Appendix M
Air quality

Australian Industrial Energy

Port Kembla Gas Terminal

Air Quality Assessment

November 2018

Executive summary

Australian Industrial Energy (AIE) proposes to develop the Port Kembla Gas Terminal (the project) in Port Kembla, New South Wales (NSW). The project involves the development of a liquified natural gas (LNG) import terminal including a Floating Storage and Regasification Unit (FSRU) moored at Berth 101 in the Inner Harbour, visiting LNG carriers, wharf offloading facilities and the installation of new pipeline to connect to the existing gas transmission network.

GHD has undertaken an air quality assessment for the construction and operation of the project. A screening level construction air quality assessment was undertaken and predicted no exceedances of the 24 hour and annual particulate criteria.

The operational assessment considered six potential operating scenarios. There are no predicted exceedances of the impact assessment criteria during normal operations which consists of two gas engines operating on the FSRU and two gas engines on the LNG carrier.

The assessment identified that formaldehyde had the potential to exceed the criteria during operation of the unlikely worst case operating scenario (Scenario 6 - which consists of four gas engines operating on the FSRU and two gas engines operating on the docked LNG carrier). This scenario is unlikely to occur as it would imply the FSRU was underway whilst transferring LNG from a carrier. Furthermore, under this scenario the areas which exceed the criteria are over water. As such, these potential formaldehyde exceedances are not considered significant and will not impact sensitive receptors in the Port Kembla region. No other exceedances of the impact assessment criteria are predicted.

Based on assumptions as outlined in the assessment, the predicted pollutant emissions from the construction and operation of the project are expected to comply with the relevant criteria when assessed in accordance with the EPA Approved Methods. The application of standard dust mitigation measures will assist to minimise potential impacts from construction of the project. During operations of the project, compliance with International Maritime Organization (IMO) legislation and guidelines will minimise the impacts and ensure compliance with domestic air quality guidelines.

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1. Introduction

1.1 Background

Australian Industrial Energy (AIE) proposes to develop the Port Kembla Gas Terminal (the project) in Port Kembla, New South Wales (NSW). The project involves the development of a liquified natural gas (LNG) import terminal including a Floating Storage and Regasification Unit (FSRU) moored at Berth 101 in the Inner Harbour, visiting LNG carriers, wharf offloading facilities and the installation of new pipeline to connect to the existing gas transmission network.

NSW currently imports more than 95 % of the natural gas it uses, with the majority of supplies coming as interstate supplies from Victoria and South Australia. In recent years, gas supplies to the Australian east coast market have tightened, resulting in increased natural gas prices for both industrial and domestic users. Several recent economic studies have predicted significant future gas shortfalls for NSW by 2022.

The project provides an immediate solution to address predicted shortages and will result in considerable economic benefits for both the Illawarra region and NSW. The project will have capacity to deliver 100 petajoules of natural gas, equivalent to more than 70 % of NSW gas needs and provide between 10 to 12 days of natural gas storage in case of interstate supply disruption. LNG will be sourced from worldwide suppliers and transported by LNG carriers to the gas terminal at Port Kembla. The LNG will then be re-gasified for input into the NSW gas transmission network.

The project has been declared critical state significant infrastructure in accordance with Section 5.13 of the *Environmental Planning and Assessment Act*, 1979 (EP&A Act) and Schedule 5 of the *State Environmental Planning Policy* (SEPP) State and Regional Development. An Environmental Impact Statement (EIS) is required to support the application for approval for determination by the NSW Minister for Planning.

1.2 Project overview

1.2.1 Objectives

Key objectives for the project are to:

- Introduce a new source of competitively priced gas to meet predicted supply shortfalls and help put downward pressure on prices
- Provide gas security to NSW with the ability to supply more than 70 % of the State's gas needs
- Provide long-term contracts to industrial users and ability to meet 100 % of the State's industrial demand (manufacturers, power stations, hospitals, small businesses etc.)
- Help support the 300,000 jobs across NSW and the 15,000 jobs in the Illawarra, which rely on the competitive, reliable supply of natural gas
- Support the diversification and future growth of Port Kembla.

