure 7-23** are presented in **Figure 7-24** to **Figure 7-30**. These locations were selected as they contain the closest residential areas as well as a selection of more distant regional centres. Exmouth has also been selected as a location to be evaluated, though this is just off the model grid shown in these figures (to the west). The presentation of the predicted concentrations in these plots is considered a better measure of the industrial sources impacts as they are measured at residential areas, whilst the maximum concentrations presented in the previous sections may occur at extremely remote locations.

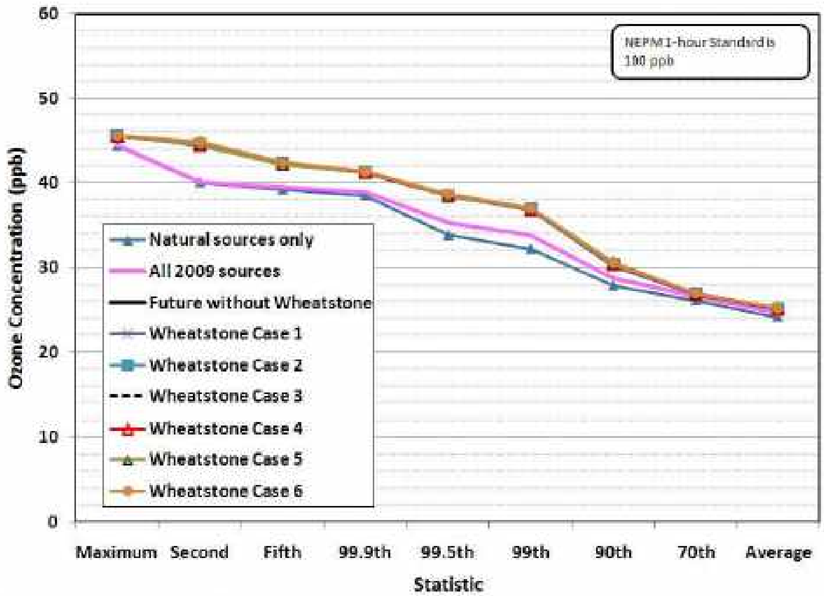

Figure 7-24 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Onslow

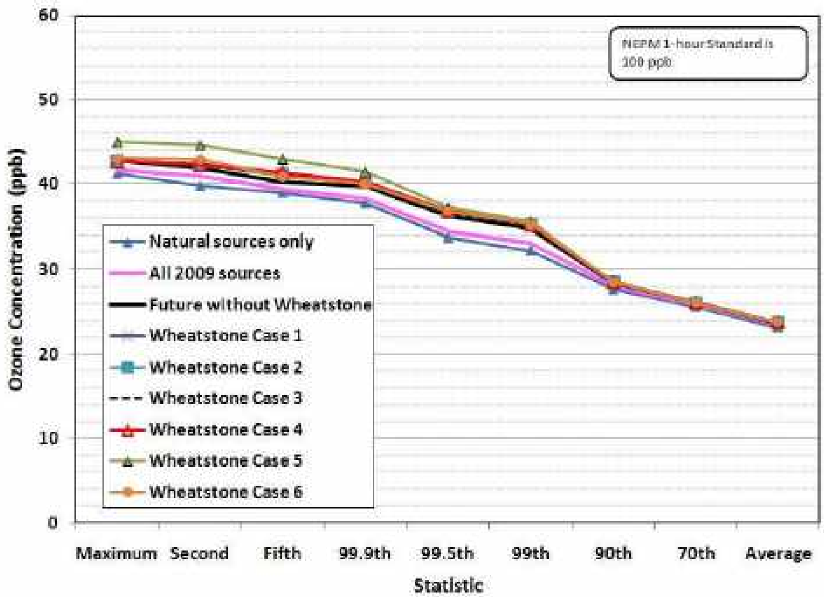

Figure 7-25 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Minderoo Station

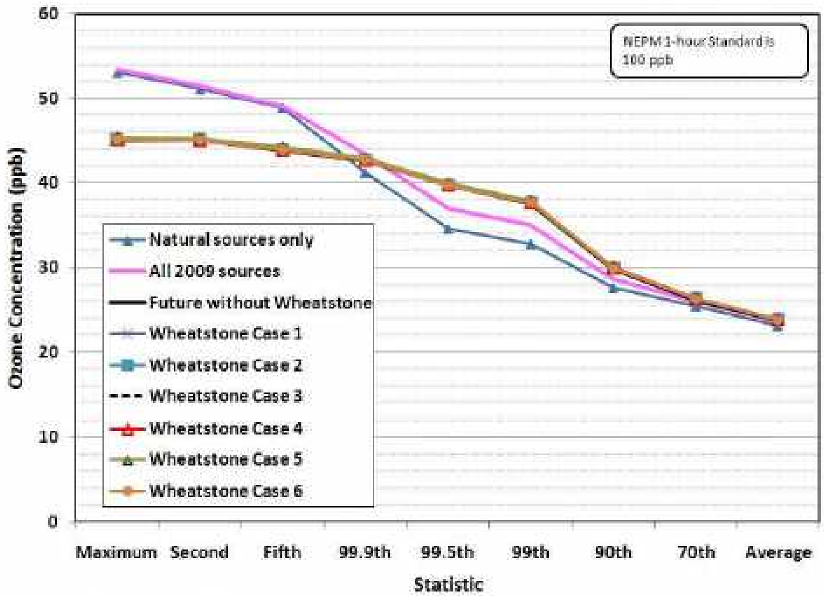

Figure 7-26 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Mardie Station

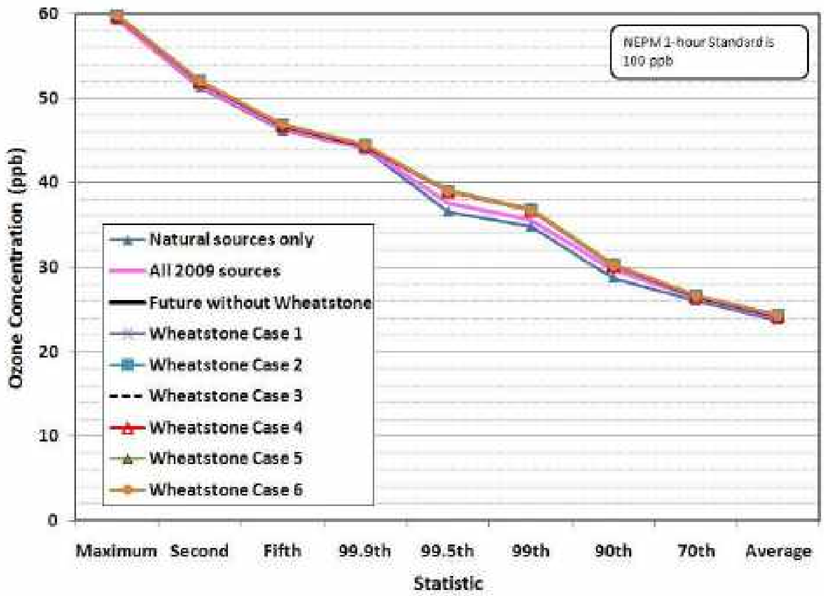

Figure 7-27 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Pannawonica

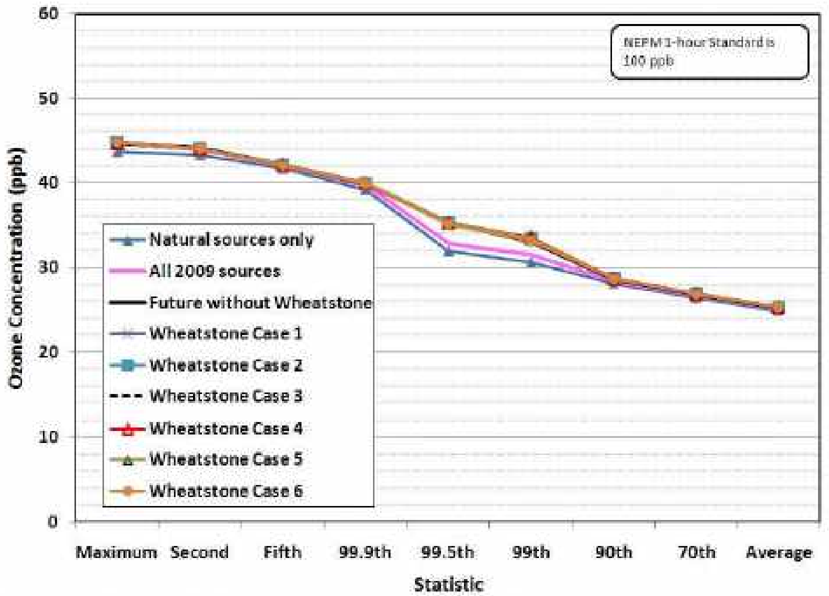

Figure 7-28 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Exmouth

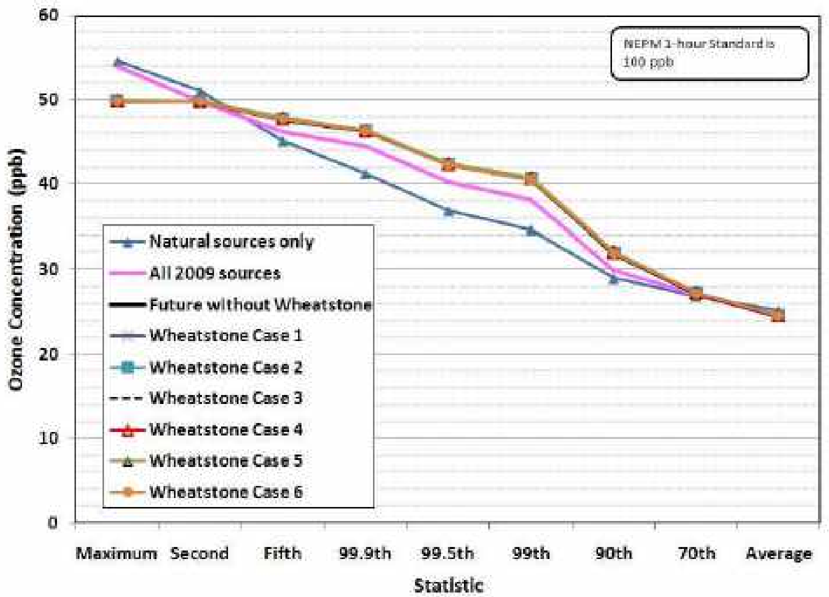

Figure 7-29 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Dampier

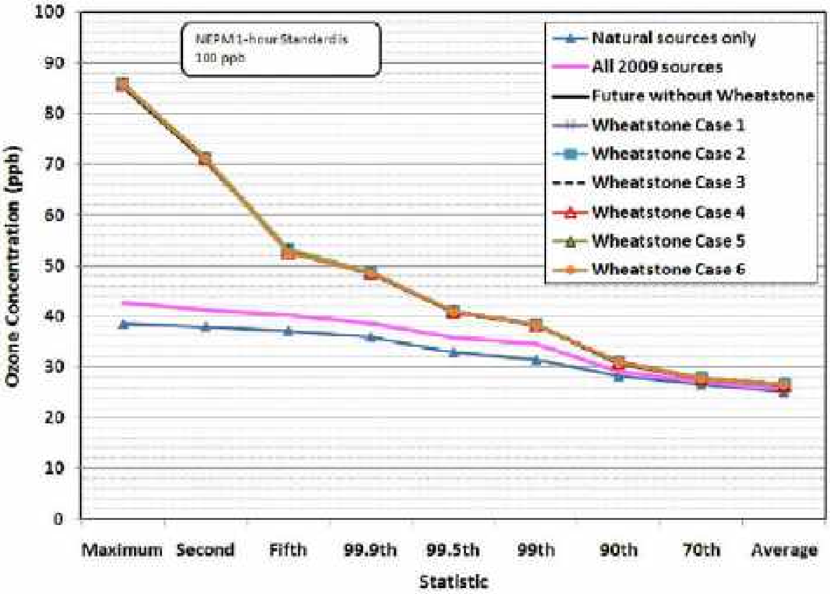

Figure 7-30 Predicted 1-hour ozone concentrations (ppb) for various scenarios at Barrow Island Chevron Camp

Figure 7-24 to **Figure 7-30** indicate that:

- Existing 2009 industrial sources have generally made a small (several ppb) increase in the ozone levels for the 99.9th to 99th percentile concentrations, but a minimal increase to the maximum and second highest concentrations due to "natural" sources;
- With the future sources (excluding the Wheatstone Foundation Project) the 99.9th to 99th percentile concentrations will increase further. Exceptions to this are at Barrow Island where a very large increase in ozone levels is predicted and for Mardie where there is a significant reduction in the maximum and second highest 1-hour ozone levels predictions. This reduction at Mardie as discussed previously is due to the industrial sources impacting on an ozone event on the 7th August that was due to fires as detailed in **Section 7.2.2**. Though the industrial emissions reduce the maximum and second highest 1-hour concentrations, there is generally an increase of a few ppb in ozone levels during the day at Mardie as further illustrated in the time history plot of predicted concentrations in **Figure 7-20**; and

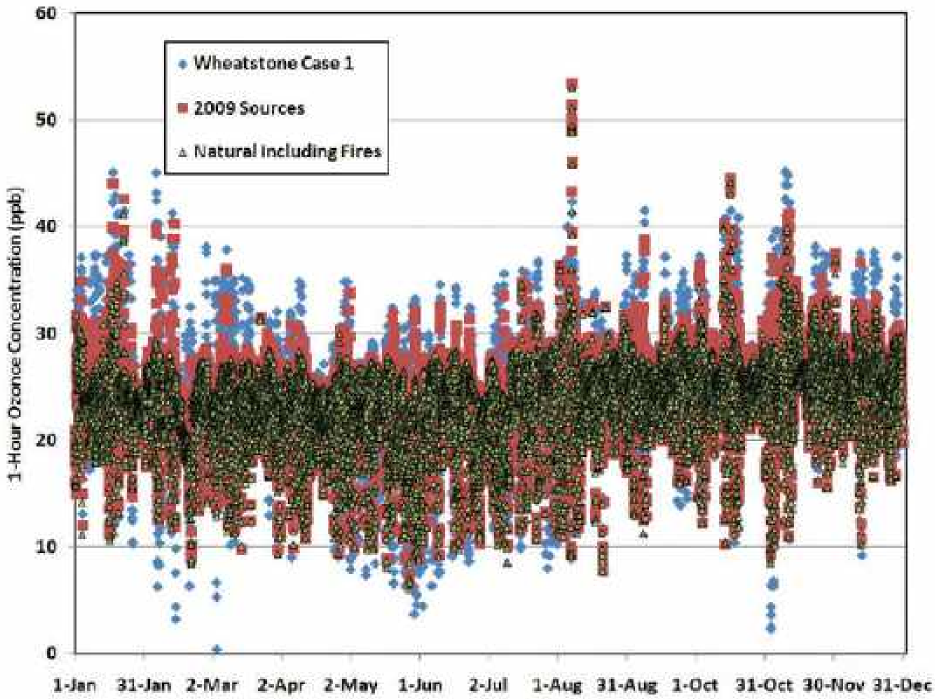

Figure 7-31 Predicted 1-hour O_3 concentrations (ppb) at Mardie for various emission scenarios

- With the addition of the Wheatstone Foundation Project, there is generally negligible change from the future case, even at Onslow. That no change occurs, is as discussed before due to the Wheatstone Foundation Project being a relatively small source compared to other under construction and proposed sources. The exception to the negligible impact from the Wheatstone Foundation Project is for the non routine case of condensate loading which is clearly seen to increase the statistics by several ppb at Onslow at Minderoo station.