1.2.2 The project

The project comprises the development of a LNG import terminal and incorporates four key components. All components are proposed to be located within industrial land declared under the State Environmental Planning Policy (Three Ports) and include:

- LNG carrier vessels — there are hundreds of these in operation worldwide transporting LNG from production facilities all around the world to demand centres;
- FSRU — a cape-class ocean-going vessel which would be moored at Berth 101 in Port Kembla. There are around 30 such vessels currently in operation around the world;
- Berth and wharf facilities – including landside offloading facilities to transfer natural gas from the FSRU into a natural gas pipeline located on shore;
- Pipeline – a short underground gas pipeline will be constructed from Berth 101 to the existing east coast gas transmission network at Cringila.

At present it is envisaged that an LNG shipment will be required every 2 to 3 weeks to provide for an annual supply of up to 100 petajoules of gas. Supply could be increased further to around 140 to 150 petajoules per annum through a slight increase in LNG delivery schedules and pipeline upgrades.

It will take 10 to 12 months to complete construction and other works in order to start operations for the project and subject to the timing of approval processes, it is possible to have first gas by early 2020.

The estimated capital cost of the development is between $200 and $250 million.

In discussions with NSW Ports they have confirmed that the establishment of a LNG import terminal at Port Kembla is consistent with their strategic plan outlined in Navigating the Future – NSW Ports' 30 Year Master Plan. AIE has been working closely with NSW Ports and the Port Authority to ensure neither the construction, nor the ongoing operation of the LNG import terminal would negatively affect other port users or the wider community.

1.3 Purpose of this document

This Air Quality Impact Assessment (AQIA) has been prepared to support the EIS for the project.

The AQIA provides a description of the existing air quality environment, the assessment criteria during the construction and operation phases of the project and an assessment of the potential impacts due to activities associated with the project.

1.4 Scope

This AQIA involved the following tasks:

- Desktop review of site plans, aerial photographs and topographic maps to gain an understanding of the existing environment in terms of local terrain, proposed operations and sensitive receptors within the study area
- Review of available ambient air quality monitoring data, to gain an understanding of existing air quality in the vicinity of the site. Ambient pollutant levels were sourced from data recorded from Office of Environment and Heritage (OEH) ambient monitoring stations located in the local area.
- Outline of the applicable air quality criteria with consideration to the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (EPA, 2016) (the Approved Methods).
- Creation of an emissions inventory to include the terminal and tankers using client supplied data, allowable United States Environmental Protection Agency (US EPA) emission limits and national pollutant inventory (NPI) emission factors from the Australian Government.

- Meteorological modelling to gain an understanding of the local wind climate and use as model input for conducting atmospheric dispersion modelling.
- Dispersion modelling using CALPUFF to predict construction and operational impacts at nearby receptors.
- Identification of recommended in principle mitigation, management and/or air quality monitoring measures to reduce.

This report has been prepared with consideration of the following documents:

- *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (Approved Methods) (NSW EPA, 2016)

1.4.1 Structure

This report is structured as follows:

- **Section 1 – Introduction:** This Section introduces the project and describes the site
- **Section 2 – Existing environment**: This Section describes the existing environmental characteristics of the site relevant to the air quality assessment
- **Section 3 – Regulatory requirements:** This Section provides an overview of air quality criteria
- **Section 4 – Project emissions**: This Section details the estimated emission rates emitted from the project
- **Section 5 – Meteorology**: This Section outlines the assessment methodology and process followed to synthesize meteorology for the project site
- **Section 6 – Impact Assessment:** This Section presents a summary of the construction and operational pollutant impact assessment results
- **Section 7 – Mitigation**: This Section provides an overview of the proposed air quality mitigation measures to be undertaken during the project
- **Section 8 – Conclusion**: This Section presents a summary of the air quality findings and sets out the principal conclusions for the assessment.

1.5 Secretary's Environmental Assessment Requirements

The specific Secretary's Environmental Assessment Requirements (SEARs) and agency requirements addressed in this report are summarised in Table 1-1.