8 Conclusions

Chevron is constructing a two Train, 8.9 Mtpa Wheatstone Foundation Project, near Onslow in the Pilbara region of Western Australia. In the environmental impact assessment, predictions of the atmospheric pollutants for the proposed 5 train project were presented using the preliminary information at the time. This assessment updates the 2010 assessment, using refined emission estimates, improved modelling systems and presents additional pollutants for the Foundation Project.

To assess the air pollution impacts, two models have been utilised - AERMOD for predicting local impacts on a scale out to 13 km from the plant and TAPM-CTM for predicting regional scale ozone and NO_2.

The results from the local AERMOD modelling, including the Foundation Project and the existing sources (the Macedon Project and Onslow power station) indicate that:

- The predicted concentrations outside the lease boundaries are relatively low compared to their respective criteria, with the 1-hour NO_2 concentrations being closest, up to 21.5% of the relevant criterion, and all other pollutants contributing less than 5% of their respective criteria;
- For all the Wheatstone operating scenarios assessed, there is generally little variation in the predicted concentrations apart from the ship loading condensate scenario – case 5. That the emissions from the various flaring scenarios do not significantly change the predicted concentrations is a result of the very large amount of heat released and subsequent large plume rise from the flares. For the condensate loading case, though the concentrations do increase they are still low, at most 3.6% of the annual average benzene criterion and 0.65% of the 24-hour xylenes criterion outside the lease boundary on land.

The results from the regional TAPM-CTM modelling for the modelled year (2009), indicate that:

- Maximum existing ozone concentrations at isolated areas in the Pilbara are relatively high, with the major contributor being emissions from bush fires. The maximum existing ozone concentrations predicted anywhere on the model grid are 87 and 95% of the 1-hour and 4-hour ozone standards respectively. Using what is considered the more appropriate second highest concentration when including natural sources, the predicted concentrations are 74 and 86% of the standard;
- With the addition of future industry and the Wheatstone Foundation Project, the maximum ozone concentrations predicted anywhere on the model grid remain essentially unchanged and, for some statistics and averaging periods, will even decrease. The minor impact or even reduction is due both to fires being the dominant source and the non linearity in the atmospheric chemical reactions, where additional NO_2 can (in some circumstances) reduce ozone concentrations;
- At residential locations, the predicted maximum 1-hour ozone concentrations for existing sources are between 43 to 60 ppb. With the addition of future industry (excluding the Wheatstone Foundation Project), these maximums are predicted to increase only marginally, typically less than 1 ppb. The exceptions to this are at Barrow Island where a large increase in ozone levels is predicted due to the Gorgon project and for Mardie where there is a significant

reduction in the maximum and second highest 1-hour ozone concentrations. This reduction at Mardie is due to the industrial sources impacting on a smog event due to fire emissions, where the additional NO_2 is predicted to reduce the ozone formation; and

- With the addition of the Wheatstone Foundation Project, under routine operations there is predicted to be negligible change in the concentrations at residential sites (including Onslow) apart from the Minderoo station with increases of no more than 1 ppb. For the non routine scenarios, the above result applies, except for the ship-loading condensate case where an increase of up to 3 ppb in the 1-hour concentrations at Minderoo station is predicted, though with the concentrations still being only 45% of the 1-hour NEPM standard. That the Wheatstone Foundation Project has such a minor impact on ozone concentrations is due to the emissions being relatively small, estimated to comprise only 0.13 to 4.9% of future anthropogenic emissions in the Pilbara. Therefore overall impacts on regional air quality from the Wheatstone Foundation Project are small.

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Appendix A Comparison to 2010 Modelling

A.1 Introduction

As required by the scope of work, this section provides:

- A review of the concerns raised in Air Assessments (2010a) and how these have been addressed in this study; and
- Provides a comparison of the emissions used in 2010 and here (2013) and of the predicted concentrations between the studies.

A.2 Summary of the 2010 Assessment

Table A-1 provides a summary of the concerns raised in Air Assessments (2010a) and how they have been addressed in this study.

Table A-1 Modelling Concerns Raised with the 2010 Assessment

Item #	Concerns Raised	How Addressed in this Study
1	Omission of other sources. The 2010 modelling omits fires and other nearby sources such as on Thevenard island, the Onslow power station and regional projects under construction, the Gorgon Project, Cape Preston sources and the Black Devil gas plant.	All sources were incorporated apart from Thevenard island as this is being decommissioned in 2014.
2	Background ozone levels were assumed to be on the low side. The 2010 modelling predicted average over water ozone levels of 17 to 18 ppb and over land average concentrations of 15 to 16 ppb, with maximum 1and 4-hour concentrations at Onslow of 19ppb for the natural source case (SKM, 2010, Figure 9.3 and 9.4).	Background average ozone concentrations were set to vary from 15 to 25 ppb, based on regional measurements.
3	RSmog emissions (used in the GRS scheme) were considered low (total of 0.0403 g/s) by a factor of approximately 10. Therefore the amount of reactive VOCs emissions may have been understated.	This study has used the CTM methodology and actual VOC emissions and therefore does not need to estimate Rsmog.
4	The ozone domain used to show concentrations was small (84 by 84 km) with the boundaries only 40 to 60 km from Wheatstone site, such that maximum ozone levels potentially did not form within the model domain.	Used larger inner grid presenting results out to Karratha.
5	Emissions from the TO when offline were not modelled.	When the TO is offline, the AGRU VOCs will be directed to the flare and therefore still be combusted and therefore this is not an issue.
6	VOC from condensate ship loading should be incorporated.	Included.
7	TAPM-GRS is only a screening model.	Used the more accurate TAPM-CTM model.
8	Landuse specification was approximate	Improved modified land use.
9	Existing dust levels were not quantified.	Dust from ambient monitoring was analysed but was not of sufficient quality to be used.
10	Did not include shipping emissions.	Shipping emissions included in regional modelling and assessed in the local modelling as to its significance.
11	Surface biogenic file only covers 100 by 100 km. Therefore potentially understates VOC and NO_X from this source	Not a major VOC source, but is addressed in the CTM modelling here.
12	Buoyancy enhancement omitted. This will be a conservative assumption.	Adopted here for GTGs and GTs
13	Surface emission file mixed over one vertical layer only. This leads to conservative, high, concentrations from surface sources.	Not used in the CTM modelling.
14	Criteria for Benzene. The report uses the NEPM investigation level, but it is suggested it is more appropriate to use the new lower European Union values. The NEPM benzene levels are only for reporting purposes and not health based reasons and are now dated.	Updated using lower European benzene criteria.

A.2 Comparison of the 2010 and 2013 Emissions

A comparison of the emission parameters used in 2010 (SKM, 2010) and as provided for this study are presented in Table A-2. The 2010 emissions have been extracted from the emission sources from two trains and associated operations such that a true comparison can be made.

Table A-2 Comparison of 2010 and 2013 Stack Emissions for a 2 Train LNG Project

Parameter	#	Stack Height (m)	Stack Tip Diam. (m)	Exit Temp. (deg K)	Exit Velocity (m/s)	Exit Volume (Nm^3/s)	PM (g/s)	NO_X as NO_2 (g/s)	SO_2 (g/s)	Benzene (g/s)	Toluene (g/s)	Xylenes (g/s)	
SKM (2010)													
Acid Gas Thermal Oxidiser	2	35	0.84	624	13.2	3.2	0.00	0.05	0.26	0.136	0.499	0.299	
Compressor Turbine Driver	12	50	2.66	732	31	64.2	0.23	5.50	0.00	0.000	0.000	0.000	
Domgas Acid Gas Incinerator	2	35	0.84	624	13.2	3.2	0.00	0.10	0.00	0.026	0.096	0.057	
Wet gas Flare	1	125	-	-	-	-	0.50	0.31	0.00	0.000	0.000	0.000	
Dry gas Flare	1	125	-	-	-	-	0.50	0.31	0.00	0.000	0.000	0.000	
Marine Flare	1	25	-	-	-	-	0.00	0.00	0.00	0.000	0.000	0.000	
Power generator LM6000	4	36	2.66	802	31	58.6	0.13	4.40	0.00	0.000	0.000	0.000	
Total							**4.28**	**84.5**	**0.52**	**0.324**	**1.19**	**0.712**	
2013 Estimates													**Ratio of Volume to 2010**
Acid Gas Therm Oxidizer	2	35	2.13	858	13.5	12.1	0.026	1.401	0.732	0.157	0.579	0.374	3.77
Comp. Turb. Driver (Bypass)	12	50.7	3.6	741	2.4	7.9	0.026	0.316	0.001	0.000	0.000	0.000	1.36
Comp. Turb. Driver (WHRU)	12	50.7	3.06	584	29.5	79.1	0.237	2.840	0.007	0.000	0.000	0.000	
Domgas Regen Gas Heater	2	39.7	1.19	467	3.3	2.2	0.108	0.221	0.0005	0.004	0.012	0.007	
Domgas Acid Gas Therm. Oxid.	2	35	1.52	1033	10.8	4.8	0.005	0.503	0.117	0.047	0.155	0.100	1.50
HP Flare	1	93.5	-	-	-	-	0.019	0.095	0.000	0.007	0.008	0.004	
Marine flare	1	44.3	-	-	-	-	0.006	0.032	0.0001	0.000	0.000	0.000	
LP Flare	1	44.2	-	-	-	-	0.157	0.774	0.002	0.060	0.061	0.032	
GTG Turbine Drive	4	35	3.28	737	27.7	85.3	0.219	3.569	0.007	0.000	0.000	0.000	1.45
Total							**4.39**	**56.6**	**1.71**	**0.433**	**1.394**	**0.890**	
Emission Ratios (2013 / 2010)							**1.03**	**0.67**	**3.28**	**1.34**	**1.17**	**1.25**	

Table A-2 indicates the following in relation to the 2013 emissions and parameters compared to 2010:

- The BTEX emissions are slightly higher, with SO_2 emissions (though still small) a factor of 3.28 times higher, though with the NO_X emissions being only 0.67 of those used in 2010;
- The flare stacks heights are generally reduced;
- The exhaust volumes to the gas turbines (normalised to 0 deg C), are 36 to 45% higher in 2013, though the NO_X emissions from the gas turbines are lower; and
- The thermal oxidiser has much larger NO_X emissions and volume of air released than in 2010.

Therefore there are reasonably significant updates from the 2010 data, with it considered that predicted ground level concentrations of NO_X would be expected to be lower due to the more buoyant plumes and generally lower emissions.

A.3 Comparison of the Predicted 2010 and 2013 Ground Level Concentrations

Table A-3 presents the predicted concentrations from the 2010 and 2013 routine case at two locations; the maximum predicted anywhere on the model grid and at Onslow. It is noted that the 2010 modelling is for a five train assessment and the 2013 modelling is for a 2 train assessment. As such, the 2010 modelling should be expected to have generally higher concentrations.

Table A-3 Predicted Concentrations[a] for Wheatstone 25 Mtpa (SKM, 2010) and Wheatstone 8.9 Mtpa (this study)

Pollutant	Ave. Period	Criteria	Units	SKM 2010 (Max on Grid)	SKM 2010 (Onslow)	This Study (Max on Grid)	This Study (Onslow)
NO_2	1-hour	120	(ppb)	42	26	40	11.5
NO_2	Annual	30	(ppb)	3.2	0.5	5	1.5
SO_2	1-hour	200	(ppb)	3.5	0.8	1.4	0.3
SO_2	24-hour	80	(ppb)	1.3	0.1	0.7	0.04
SO_2	Annual	20	(ppb)	0.6	<0.1	0.095	0.007
PM_{10}	24-hour	50	($\mu g/m^3$)	27	25	29	27.1
$PM_{2.5}$	24-hour	25	($\mu g/m^3$)	-	-	8	6.1
$PM_{2.5}$	Annual	8	($\mu g/m^3$)	-	-	5.3	5.03
Ozone	1-hour	100	(ppb)	44	38	86	46
Ozone	4-hour	80	(ppb)	40	34	75	44
Benzene	Annual	5	($\mu g/m^3$)	0.96[b] -	- -	0.13 (0.9)	0.065 (0.079)
Toluene	24-hour	1000	(ppb)	1	- [c]	0.45 (33)	0.07 (0.53)
Toluene	Annual	100	(ppb)	0.5	- [c]	0.11 (0.55)	0.055 (0.06)
Xylenes	24-hour	250	(ppb)	1.3	- [c]	0.27 (16)	0.07 (0.25)
Xylenes	Annual	200	(ppb)	0.6	- [c]	0.045 (0.25)	0.017 (0.022)

Notes :

a) Concentrations include background values and other sources.
b) SKM 2010 benzene concentrations converted from 0.3 ppb.
c) The value was not provided.
d) Value in brackets from the ship loading condensate - Case 5, whilst others.

The comparison of the predicted concentrations in **Table A-3** indicates that the 2013 predictions result in:

- Similar maximum NO_2 concentrations on the grid, but half the NO_2 concentrations at Onslow in agreement with the comments in **Section A.2**;
- Higher ozone concentrations, both regionally and at Onslow, due primarily to the inclusion of fire emissions;
- For routine operations, lower benzene, toluene, xylenes concentrations than in 2010; and
- Lower SO_2 concentrations, which occur though the 2013 SO_2 emissions are higher, the main source, the RTO has a much more buoyant plume than modelled in 2010.

Table A-3 therefore indicates fair agreement between the 2010 and 2013 modelling, indicating no major changes in the model predictions, apart from ozone levels where the cumulative concentrations are predicted to be higher (though with minor contribution from the Wheatstone Foundation Project).

Appendix B Predicted Concentrations at Select Discrete Receptors

Section 6 provides the maximum predicted concentrations from the Wheatstone Foundation Project at any location on the model grid and outside the lease boundary. Other locations of interest are listed in **Figure B-1**.

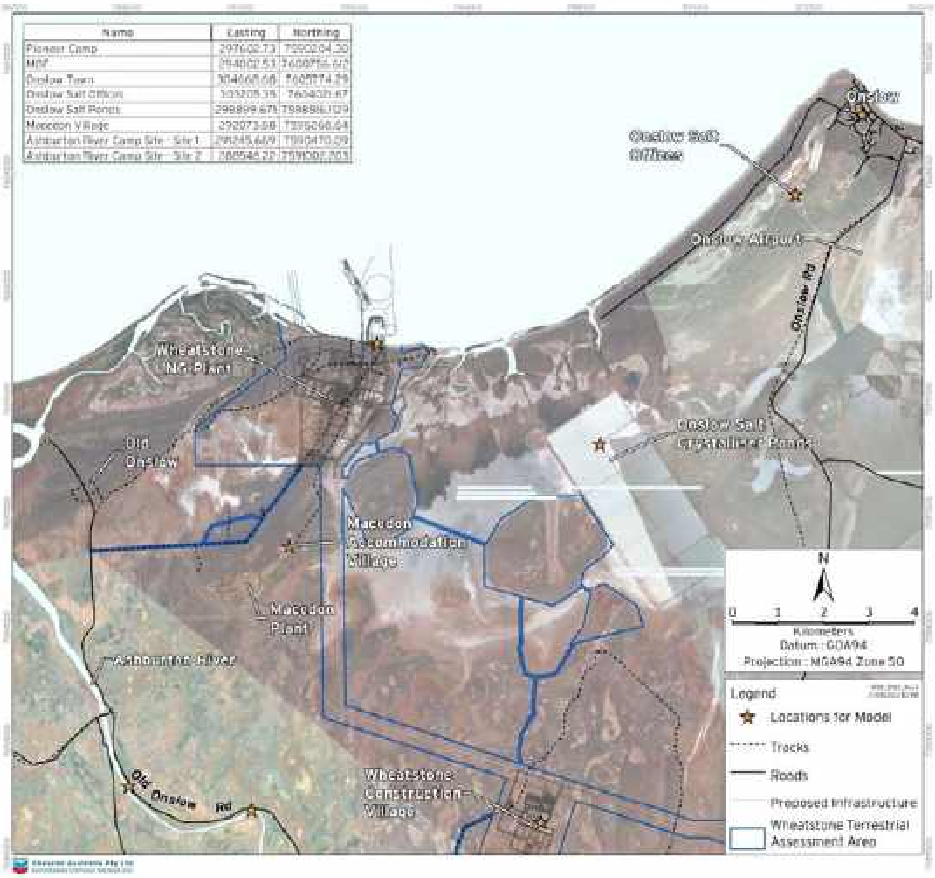

Figure B-1 Locations of Discrete Receptors

Predicted concentrations for pollutants at these locations for the pollutants with concentrations greater than 1% of their criteria from the local modelling routine case and benzene concentrations from the ship-loading case are presented in **Table B-1** and as a percent of their criteria in **Table B-2** without background concentrations included. **Table B-3** and **Table B-4** present the concentrations statistics with background concentrations included.

Table B-1 Predicted Local Concentrations at Discrete Receptors – Without Background Levels

Pollutant	Ave	Criteria	Units	Max on Grid	Outside Lease	Pioneer Camp	MOF	Onslow	Onslow Salt	Macedon Village	Ashbur. R. Site 1	Ashbur. R. Site 2
Routine												
NO_2	1-hour	120	(ppb)	38.1	25.8	9.8	14	9.5	25.8	11	6	9
NO_2	Annual	30	(ppb)	8.2	2.9	0.06	0.55	0.45	2.5	0.6	0.06	0.06
PM_{10}	24-hour	50	(μg/m³)	2.1	1.2	0.07	0.7	0.14	0.13	0.6	0.1	0.2
$PM_{2.5}$	24-hour	25	(μg/m³)	2.1	1.2	0.07	0.7	0.14	0.13	0.6	0.1	0.2
$PM_{2.5}$	Annual	8	(μg/m³)	0.32	0.24	0.011	0.1	0.03	0.03	0.12	0.01	0.01
Benzene	Annual	5	(μg/m³)	0.065	0.04	0.0008	0.017	0.0045	0.0045	0.0018	0.0007	0.0008
H_2S	1-hour	1.11	(μg/m³)	0.02	0.012	0.002	0.01	0.0028	0.0028	0.004	0.002	0.002
Ship-loading Condensate												
Benzene	Annual	5	(μg/m³)	0.87	0.18	0.0045	0.22	0.015	0.019	0.01	0.003	0.004

Note. Includes all concentrations outside the lease that are over 1% of the criteria.

Table B-2 Predicted Local Concentrations (as a Percent of the Criteria) at Discrete Receptors – Without Background Levels

Pollutant	Ave	Criteria	Units	Max on Grid (%)	Outside Lease (%)	Pioneer Camp (%)	MOF (%)	Onslow (%)	Onslow Salt (%)	Macedon Village (%)	Ashbur. R. Site 1 (%)	Ashbur. R. Site 2 (%)
Routine												
NO_2	1-hour	120	(ppb)	31.8	21.5	8.2	11.7	7.9	21.7	9.2	5.0	7.5
NO_2	Annual	30	(ppb)	27.3	9.7	0.2	1.8	1.5	8.3	2.0	0.2	0.2
PM_{10}	24-hour	50	(μg/m³)	4.2	2.4	0.1	1.4	0.3	0.3	1.2	0.2	0.4
$PM_{2.5}$	24-hour	25	(μg/m³)	8.4	4.8	0.3	2.8	0.6	0.5	2.4	0.4	0.8
$PM_{2.5}$	Annual	8	(μg/m³)	4.0	3.0	0.1	1.3	0.4	0.4	1.5	0.1	0.1
Benzene	Annual	5	(μg/m³)	1.3	0.8	0.016	0.34	0.09	0.09	0.036	0.014	0.016
H_2S	1-hour	1.11	(μg/m³)	1.8	1.1	0.2	0.9	0.3	0.3	0.4	0.2	0.2
Ship-loading Condensate												
Benzene	Annual	5	(μg/m³)	17.4	3.6	0.09	4.4	0.3	0.38	0.2	0.06	0.08

Note. Includes all concentrations outside the lease that are over 1% of the criteria.

Table B-3 Predicted Local Concentrations at Discrete Receptors – With Background Levels

Pollutant	Ave	Criteria	Units	Max on Grid	Outside Lease	Pioneer Camp	MOF	Onslow	Onslow Salt	Macedon Village	Ashbur. River Site 1	Ashbur. River Site 2
Routine												
NO_2	1-hour	120	(ppb)	40.1	27.8	11.8	16.0	11.5	28.0	13.0	8.0	11.0
NO_2	Annual	30	(ppb)	9.2	3.9	1.1	1.6	1.5	3.5	1.6	1.1	1.1
PM_{10}	24-hour	50	($\mu g/m^3$)	29.1	28.2	27.1	27.7	27.1	27.1	27.6	27.1	27.2
$PM_{2.5}$	24-hour	25	($\mu g/m^3$)	8.1	7.2	6.1	6.7	6.1	6.1	6.6	6.1	6.2
$PM_{2.5}$	Annual	8	($\mu g/m^3$)	5.32	5.24	5.01	5.10	5.03	5.03	5.12	5.01	5.01
Benzene	Annual	5	($\mu g/m^3$)	0.13	0.1	0.061	0.077	0.065	0.065	0.062	0.061	0.061
H_2S	1-hour	1.11	($\mu g/m^3$)	0.02	0.012	0.002	0.01	0.0028	0.0028	0.004	0.002	0.002
Ship-loading Condensate												
Benzene	Annual	5	($\mu g/m^3$)	0.93	0.24	0.065	0.28	0.075	0.079	0.07	0.063	0.064

Note. Includes all concentrations outside the lease that are over 1% of the criteria

Table B-4 Predicted Local Concentrations (as a Percent of the Criteria) at Discrete Receptors – With Background Levels

Pollutant	Ave	Criteria	Units	Max on Grid (%)	Outside Lease (%)	Pioneer Camp (%)	MOF (%)	Onslow (%)	Onslow Salt (%)	Macedon Village (%)	Ashbur. River Site 1 (%)	Ashbur. River Site 2 (%)
Routine												
NO_2	1-hour	120	(ppb)	33.4	23.2	9.8	13.3	9.6	23.3	10.8	6.7	9.2
NO_2	Annual	30	(ppb)	30.7	13.0	3.5	5.2	4.8	11.7	5.3	3.5	3.5
PM_{10}	24-hour	50	($\mu g/m^3$)	58	56	54	55	54	54	55	54	54
$PM_{2.5}$	24-hour	25	($\mu g/m^3$)	32	29	24	27	25	25	26	24	25
$PM_{2.5}$	Annual	8	($\mu g/m^3$)	67	66	63	64	63	63	64	63	63
Benzene	Annual	5	($\mu g/m^3$)	2.5	2.0	1.2	1.5	1.3	1.3	1.2	1.2	1.2
H_2S	1-hour	1.11	($\mu g/m^3$)	1.8	1.1	0.2	0.9	0.3	0.3	0.4	0.2	0.2
Ship-loading Condensate												
Benzene	Annual	5	($\mu g/m^3$)	18.6	4.8	1.3	5.6	1.5	1.6	1.4	1.3	1.3

Note. Includes all concentrations outside the lease that are over 1% of the criteria

Table B-1and **Table B-2** indicate that concentrations are generally low with the pollutant closest to its criteria being the 1-hour NO_2 concentrations at Onslow Salt which is due to the Onslow power station near there and not the Wheatstone Foundation Project. Apart from that, the predicted concentrations from the Wheatstone Foundation Project are very low.

Inclusion of the background concentrations in **Table B-3** and **Table B-4** only appreciably changes the particulate concentrations relative to their criteria, but again the concentrations are well below the criteria and not of concern at any location.

Appendix C Local Modelling Including Ship Engine Emissions

C.1 Introduction

The local modelling in **Section 6** was presented without including ship engines emissions as it was considered that the modelling of these was too uncertain to include. The primary reasons being the uncertainty in estimating emissions (load of the engines, the sulphur content etc), that the model AERMOD was set to model dispersion over the land sources where the LNG plant is and modelling of the plume interaction with ships superstructure. Therefore to provide some indication of the likely levels that may occur, predictions for the routine scenario with the inclusion of the ship engine emissions for the pollutants of most concern from ships, NO_X, SO_2 and PM are presented in the following.

C.2 Predicted Concentrations

Predicted concentrations with ship engine emissions are presented in **Figure C-1** to **Figure C-7** for NO_2, PM and SO_2. These indicate negligible change in the PM concentrations on land and minor change in the NO_2 concentrations on land except for small increase in the area near to the ships berth. The largest increase occurs for the predicted SO_2 concentrations due to the assumed high sulphur content in condensate carriers heavy fuel oil, but these are remain only a small fraction of the SO_2 criteria. The maximum 1-hour SO_2 concentration on land outside the lease boundary is predicted to increase to 10 ppb, which is 5% of the NEPM 1-hour standard, the 24-hour concentration to 0.5 ppb, which is 0.6% of the 24-hour standard and the annual average to 0.046 ppb which is 0.2% of the annual average standard.

Therefore inclusion of ship engine emissions is not considered to change the predicted local concentrations, especially at nearby sensitive receptor locations.

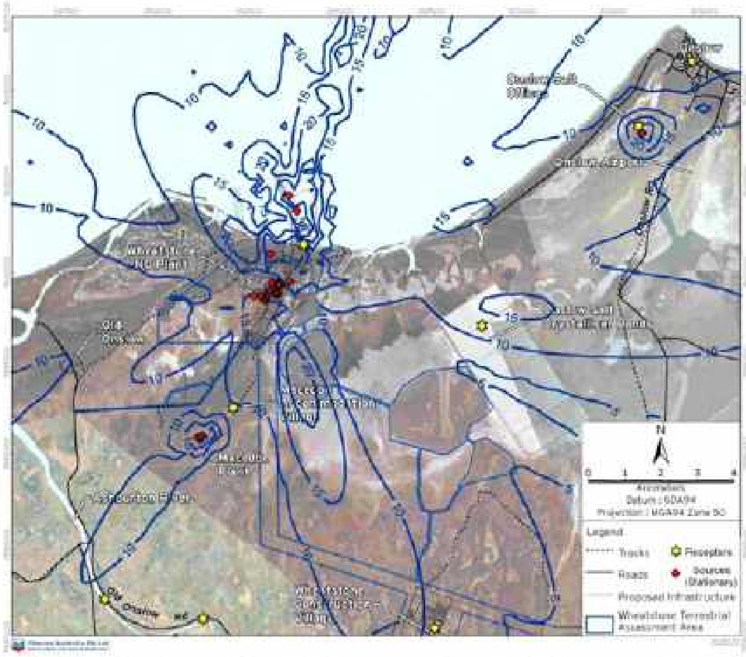

Figure C-1 Predicted maximum 1-hour NO_2 concentrations (ppb) from normal operation with shipping engine emissions

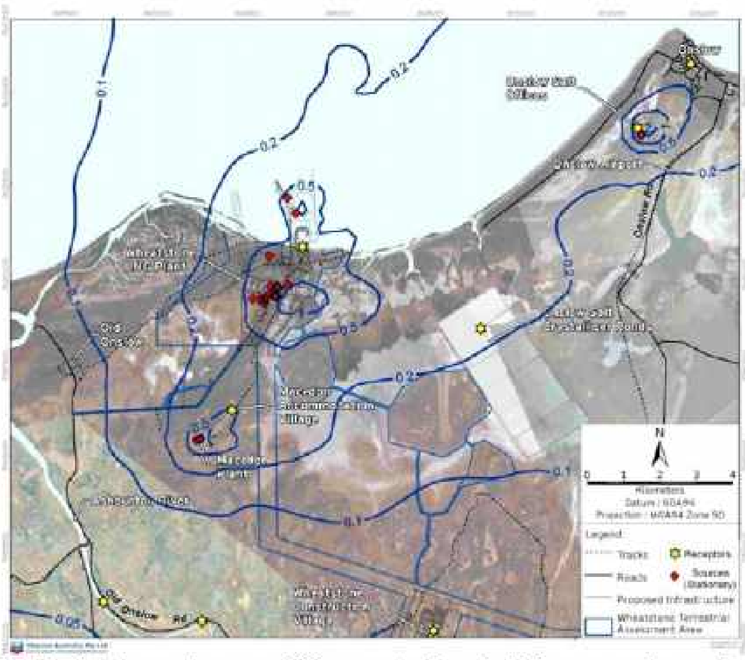

Figure C-2 Predicted annual average NO_2 concentrations (ppb) from normal operation with shipping engine emissions

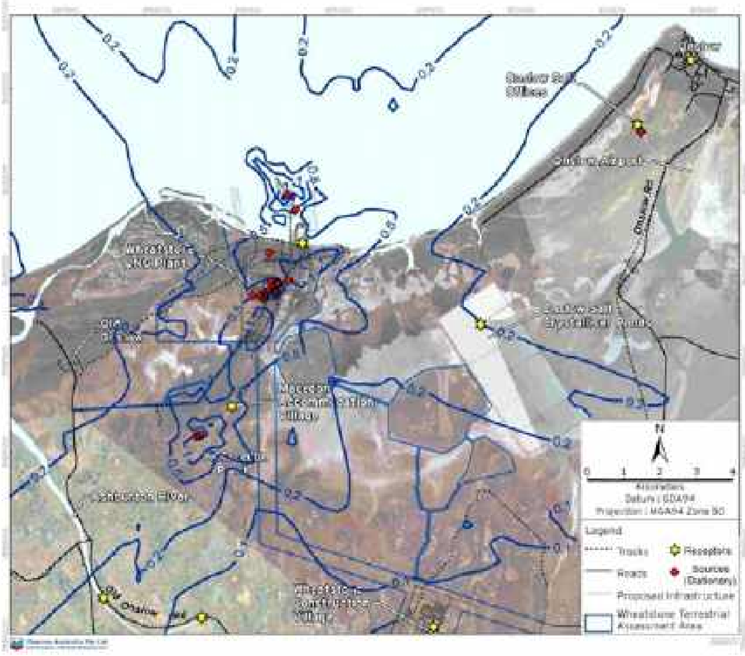

Figure C-3 Predicted maximum 24-hour average $PM_{2.5}$ (or PM_{10}) concentrations ($\mu g/m^3$) from normal operation with shipping engine emissions