Table 1-1 Secretary's environmental assessment requirements and agency requirements

Assessment requirements	Section(s) of this report where addressed
Legislation	
Relevant legislation • *Protection of the Environment Operations (POEO) Act 1997* • *Protection of the Environment Operations (Clean Air) Regulation 2002* • Secretary's Environmental Assessment Requirements 1167	 Section 3 Section 3 Section 3
Relevant policies and guidelines • Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (NSW EPA, 2016)	Section 3

Assessment requirements	Section(s) of this report where addressed
Air quality	
• Assess the likely air quality impacts of the project in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW.	Section 6
• Demonstrate the projects ability to comply with the relevant regulatory framework, specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation 2010	Section 6
• Assess the likely greenhouse gas impacts of the project	EIS Volume 2 - Appendix P

1.6 Limitations

This report: has been prepared by GHD for Australian Industrial Energy and *may only be used and relied on by Australian Industrial Energy for the purpose agreed between GHD and the Australian Industrial Energy as set out in Section 1.7 of this report.*

GHD otherwise disclaims responsibility to any person other than Australian Industrial Energy arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Australian Industrial Energy and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.7 Assumptions

This air quality assessment relied upon the following assumptions:

- General construction activities are undertaken based on an overview of the proposed construction methodology and were characterised using generic emission factors published in the *Western Regional Air Partnership Fugitive Dust Handbook* (WRAP) (Countess Environmental, 2006)
- Operational emission rates were calculated using data sheets supplied by AIE and NPI emissions factors
- Operational characteristics and likely operational scenarios of the FSRU and LNG carrier were supplied by AIE
- Modelling assumptions in Section 6 of this report

2. Existing environment

2.1 Location

2.1.1 Port Kembla

Port Kembla is a deep water harbour located in the Illawarra region, approximately 3km south of the Wollongong Central Business District and 80km south of Sydney. The port operates across two harbours, consisting of the Inner Harbour and Outer Harbour. NSW Ports is responsible for port infrastructure at the port, while the NSW Port Authority manage functions including harbour control, vessel tracking, pilotage and navigation.

There are a total of 18 berths at Port Kembla with services ranging from motor vehicle imports, grain and coal exports, general cargo facilities, dry bulk and break bulk facilities and bulk liquid facilities as shown on Figure 2-1.

Two grain terminals operate on the northern side of the Inner Harbour along with bulk liquid facilities and a number of multi-purpose berths. BlueScope Steelworks operate five berths on the western side of the Inner Harbour and the Port Kembla Coal Terminal (PKCT) is a coal export facility located on the eastern side of the Inner Harbour operating from two berths.

Six berths operate in the Outer Harbour for use in fuel discharge and loading, bulk and break bulk cargo including copper concentrate, fertiliser, clinker, pulp/saw logs and steel products. The Outer Harbour redevelopment project has also been approved and involves reclamation and dredging to enable additional port facilities to be developed in the Outer Harbour.

2.1.2 Berth 101

B101 is proposed for use as part of the project and is located between B102 and “The Cut” shipping channel providing access to the Inner Harbour. B101 is currently operated by the PKCT and was most recently utilised as an off-loading wharf for materials handling equipment, but does not currently have any regular use with the majority of coal exports operating out of B102.

Land use surrounding B101 is predominantly heavy industrial or special uses associated with port operations. Wollongong Sewage Treatment Plant is located to the north of the coal export facility.

The closest residential properties to Berth 101 are located approximately 2km to the north in Coniston, to the west in Cringila and to the south at Port Kembla and Warrawong.

The pipeline to connect the FSRU with the existing gas transportation network at Cringila passes through a predominantly industrial setting around the outskirts of Port Kembla.

2.2 Existing air quality

The NSW OEH operates ambient air quality monitoring stations in selected areas around NSW. The nearest station to the site is Kembla Grange, however Wollongong has been included as it contains background data for SO_2, $PM_{2.5}$ and CO.

Daily pollutant average and maximum ambient concentrations for the modelled year (2014, see Section 5.2 for a discussion on why 2014 was selected as the most appropriate representative year) are presented in Table 2-1.

Table 2-1 Ambient air quality daily concentrations (2014)

Pollutant		OEH monitoring site	
		Wollongong	Kembla grange
SO_2	Average (µg/m^3)	2.0	-
	Maximum (µg/m^3)	13.1	-
NO	Average (µg/m^3)	5.9	2.1
	Maximum (µg/m^3)	57.8	20.9
NO_2	Average (µg/m^3)	14.8	0.0
	Maximum (µg/m^3)	37.6	30.1
CO	Average (µg/m^3)	253.4	-
	Maximum (µg/m^3)	575.0	-
PM_{10}	Average (µg/m^3)	17.7	17.3
	Maximum (µg/m^3)	45.3	99.2
	70th percentile (µg/m^3)	20.2	20.3
$PM_{2.5}$	Average (µg/m^3)	7.0	-
	Maximum (µg/m^3)	17.3	-
	70th percentile (µg/m^3)	8.2	

'-' denotes data not sampled at the site

The top 10 measured $PM_{2.5}$ levels (from Wollongong) and PM_{10} concentrations (from Kembla Grange) are provided below in Table 2-2. These are used for a contemporaneous assessment of operational particulate impacts.