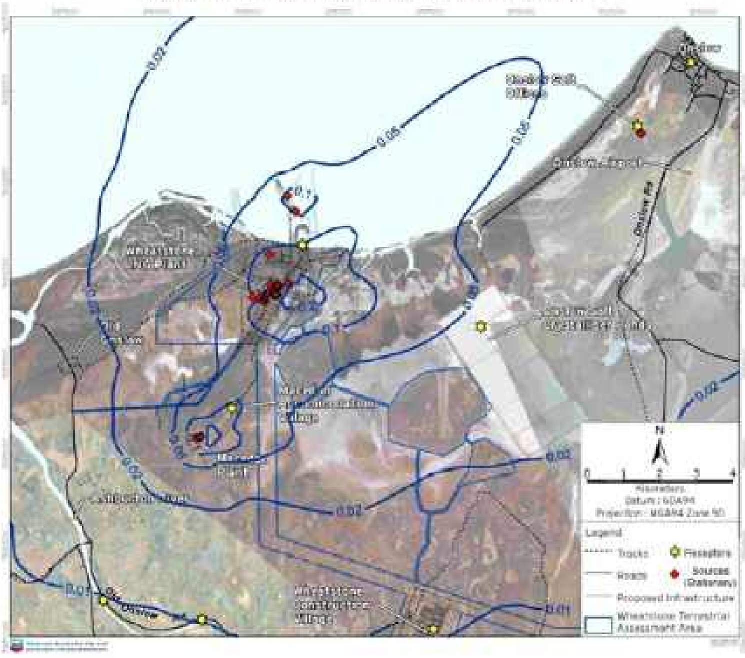

Figure C-4 Predicted annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) from normal operation with shipping engine emissions

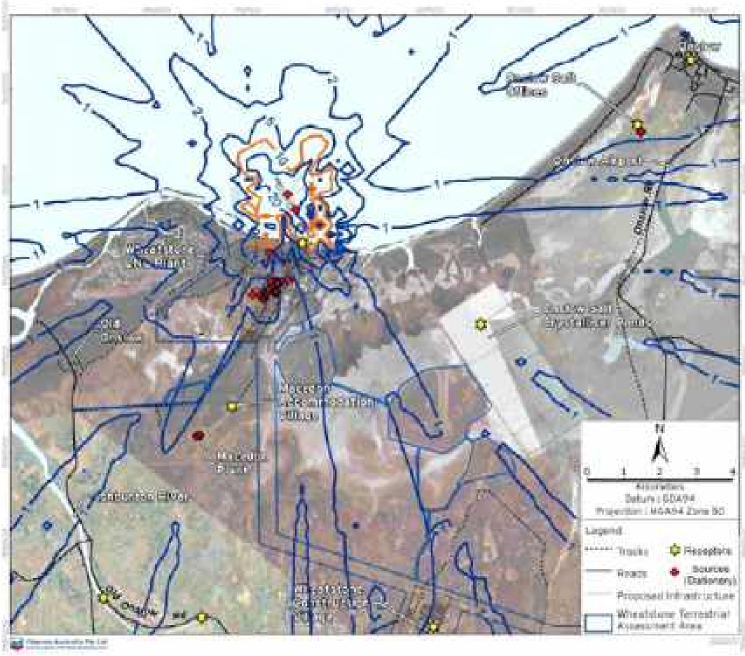

Figure C-5 Predicted maximum 1-hour average SO_2 concentrations ($\mu g/m^3$) from normal operation with shipping engine emissions. Orange level just to highlight contour.

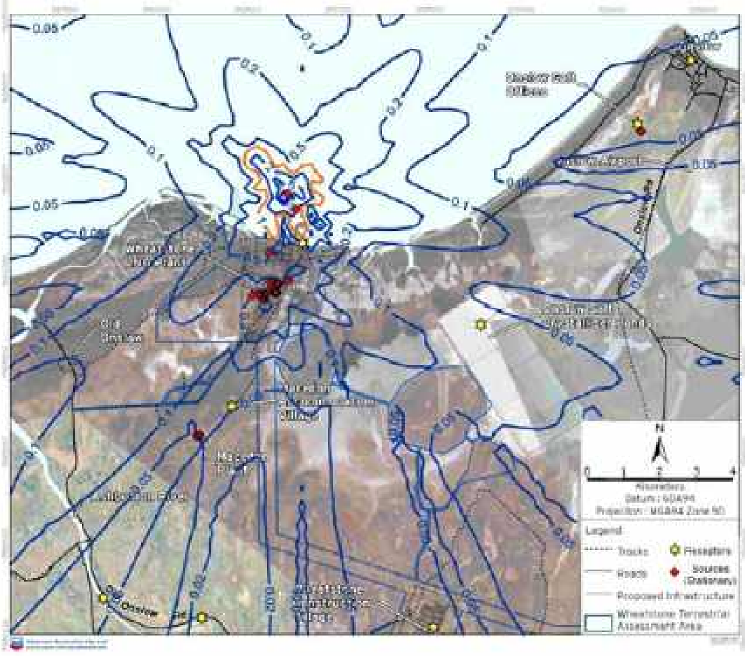

Figure C-6 Predicted maximum 24-hour average SO_2 concentrations ($\mu g/m^3$) from normal operation with shipping engine emissions. Orange level just to highlight contour

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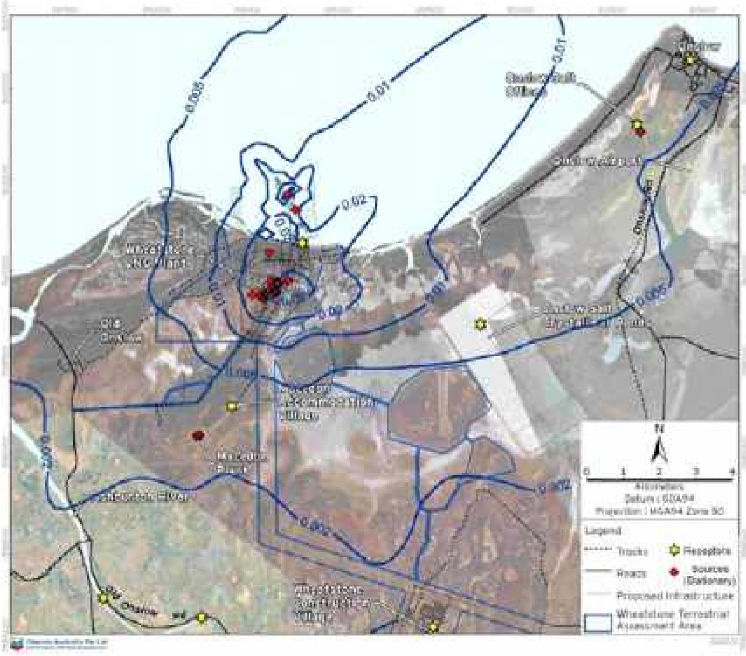

Figure C-7 Predicted annual average SO_2 concentrations ($\mu g/m^3$) from normal operation with shipping engine emissions

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APPENDIX D:

WHEATSTONE PROJECT
ENVIRONMENTAL NOISE IMPACT ASSESSMENT

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Wheatstone Project

Title: Environmental Noise Impact Assessment

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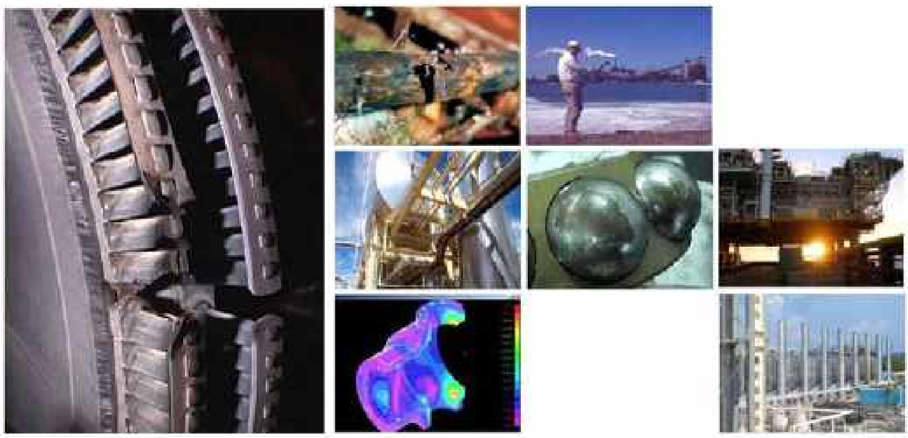
ENVIRONMENTAL NOISE IMPACT ASSESSMENT - CHEVRON WHEATSTONE LNG PLANT



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Client: URS Australia Pty Ltd

Client Contact: Chris Thomson

SVT Contact: Jim McLoughlin

SVT Office: Perth

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SVT Engineering Consultants ABN: 18 122 767 944		
SVT Perth (HEAD OFFICE)	SVT Kuala Lumpur Office	SVT Melbourne Office
112 Cambridge Street West Leederville WA 6007 Australia Tel: +61 (0)8 9489 2000 Fax: +61 (0)8 9489 2088 Email: mailbox@svt.com.au	SVT-Engineering Malaysia Sdn Bhd (Malaysian Office) 62A, Jalan Badminton 13/29, Tadisma Business Centre, 40100 Shah Alam, Selangor, Malaysia Tel: +603 5513 6487 (h/p 012 330 1071) Fax: +603 5513 6486 Email: mailbox@svt.com.au	Suite 1, 20 Cato Street Hawthorn East, VIC 3123 Australia Tel: +61 (0)3 9832 4406 Fax: +61 (0)3 9917 2204 Email: mailbox@svt.com.au

EXECUTIVE SUMMARY

Introduction

This study presents an assessment of potential noise impacts from the proposed Chevron Wheatstone Liquefied Natural Gas Plant near Onslow in Western Australia on surrounding noise sensitive receptors. Noise emissions from normal plant operations, emergency flaring and piling during construction have been assessed. The study considers airborne noise impacts in relation to humans. Noise impacts on fauna are beyond the scope of this assessment.

Methodology

The assessment methodology follows the procedure outlined in Environmental Protection Authority's (EPA) Draft Guidance No. 8[1] for assessing noise impacts in accordance with the Environmental Protection (Noise) Regulations 1997 which operate under the Environmental Protection Act 1986.

A noise model has been developed and used to predict noise levels associated with normal plant operations, emergency flaring and construction piling at receptors in the vicinity of the plant. Noise contours for the study area have also been prepared. Noise predictions and contours are for worst-case weather conditions for sound propagation.

Ambient noise levels at 5 locations in the vicinity of the proposed development site have been measured to establish current background noise levels prior to construction.

Predicted noise levels have been compared with regulatory noise limits and ambient noise levels to determine noise impacts.

Baseline Conditions

Ambient noise levels have been monitored at five locations in the vicinity of the proposed development site:

- Onslow Town Site (nearest residential area);
- 4 Mile Creek (public access beach and popular fishing and BBQ area);
- 5 Mile Pool (camping area);
- Old Onslow Heritage Site (original site of Onslow);
- 10 Mile Dam (proposed location of workforce accommodation camp)

The noise model has been used to predict noise levels at the same locations as well as at the boundary of Onslow Salt which is the nearest industrial receptor to the proposed plant. These locations are shown in the following figure.

[1] EPA Draft Guidance No. 8, May 2007

Monitoring and Prediction Locations

A summary of the ambient noise monitoring data is provided below. The data presented is representative of the quietest background noise levels. The monitored noise levels are very low, particularly at remote inland locations. Monitored levels at coastal locations (Onslow town site and 4 Mile Creek) are slightly higher due to the influence of ocean noise and human activity.

Summary of Ambient Noise Levels

	Underlying Background Noise Level LA90		
	Day time	Evening	Night-time
Onslow Town Site	31	35	28
4 Mile Creek	30	36	32
5 Mile Pool	25	21	<20
Old Onslow (heritage site)	23	22	<20
10 Mile Dam (likely construction camp location)	22	<20	<20

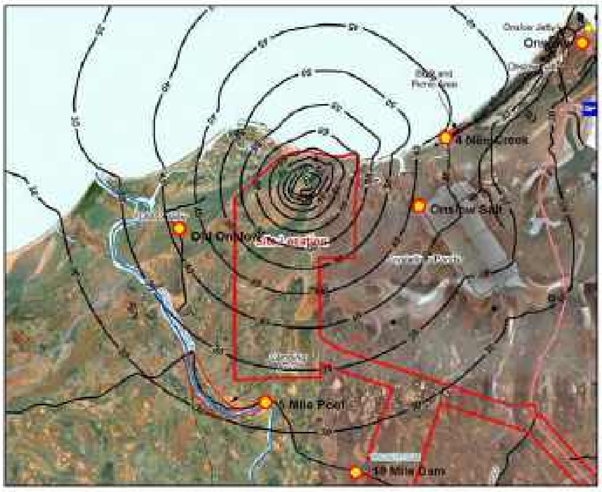
Results

A summary of predicted noise levels for normal plant operations, emergency flaring and pile driving under worst-case sound propagation conditions is presented in the following table and noise contours.

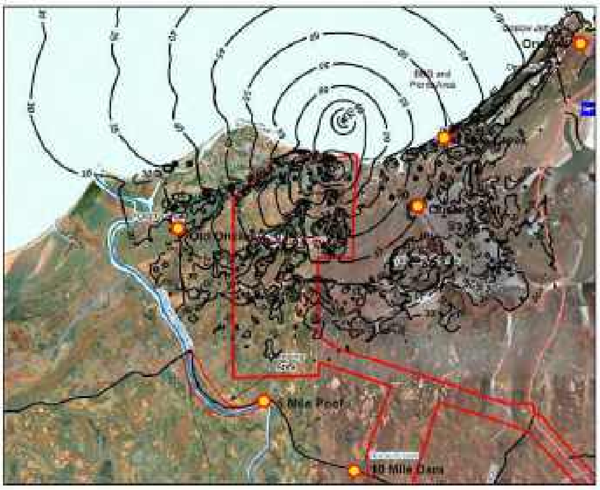
Predicted Noise Levels for Worst-case Sound Propagation Conditions

	Predicted Noise Level – dB(A)		
	Normal Plant Operation	Emergency Flaring	Construction Piling
Onslow Town Site	27	30	31
4 Mile Creek	37	41	48
5 Mile Pool	28	32	26
Old Onslow	36	41	35
10 Mile Dam	24	27	22
Onslow Salt	35	41	41

Noise Contours for Normal Plant Operation



Noise Contours for Emergency Flaring



Noise Contours for Piling During Construction

Conclusion

Predicted noise levels for normal plant operation are compliant with the most stringent night-time assigned noise levels imposed under the Environmental Protection (Noise) regulations 1997 assuming that industry standard noise controls are applied to compressor piping and gas turbines.

The LNG plant is unlikely to be audible above background noise at Onslow town site even under worst-case meteorological conditions for sound propagation.

The proposed location for the workforce accommodation camp is sufficiently distant from the LNG plant site that received noise levels will be significantly below the assigned noise levels.

Predicted noise levels for normal plant operation at the public access areas (4 Mile Creek, 5 Mile Pool and Old Onslow) are higher than underlying background noise. It is possible, therefore, that plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation.

Predicted noise levels from emergency flaring comply with the assigned noise levels.

It is feasible (although unlikely) that noise from piling during construction could exceed assigned noise levels at Onslow if the received noise protrudes sufficiently above background levels to exhibit impulsive characteristics. It is, therefore, recommended that noise monitoring be undertaken during piling so as to determine whether or not noise mitigation measures are warranted.

TABLE OF CONTENTS

1. INTRODUCTION

This report provides an assessment of potential airborne noise impacts from the proposed Chevron Wheatstone Liquefied Natural Gas (LNG) plant near Onslow in Western Australia.

1.1 Description of Proposal

Chevron proposes to construct and operate a multi train LNG and domestic gas (domgas) plant on the Pilbara Coast. Gas, condensate and water will enter the main processing plant where the gas and condensate will be processed for export. The key components for processing and export will comprise:

- Separation of gas, liquid and water streams;
- Pre-treatment of the gas stream to remove acid gases, water and other contaminants;
- LNG trains to liquefy the gas;
- LNG storage and loading facilities;
- Domestic gas (domgas) plant;
- Water management;
- Condensate stabilisation and storage;
- LNG and condensate tanks;
- Port facilities including jetties and material offloading facilities.

The current design shows two LNG trains and two domgas plants. (See site layout reproduced in Appendix A.) However, space is provided for future LNG trains and domgas plants. This study assumes 5 operating LNG trains and associated domgas plants.

Construction of the facility will require extensive piling operations which are scheduled to occur 24 hours per day, 7 days per week for approximately 14 months.

1.2 Receptors

The proposed LNG plant is remote from any noise sensitive premises, with the nearest residential area (Onslow Town Site) some 12 km to the north-east of the development site. The nearest industrial receptor is Onslow Salt, approximately 4 km to the east. A workforce accommodation camp is also proposed at location know as 10 Mile Dam approximately 12 km to the south of the development site. The noise model has been used to predict noise levels at these locations.

In addition, noise predictions have also been undertaken for the following public access areas:

- 4 Mile Creek. This is a public access beach approximately 4 km to the east of the development site which is a popular fishing and BBQ area.
- 5 Mile Pool. This area is used for camping and is located approximately 10 km to the south of the development site.
- Old Onslow. This heritage listed area is the site of the original town of Onslow and is approximately 5 km to the west of the development site.

All receptors are shown in the noise contours presented in Appendix B.

1.3 Scope of Study

The following list outlines the major activities undertaken during the course of this study:

- Assessment of existing ambient noise levels in the vicinity of the proposed development;
- Review of documentation provided by URS including a site layout and preliminary noise emission data;
- Development of an acoustic model to represent normal operating conditions and emergency flaring for the LNG plant;
- Plotting of noise contours around the proposed LNG plant for worst case meteorological conditions for sound propagation;
- Prediction of noise levels at the receptors described above (section 1.2);
- Assessment of noise emissions from the plant for compliance with noise limits imposed under the Environmental Protection (Noise) Regulations 1997 at the nearest noise sensitive and industrial receptors;
- Identification of high noise equipment items which significantly contribute received noise levels; and
- Review of construction noise impacts associated with pile driving operations.

2. AMBIENT NOISE ASSESSMENT

Ambient noise levels were measured for 1 – 2 weeks at the following five locations in the vicinity of the proposed Project site:

- Onslow Town Site;
- 4 Mile Creek;
- 5 Mile Pool;
- Old Onslow (heritage site);
- 10 Mile Dam (likely construction camp location).

The noise monitoring equipment was set to continuously record $L_{A\,1}$, $L_{A\,10}$ and $L_{A\,90}$ noise levels at 15-minute intervals, where:

- $L_{A\,1}$ is the noise level exceeded for 1% of the time;
- $L_{A\,10}$ is the noise level exceeded for 10% of the time;
- $L_{A\,90}$ is the noise level exceeded for 90% of the time.

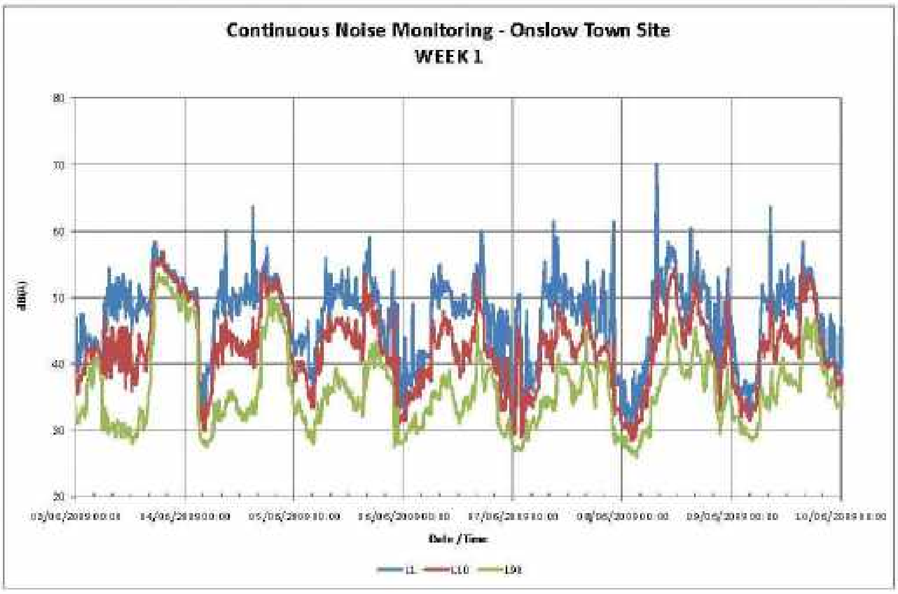
The logging was undertaken from 3 to 17 June 2009.

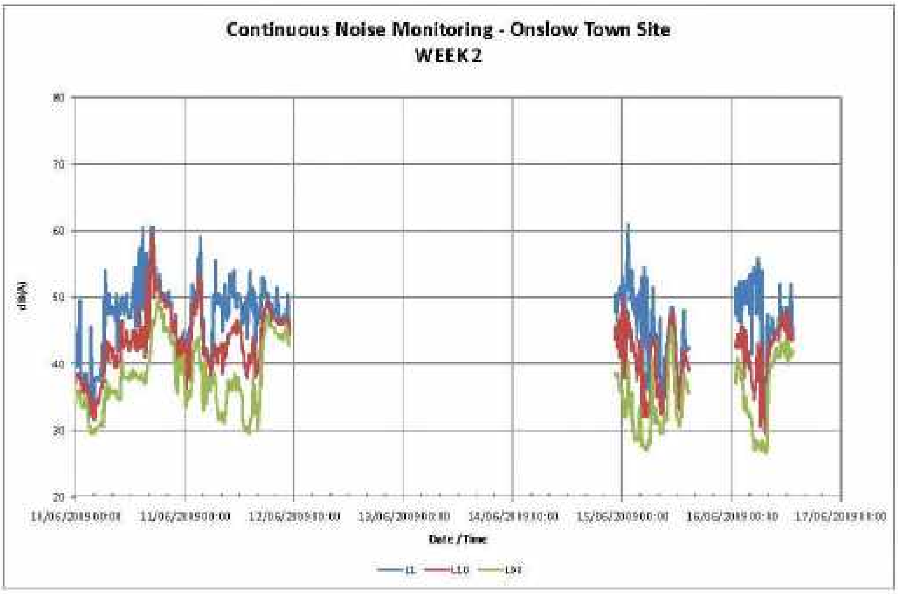
The following sections provide the results of the ambient noise monitoring recorded at each location. Summary tables are provided which include the average $L_{A\,10}$ and $L_{A\,90}$ values collected over the monitoring period during daytime hours, evening hours and night-time hours, and for all periods combined. The standard deviations in the measurement results are also provided. The data have also been analysed to determine the L_{90} (90th percentile) of the $L_{A\,90}$ noise levels for the various time periods. These data provide a good indication of the lowest ambient noise levels. Charts showing the monitored noise data are also presented.

2.1 Onslow Town Site

Table 2-1: Summary of noise logging results for Onslow Town Site

Period	Average $L_{A\,10}$ (dB(A))	Standard deviation in $L_{A\,10}$ (dB)	Average $L_{A\,90}$ (dB(A))	Standard deviation in $L_{A\,90}$ (dB)	L_{90} of $L_{A\,90}$ (dB(A))
Day (0700 to 1900)	44.7	4.7	37.5	5.4	31.0
Evening (1900 to 2200)	44.9	4.9	41.1	5.6	34.5
Night (2200 to 0700)	39.3	5.7	33.7	5.6	28.0
All data	42.6	6.1	36.6	6.1	29.0



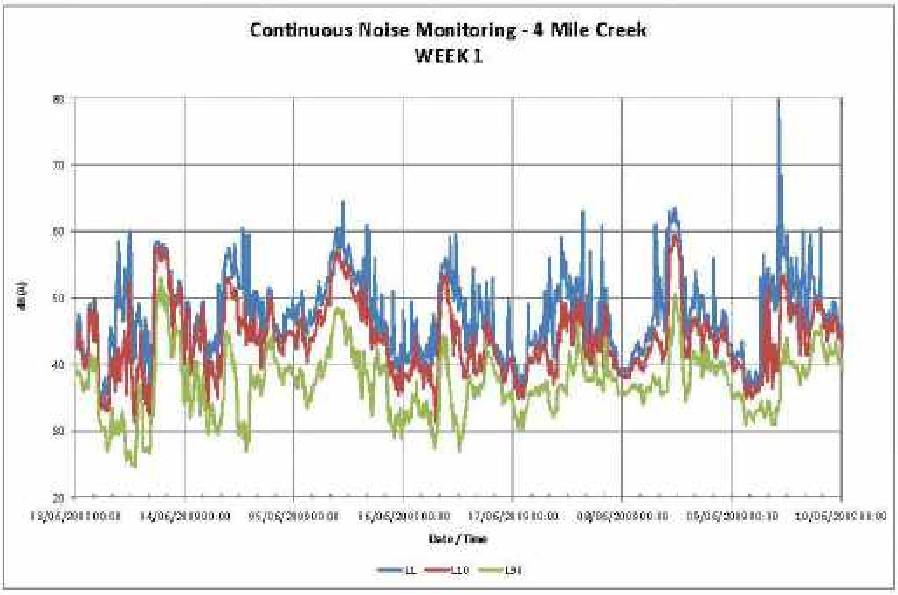


Note that no data was recorded on several occasions during the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.2 4 Mile Creek

Table 2-2: Summary of noise logging results for 4 Mile Creek

Period	Average $L_{A,10}$ (dB(A))	Standard deviation in $L_{A,10}$ (dB)	Average $L_{A,90}$ (dB(A))	Standard deviation in $L_{A,90}$ (dB)	L_{10} of $L_{A,90}$ (dB(A))
Day (0700 to 1900)	45.7	6.0	37.6	5.9	29.5
Evening (1900 to 2200)	44.8	4.0	39.9	3.8	36.3
Night (2200 to 0700)	41.3	3.7	36.0	3.3	31.8
All data	43.7	5.2	37.4	4.8	31.0

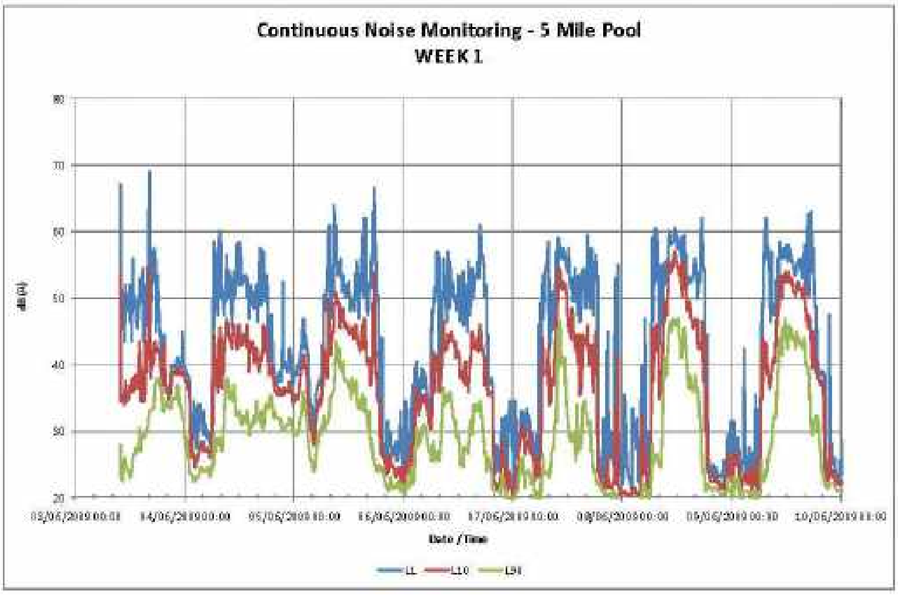


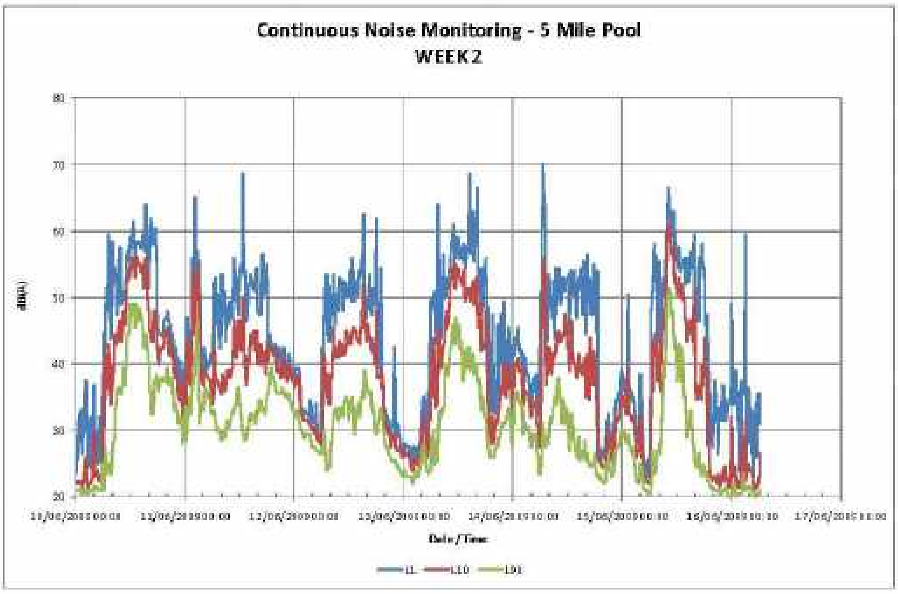
Note that no data was recorded during the second week of the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.3 5 Mile Pool