Table 2-2 Top ranked PM_{10} and $PM_{2.5}$ concentrations

Rank	PM_{10} concentration (Kembla Grange)	$PM_{2.5}$ concentration (Wollongong)
1	99.2	17.3
2	43.6	16.8
3	42.2	16.1
4	41.5	15.8
5	40.8	15.5
6	37.8	15.2
7	37	14.9
8	36.8	14.8
9	36.8	14.4
10	36.2	14.3

2.2.1 Background for construction impacts

The NSW Approved Methods approach to assess potential particulate impacts is to add the contemporaneous hourly background concentration to predictions based on representative local measurements. Due to the length of the alignment and the fact that construction will move along the alignment (construction of the pipeline will not likely occur in any one location for more than a few days), another method to assess potential construction impacts has been used.

The 70th percentile concentration of PM_{10} at Kembla Grange has been presented in Table 2-1 for consideration in the cumulative impact assessment. It is noted that the maximum measured 24 hour average PM_{10} concentration at Kembla Grange exceeds the criteria in 2014.

Consequently, an alternative method for the cumulative construction assessment was undertaken. The use of the Victorian PEM (2007) method, where the maximum predicted 24-hour average project emissions are added to a 70th percentile 24-hour average background concentration of PM_{10}, was undertaken as is commonly done in Victoria and Queensland for 24 hour average criteria.

Considering the low ground-level concentrations of particulates predicted from the Project's construction, the use of a 70th percentile background concentration was considered to be appropriate and the Project's contribution to the region's overall dust load to be negligible.

This is considered appropriate as construction-based dust emissions will be time and space variant and highly variable in emission load due to activity and localised weather conditions. This non-continuous emission rate associated with construction cannot be meaningfully assessed concurrently with a contemporaneous background at a site not representative of the local area.

2.2.2 Sensitive receptors

The location of the nearest identified sensitive receptors to the site are presented in Table 2-3 along with the address and receptor type. The Approved Methods (EPA, 2016) defines sensitive receptors as locations where people are likely to work or reside and may include a dwelling, school, hospital, office or recreation area. A figure showing the location of the site with representative receptors is supplied in Figure 2-1.

Table 2-3 Sensitive receptors locations

ID	X coordinate (m)	Y coordinate (m)	Address	Description
R01	306857	6187485	179 Corrimal St	Residential
R02	306232	6187186	398 Keira St	Baby Bounce (Commercial)
R03	306812	6186504	Port Kembla Rd	Industrial
R04	306396	6185950	Tom Thumb Rd	Incitec Pivot Fertilisers (industrial)
R05	305723	6184571	Port Kembla	Port Kemble steelworks (industrial)
R06	304834	6184104	41 Five Island Rd	GM fabrication (Commercial)
R07	305975	6183350	Port Kembla	Meatworks central (industrial)
R08	306606	6183717	16 Flinders St	Caltex (Commercial)
R09	306853	6184327	Christy Dr	Near Gabriella Memorial (Industrial)
R10	307390	6182968	Port Kembla	Port Kembla Station
R11	308190	6183101	Gloucester Blvd	Breakwater Battery Museum

Paper Size ISO A4

0 260 520 780 1,040

Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Australian Industrial Energy
Port Kembla Gas Terminal

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Site and sensitive receptor Location

Figure 2-1

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Print date: 31 Oct 2018 - 15:49 (SMA record: 2) (SMA record: 38)

Data source: ; (c) Department of Finance, Services and Innovation 2015; (c) Department of Finance, Services and Innovation 2012; (c) Forest Corporation of NSW 2017; (c) State of New South Wales and Office of Environment and Heritage; NSW Crown Copyright - Department of Planning and Environment; (c) Commonwealth of Australia (Department of the Environment) 2013; (c) Commonwealth of Australia (Department of the Environment) 2014. Created by: afoddy

3. Regulatory requirements

3.1 Legislative and policy context to the assessment

The Protection of the Environment Operations (POEO) Act 1997 provides the statutory framework for managing pollution in NSW, including the procedures for issuing licences for environmental protection on aspects such as waste, air, water and noise pollution control. Companies and property owners are legally bound to control emissions (including particulates and deposited dust) from construction sites under the POEO Act. Activities undertaken onsite must not contribute to environmental degradation, and pollution and air emissions must not exceed the standards. Where an environment protection licence applies, air quality requirements (including criteria) may be specified by the licence.