Table 2-3: Summary of noise logging results for 5 Mile Pool

Period	Average $L_{A,10}$ (dB(A))	Standard deviation in $L_{A,10}$ (dB)	Average $L_{A,90}$ (dB(A))	Standard deviation in $L_{A,90}$ (dB)	L_{90} of $L_{A,90}$ (dB(A))
Day (0700 to 1900)	44.3	5.8	34.1	6.6	25.0
Evening (1900 to 2200)	34.5	8.8	28.1	6.1	21.0
Night (2200 to 0700)	30.2	7.3	24.5	7.8	<20
All data	36.9	9.5	29.2	8.2	21.0

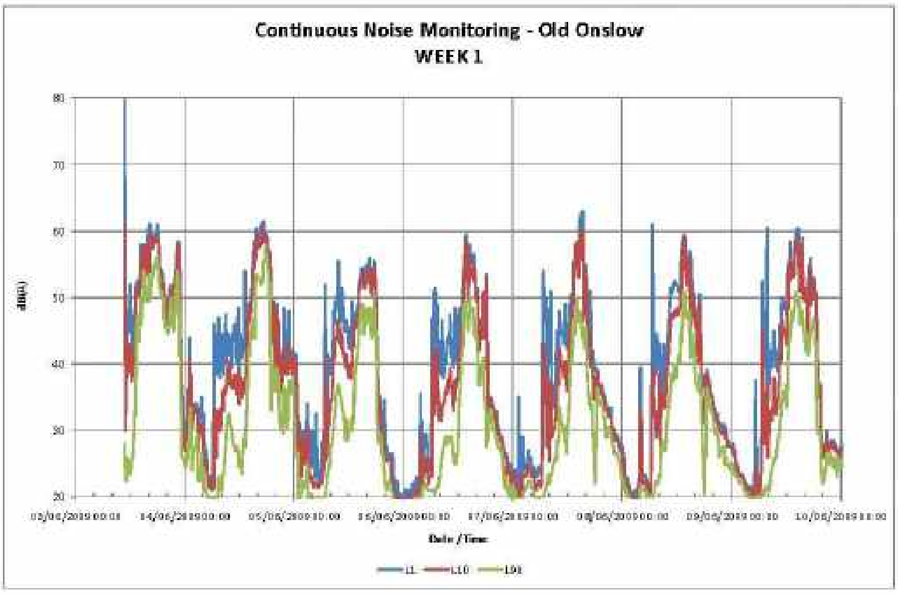


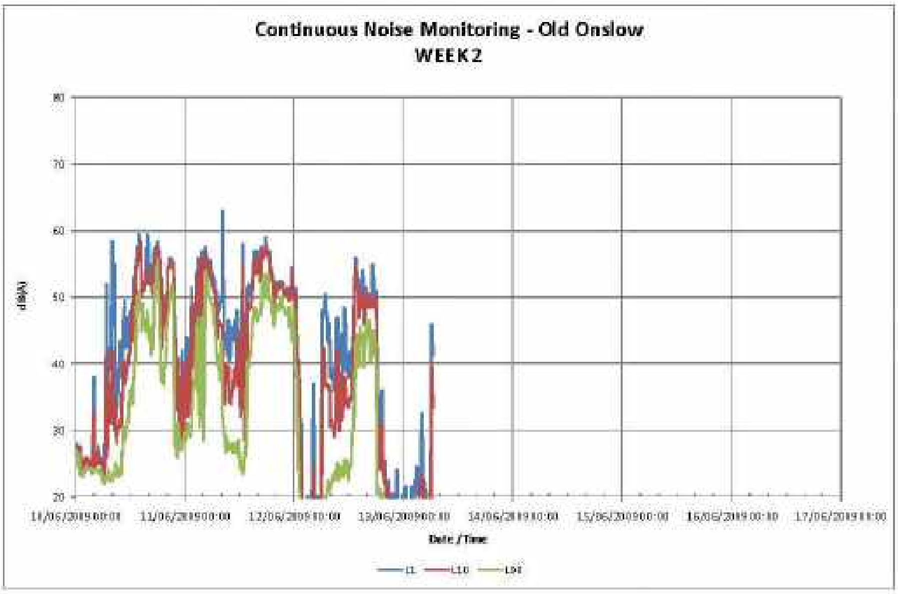


2.4 Old Onslow (Heritage Site)

Table 2-4: Summary of noise logging results for Old Onslow

Period	Average L_{A10} (dB(A))	Standard deviation in L_{A10} (dB)	Average L_{A90} (dB(A))	Standard deviation in L_{A90} (dB)	L_{90} of L_{A90} (dB(A))
Day (0700 to 1900)	44.6	9.1	36.4	10.5	23.0
Evening (1900 to 2200)	38.7	10.6	34.0	9.6	21.9
Night (2200 to 0700)	28.2	9.7	24.6	7.8	<20
All data	37.2	12.2	31.4	10.8	<20



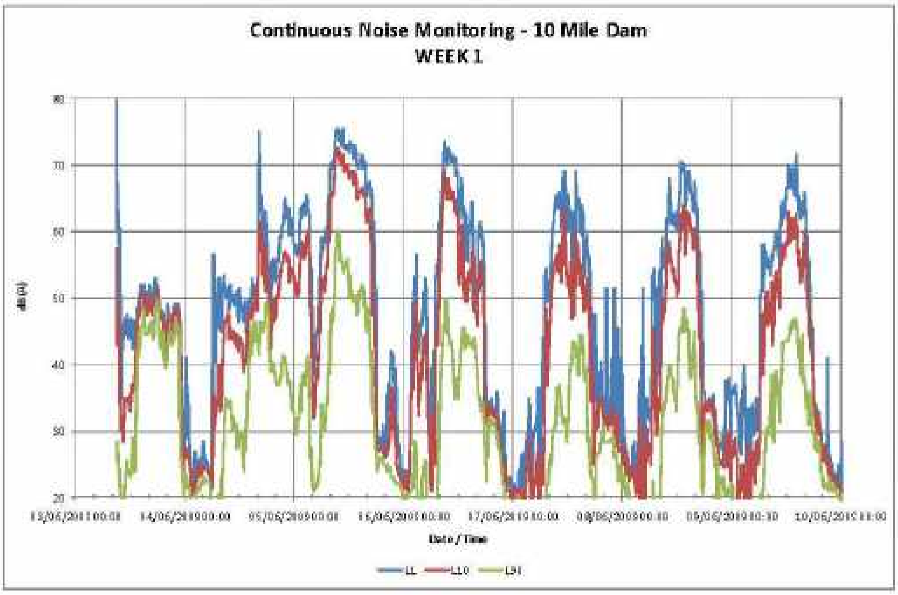


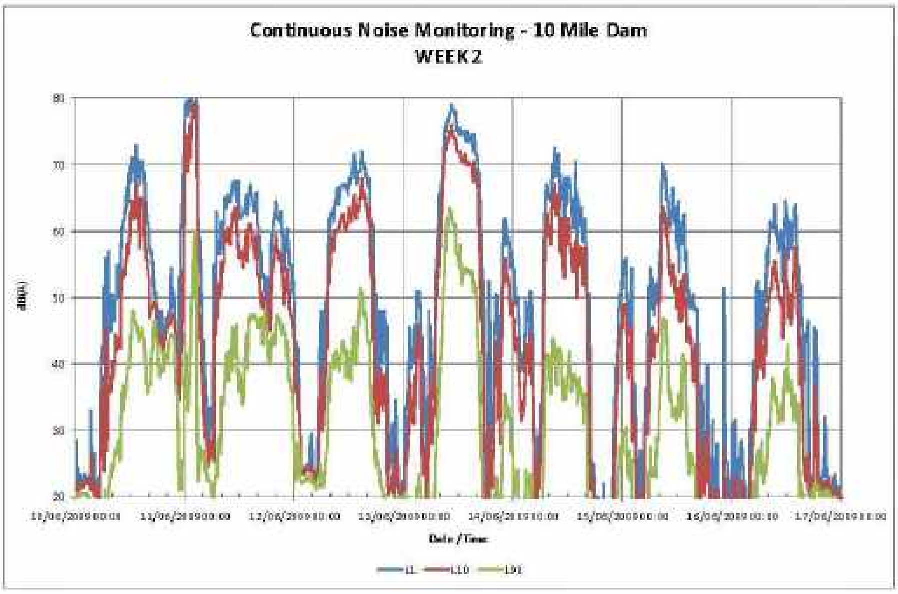
Note that no data was recorded during the second half of the second week of the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.5 10 Mile Dam (Likely Construction Camp Location)

Table 2-5: Summary of noise logging results for 10 Mile Dam

Period	Average $L_{A,10}$ (dB(A))	Standard deviation in $L_{A,10}$ (dB)	Average $L_{A,90}$ (dB(A))	Standard deviation in $L_{A,90}$ (dB)	L_{10} of $L_{A,90}$ (dB(A))
Day (0700 to 1900)	51.7	12.2	37.5	10.2	22.0
Evening (1900 to 2200)	38.8	14.0	30.3	9.1	<20
Night (2200 to 0700)	32.4	13.1	23.6	6.4	<20
All data	41.8	15.6	30.7	10.7	<20





2.6 Summary

The noise logging data at all locations showed very low underlying background noise levels[2] as would be expected for such a remote area. Background noise levels for inland locations (10 Mile Dam, 5 Mile Pool and Old Onslow) were particularly low. For coastal locations (Onslow town site and 4 Mile Creek), monitored noise levels were higher and are likely to be influenced by ocean noise. Noise levels at Onslow town site are also likely to be significantly influenced by human activity during day-time hours.

[2] Although there were some drop outs in the noise data presented, ample data was collected at each location to reliably assess background noise.

3. NOISE MODELLING

3.1 Methodology

An acoustic model has been produced using the SoundPlan noise modelling program developed by Braunstein & Berndt GmbH. The SoundPlan program calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. SoundPlan is a program which has a worldwide clientele including acoustic consultancies, government agencies, industry, and academic institutions. SoundPlan provides a range of prediction algorithms that can be selected by the user. The CONCAWE[3,4] prediction algorithms have been selected for this study. The inputs required are noise source data, ground topographical data, meteorological data and receiver locations. The model produces noise contours or noise levels at specified receiving locations for specific meteorological conditions.

3.2 Input Data and Assumptions

3.2.1 Modelling Scenarios

Noise modelling has been undertaken for the following operating scenarios:

- Normal plant operation assuming 5 LNG trains and associated domgas trains;
- Emergency flaring.

Noise emissions from construction piling have also been considered (see section 6).

3.2.2 Noise Sources and Sound Power Levels

Noise sources associated with the LNG plant have been identified from the following documents which were provided by URS for the study:

- Wheatstone Development Downstream Project overall site layout, drawing no: WS1-0000-PIP-PLT-BEC-000-00001-00 Rev 0 (Reproduced in Appendix A);
- Wheatstone Development Downstream Project LNG Plant – Emissions, Discharges, and Disposal Plan, document no: WS1-0000-HES-PHL-BEC-000-00003-00 Rev A;
- EIS/ERMP Section 8.0 Noise[5]; and
- Email correspondence with URS.

Equipment sound power levels have been developed based on preliminary data provided in the EIS/ERMP Section 8 Noise document (overall levels only) and SVT's in-house data base for similar equipment (spectral composition).

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[3] CONCAWE (Conservation of Clean Air and Water in Europe) was established in 1963 by a group of oil companies to carry out research on environmental issues relevant to the oil industry.

[4] *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities*, CONCAWE Report 4/81, 1981

[5] Extract from document provided by Bechtel and supplied to SVT in hard copy on 11 August 2009

Table 3-1 provides equipment sound power levels for the equipment included in the noise model. The cumulative total sound power level for all equipment in the normal operating scenario is 137 dB(A).

Table 3-1 : Equipment Sound Power Levels

Equipment	Octave band & overall sound power levels – dB(A)									Comment
	63	125	250	500	1000	2000	4000	8000	A-wt	
LNG Train Sources (5 operating trains)										
Air fin coolers	108	115	117	116	117	117	112	101	124	Assuming individual fan sound power level of 99 dB (A)
Methane compressor	75	82	91	100	108	105	96	101	110	2 compressors per train, each comprising LP, MP & HP stages
Ethylene compressor	93	94	97	100	105	108	106	100	113	2 compressors per train, each comprising LP & HP stages
Propane compressor	90	91	94	97	102	105	103	97	109	2 compressors per train, each comprising LP & HP stages
Compressor turbines	80	91	96	102	103	107	106	104	112	6 turbines per train (3 x 2 compressors)
Compressor piping	49	60	93	106	116	113	110	107	118	Distributed as line sources over length of compressor area
Regeneration gas compressor	72	83	90	99	103	102	102	94	108	1 per train
Fuel gas compressor	87	91	96	100	107	106	106	98	112	1 per train
Lean solvent charge pump	80	100	98	100	103	103	100	89	108	1 per train
Lean solvent booster pump	74	94	92	97	97	97	94	83	103	2 per train
LNG transfer pump	80	100	98	100	103	103	100	89	108	1 per train
Feed gas expander	87	91	96	100	107	106	106	98	112	1 per train
Hot oil circulation pump	80	100	98	100	103	103	100	89	108	1 per train
Thermal combustion unit	81	84	92	93	100	96	96	87	105	1 per train
Other Sources										
Gas turbine generator	91	94	98	101	104	108	106	102	112	11 generators operating
Coolers at Domgas plant	97	104	105	104	104	104	99	96	112	Assuming individual fan sound power level of 99 dB (A)
Export compressor at Domgas plant	87	91	96	100	107	106	106	98	112	1 per plant
Boil off gas compressor	87	91	92	97	100	108	109	99	112	2 compressors operating
Instrument air compressor	68	78	84	93	93	100	96	90	105	1 compressor operating
Water pumps	71	90	96	99	100	99	95	91	106	Cumulative total for demineralised, service and potable water pumps
Inlet feed gas air coolers	90	97	98	97	97	97	92	82	105	Assuming individual fan sound power level of 99 dB (A)

Equipment	Octave band & overall sound power levels – dB(A)									Comment
	63	125	250	500	1000	2000	4000	8000	A-wt	
Stabiliser overhead compressor	87	91	96	103	107	106	106	98	112	Inlet feed gas area
Elevated flare	111	117	120	124	131	135	133	121	138	3 flares operating at 85 m height (flaring scenario only)
Marine flare	84	90	93	97	104	108	106	94	111	2 flare operating at 13 m height (flaring scenario only)
Pile driver	90	109	117	119	121	117	109	96	125	12 units operating at plant site and 2 at end of jetty (construction scenario only)

3.2.3 Topography, Ground Type and Barriers

Topographical data for the models was provided by URS as ground contours in electronic format. The contours were modified to account for the construction of the materials offloading facility / tug jetty, and the ground height at the LNG plant site was raised to an elevation of 7 m. The modified topography was imported directly into the noise model.

A partially absorptive ground type (ground factor of 0.7) has been used in the model for sound propagation over land. For propagation over water a fully reflective (hard) ground type (ground factor of 0) has been used. Hard ground has also been assumed for the LNG plant site and the evaporation ponds at Onslow Salt.

The noise model does not include noise barriers or buildings[6].

3.2.4 Meteorology

Certain meteorological conditions can increase noise levels at a receiving location by a process known as refraction. When refraction occurs, sound waves that would normally propagate directly outwards from a source can be bent downwards causing an increase in noise levels. Such refraction occurs during temperature inversions and where there is a wind gradient.

The SoundPlan noise model calculates noise levels for user defined meteorological conditions. In particular, temperature, relative humidity, wind speed and direction data, and atmospheric stability are required as input to the models.

The noise model has been used to predict noise levels and prepare noise contours for 3 m/s winds combined with a thermal inversion. These conditions are consistent with the default worst-case conditions for night-time sound propagation specified in Environmental Protection Authority's (EPA) Draft Guidance No. 8[7] for assessing noise impacts. The noise contours for worst-case weather conditions represent the worst-case noise propagation envelopes, i.e., worst-case propagation in all directions simultaneously.

[6] The large storage tanks at the site will provide shielding for some noise sources. However, due to the preliminary stage of the plant design the barrier effects of the tanks have been excluded from the model. The attenuation achieved by the tanks will strongly depend on the source / barrier / receptor geometry and this is likely to change as the design develops. Hence the model represents a worst-case.

[7] EPA Draft Guidance No. 8, May 2007

3.3 Noise Modelling Results

3.3.1 Normal Plant Operation

Predicted noise levels are presented in Table 3-2 below for normal plant operation and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 1 in Appendix B for worst-case weather conditions.

Table 3-2 : Predicted Noise Levels – Normal Operations

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	23	27
4 Mile Creek	32	37
5 Mile Pool	24	28
Old Onslow (Heritage Site)	32	36
10 Mile Dam (Likely Construction Camp Location)	21	24
Onslow Salt	31	35

Air fin coolers are the most significant contributor to received noise levels at all locations.

3.3.2 Emergency Flaring

Predicted noise levels are presented in Table 3-3 below for emergency flaring and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 2 in Appendix B for worst-case weather conditions.

Table 3-3 : Predicted Noise Levels – Emergency Flaring

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	26	30
4 Mile Creek	37	41
5 Mile Pool	28	32
Old Onslow (Heritage Site)	38	41
10 Mile Dam (Likely Construction Camp Location)	24	27
Onslow Salt	37	41

4. NOISE LIMIT CRITERIA

4.1 Summary of Legislation

Noise management in Western Australia is implemented through the Environmental Protection (Noise) Regulations 1997 (noise regulations) which operate under the Environmental Protection Act. The Regulations specify maximum noise levels (assigned levels) which are the highest noise levels that can be received at noise-sensitive premises, commercial and industrial premises.

Assigned noise levels have been set differently for noise sensitive premises, commercial premises, and industrial premises. For noise sensitive premises, eg residences, an "influencing factor" is incorporated into the assigned noise levels. The influencing factor depends on land use zonings within circles of 100m and 450m radius from the noise receiver, including:

- the proportion of industrial land use zonings;
- the proportion of commercial zonings; and
- the presence of major roads.

For noise sensitive residences, the time of day also affects the assigned levels.

The regulations define three types of assigned noise level:

- $L_{A\ max}$ assigned noise level means a noise level which is not to be exceeded at any time;
- $L_{A\ 1}$ assigned noise level which is not to be exceeded for more than 1% of the time; and
- $L_{A\ 10}$ assigned noise level which is not to be exceeded for more than 10% of the time.

The L_{A10} noise limit is the most significant for this study since this is representative of continuous noise emissions from the LNG plant.

4.2 Noise Limits

4.2.1 Onslow Town Site

The assigned noise levels at residential premises in Onslow will vary depending on the proximity of particular premises to industrial or commercial areas and also the time of day. The most stringent night-time L_{A10} assigned noise level at residential premises in Onslow is 35 dB(A) for those residences that are greater than 450m from land zoned for industrial or commercial use. This limit has been used for the purposes of this assessment.

4.2.2 Proposed Accommodation Camp at 10 Mile Dam

The EPA's policy on accommodation camps (as defined in EPA draft guidance no 8[8]) is that they should be located and designed so as to achieve compliance with the assigned levels and acceptable standards. Since the proposed camp site is remote from any industrial or commercial

[8] EPA draft guidance no 8, May 2007

activity, the most stringent night-time L_{A10} assigned noise level of 35 dB(A) is deemed to apply and has been used for the purposes of this assessment.

4.2.3 Onslow Salt

Onslow Salt is an industrial site and consequently the L_{A10} assigned noise level is 65 dB(A) at all times of the day and night.

4.2.4 Public Access Areas

Old Onslow, 4 Mile Creek, and 5 Mile Pool are public access areas, but are not considered as premises. Since the noise regulations apply only to noise received at premises, the assigned noise levels do not apply and noise limit criteria are not defined for these locations. The potential for noise impacts at these locations is determined by comparing predicted noise levels with measured background noise levels.

4.3 Intrusive or Dominant Noise Characteristics

Noise levels at receiving premises are subject to penalty corrections if the noise exhibits intrusive or dominant characteristics, i.e. if the noise is impulsive, tonal, or modulated. That is, the measured or predicted noise levels are adjusted and the adjusted noise levels must comply with the assigned noise levels. Regulation 9 sets out objective tests to assess whether the noise is taken to be free of these characteristics.

Based on the large source-receiver distance between the proposed development site and surrounding receptors, and considering the large number of noise emission sources, it is not anticipated that noise from the LNG plant will exhibit impulsive, tonal or modulating characteristics when assessed at the receivers.

Noise emissions from piling during construction may, however, exhibit impulsive characteristics (refer section 6.2).

5. COMPLIANCE ASSESSMENT

5.1 Normal Plant Operation

Table 5-1 presents a comparison of predicted noise levels under worst-case meteorological conditions with applicable noise limits for normal plant operating conditions. It can be seen that compliance is achieved at all locations.

Table 5-1 : Compliance Assessment – Normal Plant Operation

Receiving Location	Noise Limit Criterion	Predicted Noise Level dB(A)
Onslow Town Site	35	27
4 Mile Creek	n/a	37
5 Mile Pool	n/a	28
Old Onslow (Heritage Site)	n/a	36
10 Mile Dam (Likely Construction Camp Location)	35	24
Onslow Salt	65	35

5.2 Emergency Flaring

Table 5-2 presents a comparison of predicted noise levels under worst-case meteorological conditions with applicable noise limits for emergency flaring conditions. It can be seen that compliance is achieved at all locations.

Table 5-2 : Compliance Assessment – Emergency Flaring

Receiving Location	Noise Limit Criterion	Predicted Noise Level dB(A)
Onslow Town Site	35	30
4 Mile Creek	n/a	41
5 Mile Pool	n/a	32
Old Onslow (Heritage Site)	n/a	41
10 Mile Dam (Likely Construction Camp Location)	35	27
Onslow Salt	65	41

5.3 Cumulative Noise Impacts

SVT have been advised (by URS) that there will be two gas plants located immediately to the south and adjacent to the proposed facility. These are:

1) A single train LNG plant;

2) A Domgas plant.

These plants are much smaller than the proposed Chevron facility (which has been assessed assuming 5 operating LNG trains and 5 Domgas units) and thus noise emissions are likely to be significantly lower.

Since the adjacent gas plants are very close to proposed Chevron facility, any increase in noise levels is only likely to affect localised areas in the immediate vicinity of the gas plants. Further afield, noise from the larger Chevron facility will dominate over noise from the adjacent gas plants. Therefore, any increase in noise received at Onslow and 10 Mile Dam will be marginal and will not result in cumulative impacts which exceed the assigned noise levels.

6. CONSTRUCION NOISE

With the exception of pile driving, noise from construction activities is expected to be significantly below noise associated with normal plant operations.

Extensive piling is anticipated during construction using a total of up to 12 impact pile drivers at the plant site and 2 at the jetty. Piling operations are planned to run for 14 months, 24 hours per day, 7 days per week. Noise modelling has been undertaken for a worst-case pile driving scenario assuming 2 pile drivers are operating simultaneously at the end of the jetty (i.e. the worst-case location for sound propagation over water towards Onslow town site) and 12 pile drivers are operating simultaneously at the location of the storage tanks at the plant site.

This is a very conservative approach since it is highly unlikely that all pile drivers will operate simultaneously and that the noise received from each pile driver will arrive at precisely the same time at noise sensitive receiving locations.

6.1 Noise Modelling Results

Predicted noise levels are presented in Table 6-1 below for pile driving and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 3 in Appendix B for worst-case weather conditions.

Table 6-1 : Predicted Noise Levels – Pile Driving

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	27	31
4 Mile Creek	42	48
5 Mile Pool	22	26
Old Onslow (Heritage Site)	30	35
10 Mile Dam (Likely Construction Camp Location)	18	22
Onslow Salt	35	41

6.2 Construction Noise Impact Assessment

The noise regulations require an adjustment of 10 dB to be added to predicted noise levels for noise emissions that exhibit impulsive characteristics. Impulsiveness is assessed at the receiving premises and must, therefore, protrude above background noise. If impulsiveness were evident then the adjusted worst-case noise levels for Onslow town site and 10 Mile Dam are as shown in Table 6-2.

Table 6-2 : Predicted Noise Levels for Pile Driving Including Penalty for Impulsiveness

	Predicted Level dB(A)	Penalty for Impulsive Characteristic dB(A)	Adjusted Level Including Penalty for Impulsiveness dB(A)
Onslow Town Site	31	+ 10	41
10 Mile Dam (Likely Construction Camp Location)	22	+ 10	32

For 10 Mile Dam, the adjusted noise levels are below the assigned noise levels for day, evening and night-time periods. However, for Onslow town site, the adjusted noise levels exceed the evening and night-time assigned noise levels and, therefore, a noise management plan may be required. (Refer section 6.3.2 below).

It is noted, however, that the predicted noise levels (before applying penalties for impulsiveness) are only marginally above the lowest background noise levels recorded at both Onslow and 10 Mile Dam. (Refer sections 2.1 and 2.5.). Therefore, the risk of exceeding the assigned noise levels is very low since this would require:

- All pile drivers to be operating;
- Noise from all pile drivers to arrive simultaneously at the noise sensitive premises;
- Worst-case meteorological conditions for sound propagation; and
- Very low background noise (i.e. no extraneous noise) at the receiving premises.

Because of the conservative nature of the assessment undertaken, it is suggested that predicted noise levels are verified during construction and that noise impacts are re-assessed based on the measured levels. In the event that noise emissions exceed the assigned levels then the following noise reduction options may be considered to minimise noise impacts:

- Limit the number of pile drivers operating simultaneously;
- Restrict piling operations during night time hours;
- Restrict night time piling operations under wind conditions which favour sound propagation towards Onslow town site.

Because of the very large distances between the piling operations and receiving locations considered in this assessment, ground borne vibration will be attenuated to such a degree during propagation that there will be no vibration impacts.

6.3 Construction Noise Management Criteria

6.3.1 Daytime Construction Activities

The Environmental Protection Noise Regulations 1997 state that for construction work carried out between 7am and 7pm on any day, which is not a Sunday or public holiday the assigned noise levels do not apply provided that:

- The construction work is carried out in accordance with control of noise practices set out in Section 6 of Australian Standard 2436-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites"; and
- The equipment used for the construction is the quietest reasonably available.

The Chief Executive Officer[8] (CEO) may request that a noise management plan be submitted for the construction work at any time.

6.3.2 Night-time Construction Activities

For construction work done outside daytime hours:

- The construction work must be carried out in accordance with control of noise practices set out in Section 6 of Australian Standard 2436-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites"; and
- The equipment used for the construction must be the quietest reasonably available.

Furthermore, if noise emissions are likely to exceed the assigned noise levels then:

- The contractor must advise all nearby occupants or other sensitive receptors who are likely to receive noise levels which fail to comply with the standard under Regulation 7, of the work to be done at least 24 hours before it commences;
- The contractor must show that it was reasonably necessary for the work to be done out of hours; and
- The contractor must submit to the CEO a Noise Management Plan at least seven days before the work starts, and the plan must be approved by the CEO. The plan must include details of:
    - Need for the work to be done out of hours;
    - Types of activities which could be noisy;
    - Predictions of the noise levels;
    - Control measures for noise and vibration;
    - Procedures to be adopted for monitoring noise emissions; and
    - Complaint response procedures to be adopted.

[8] The power of the CEO of the Department of Environment and Conservation is delegated under the noise regulations to the CEOs of all local governments in the State of Western Australia.

7. DISCUSSION & CONCLUSIONS

Predicted noise levels for normal plant operation have been shown to be in compliance with the most stringent night-time noise limits imposed under the noise regulations.

Onslow town site is the nearest residential area to the proposed development site. A comparison of predicted noise levels at Onslow with ambient noise levels demonstrates that the LNG plant is unlikely to be audible above background noise even under worst-case meteorological conditions for sound propagation.

The proposed location for the workforce accommodation camp is sufficiently distant from the LNG plant site that received noise levels will be significantly below the assigned noise levels.

Although there are no regulatory criteria for noise received at the public access areas (4 Mile Creek, 5 Mile Pool and Old Onslow), predicted noise levels for normal plant operation are higher at these locations than underlying background noise. It is possible, therefore, that plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation.

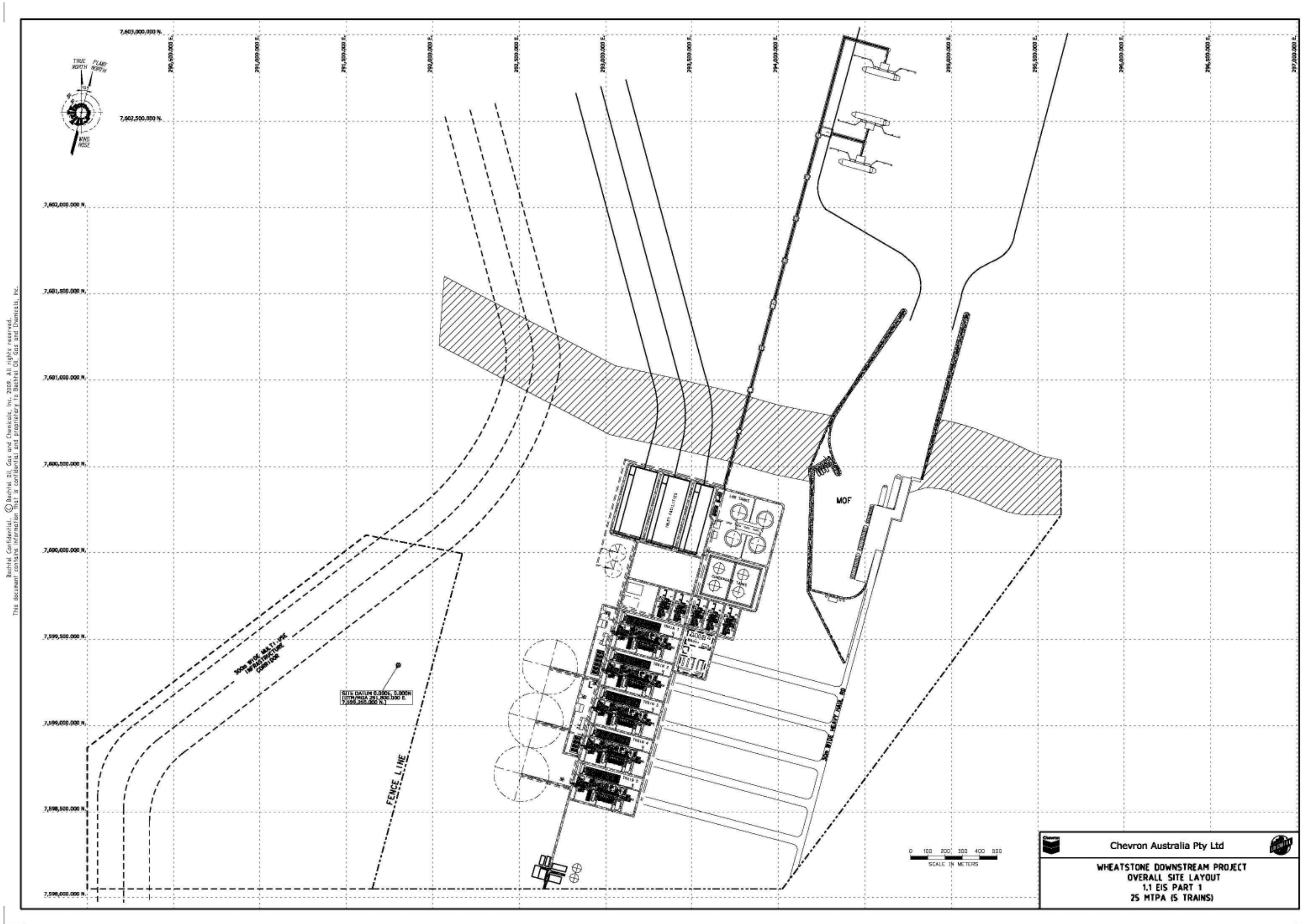
Predicted noise levels from emergency flaring have also been shown to comply with the assigned noise levels.

Noise from piling may potentially impact the town of Onslow. The modelling undertaken demonstrates that under extreme circumstances it is feasible that noise emissions could exceed assigned levels when accounting for impulsiveness. However, it is SVT's opinion that the conditions required to cause an exceedance of the assigned levels would be considered as a very remote possibility. It is, therefore, suggested that noise monitoring be undertaken during piling so as to determine whether or not noise mitigation measures are warranted. Potential noise mitigation options include:

- Limiting the number of pile drivers operating simultaneously;
- Restricting piling operations during night time hours;
- Restricting night time piling operations under wind conditions which favour sound propagation towards Onslow town site.

Measure background noise levels have been shown to be very low, particularly for inland locations.

APPENDIX A : SITE LAYOUT


MOF
FENCE LINE
500m WIDE MULTI USE INFRASTRUCTURE CORRIDOR
SCALE IN METERS
Chevron Australia Pty Ltd
WHEATSTONE DOWNSTREAM PROJECT
OVERALL SITE LAYOUT
1.1 EIS PART 1
25 MTPA (5 TRAINS)

APPENDIX B : NOISE CONTOURS

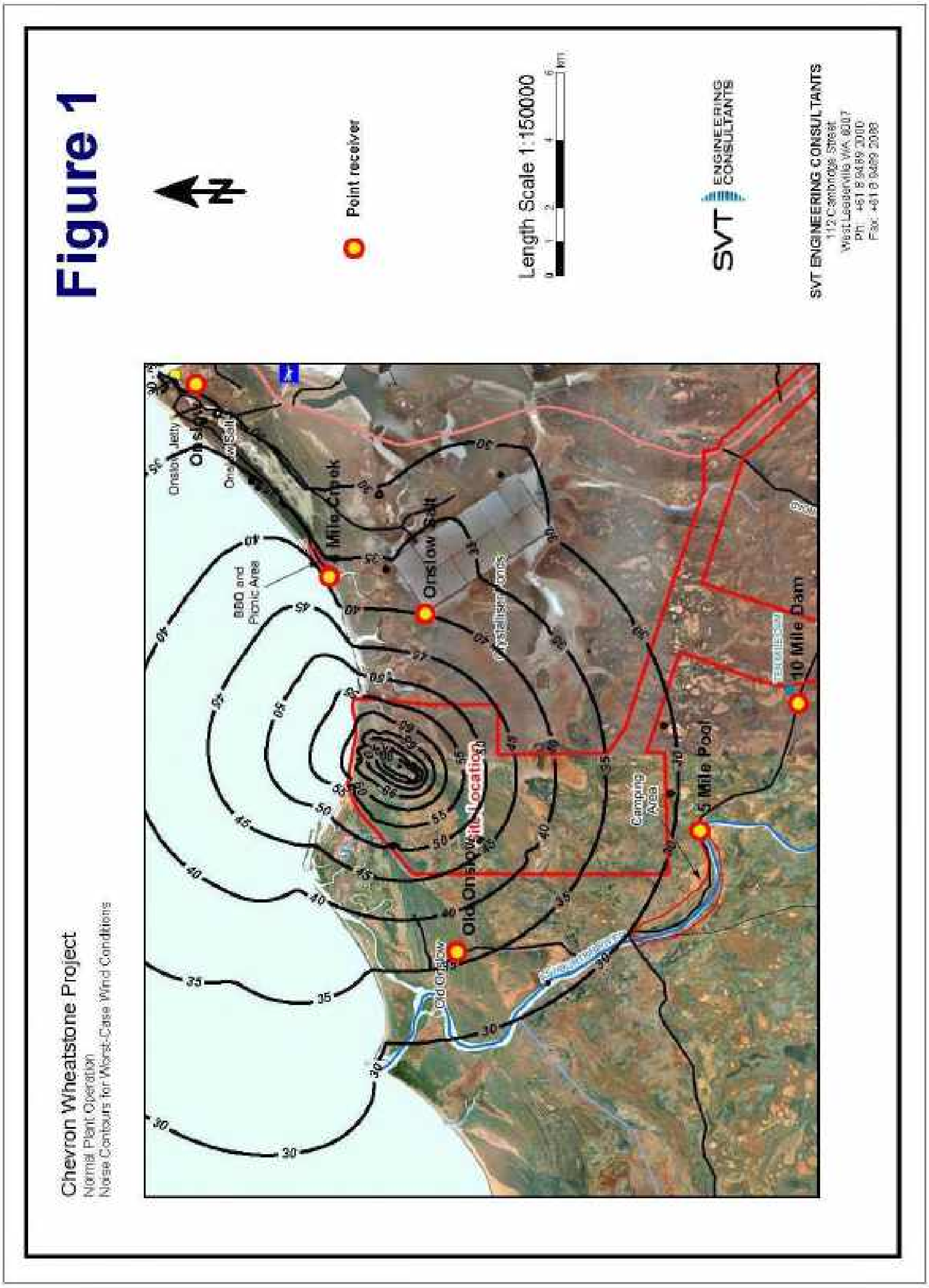


Figure 1
Point receiver
Length Scale 1:150000
SVT ENGINEERING CONSULTANTS
Chevron Wheatstone Project
Normal Plant Operation
Noise Contours for Worst-Case Wind Conditions
Onslow Jetty
Onslow Salt
BBQ and Picnic Area
Onslow Salt
Old Onslow
Old Onslow
Camping Area
5 Mile Pool
10 Mile Dam

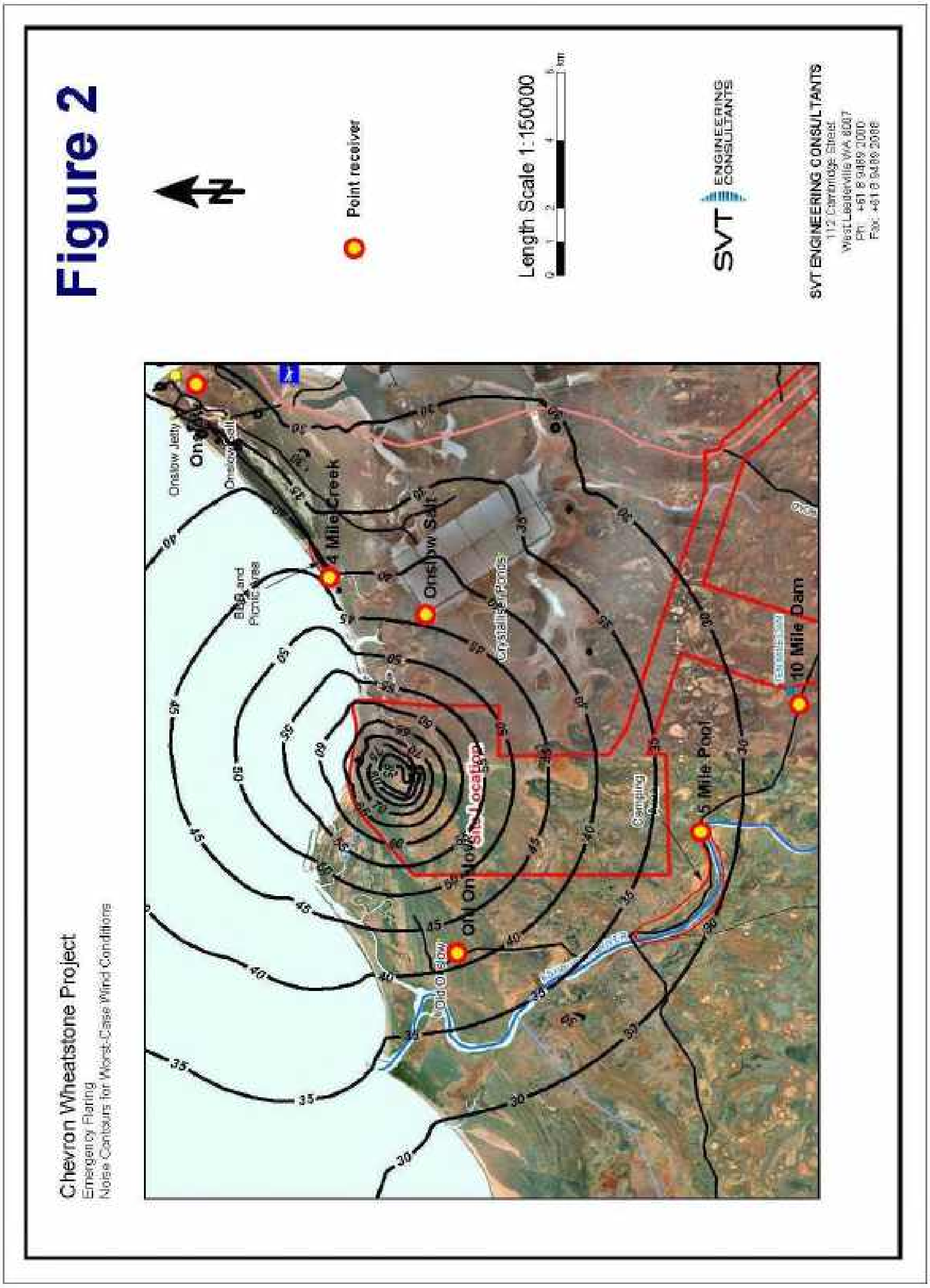


Figure 2
Point receiver
Length Scale 1:150000
SVT ENGINEERING CONSULTANTS
Chevron Wheatstone Project
Emergency Flaring
Noise Contours for Worst-Case Wind Conditions
4 Mile Creek
Onslow Salt
5 Mile Pool
10 Mile Dam

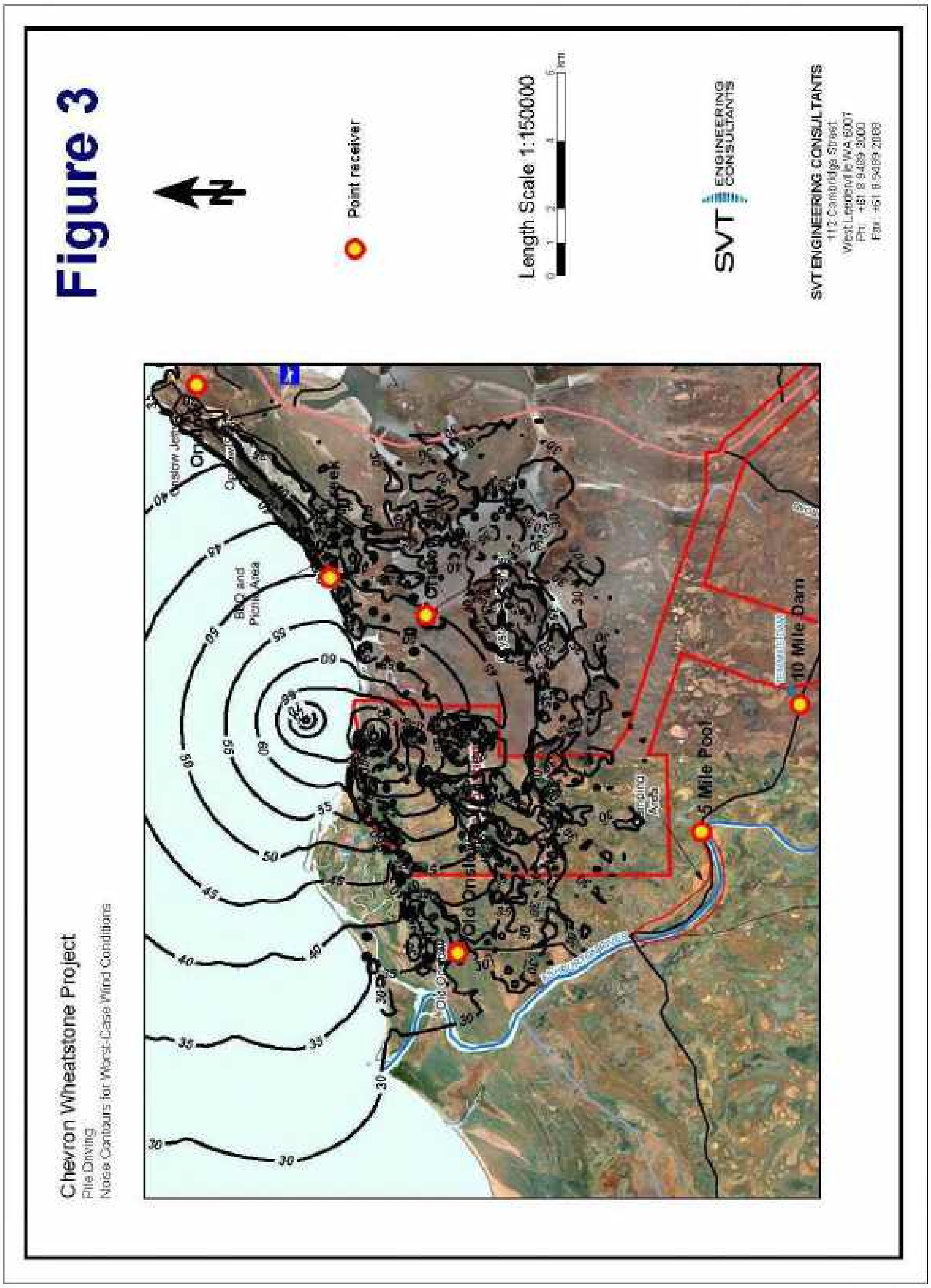


Figure 3
Point receiver
Length Scale 1:150000
SVT ENGINEERING CONSULTANTS
SVT ENGINEERING CONSULTANTS
Chevron Wheatstone Project
Pile Driving
Noise Contours for Worst-Case Wind Conditions
5 Mile Pool
10 Mile Dam
BBQ and Picnic Area

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