The *Protection of the Environment Operations (Clean Air) Regulation 2010* (the Clean Air Regulation) provides regulatory measures to control emissions from motor vehicles, fuels, and industry. The project would be operated to ensure it complies with the Clean Air Regulation.

The National Environment Protection Council of Environmental Ministers, now the National Environment Protection Council (NEPC), set uniform national standards for ambient air quality in February 2016. These are known as the *National Environment Protection (Ambient Air Quality) Measure* ('the Air NEPM'). The Air NEPM sets non-binding standards and ten-year goals (for 2026). The Air NEPM contains goals for the identified relevant pollutants inclusive of particulates such as PM_{10} and $PM_{2.5}$ and toxic pollutants including carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The Air NEPM contains concentration limits, averaging periods and number of allowed exceedances for each of the identified pollutants.

The Air NEPM standards apply to regional air quality as it affects the general population. The standards do not apply in areas impacted by localised air emissions, such as industrial sources, construction activity, and heavily trafficked streets and roads.

The Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2016) (the Approved Methods) lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources in NSW. It considers the above mentioned legislation and acts to construct pollutant assessment criteria. The Approved Methods assess the cumulative (background plus incremental site emissions) pollutant impact at the site boundary or the nearest existing or likely future off-site sensitive receptor depending on pollutant. Background concentrations of air pollutants are ideally obtained from ambient monitoring data collected at a proposal site in accordance with the Approved Methods. The Approved Methods recognises that this data is rare, and that data is typically obtained from monitoring sites as close as possible to a proposal site, where sources of air pollution resemble the existing sources at the project site.

3.2 Project impact assessment criteria

Assessment criteria has been taken from the Approved Methods to set the impact assessment criteria for the project. To ensure that environmental outcomes are achieved, the emissions impact from the project must be assessed against the assessment criteria shown in Table 3-1.

Note, the values of some of these pollutants have been converted from milligram (mg) to µg in order to be consistent. Impact assessment criteria included in the assessment are based on the pollutants listed in the supplied engine data from AIE.

Table 3-1 Impact assessment criteria

Pollutant	Averaging period	Percentile	Assessment criteria ($\mu g/m^3$)
TSP (total suspended particulates)	Annual	100th	90
PM_{10}	24 hour	100th	50
	Annual	100th	25
$PM_{2.5}$	24 hour	100th	25
	Annual	100th	8
CO	1 hour	100th	30000
	8 hour	100th	10000
NO_2	1 hour	100th	246
	Annual	100th	62
SO_2	1 hour	100th	570
	24 hour	100th	228
	Annual	100th	60
Benzene	1 hour	99.9th	29
Formaldehyde	1 hour	99.9th	20
Total PAHs (polycyclic aromatic hydrocarbons)	1 hour	99.9th	0.4

4. Project emissions

4.1 Emissions overview

Air quality may be impacted by a number of pollutants, each of which has different emission sources and effects on human health and the environment. The air quality assessment of the Project focuses on the highest-risk impacts with the potential to occur during construction and operation of the project.

This Section details the estimated air emissions from the project.

4.2 Project construction activities

Dust and particulate matter was identified as the primary emission to air during the construction of the project. Construction activities that generate dust include earthworks and the handling and transfer of earth and other material.

The project is anticipated to involve two separate construction work stages detailed in Table 4-1. Construction of the project is expected to take 10 to 12 months with completion due in early 2020.

Table 4-1 Construction staging

Stage	Description	Timeframe	Type of works
1	Pipeline construction	6 months	Trenching works through the industrial port precinct Transport of material Pipe laying Rehabilitation works
2	Dredging, excavation and disposal	10 – 12 months	Construction of berth Excavation and dredging for quay wall construction Transport of material Installation of mooring facilities

Stage 1 of construction involves construction of the pipeline. Minor earthworks are expected to occur during Stage 1 construction works as pipeline trenching is undertaken. Weather conditions that cause maximum dust impact are generally consistent winds in the direction of the nearest sensitive receivers throughout the daytime period outside of rain events. The earthworks are expected to be completed using a single trencher and excavator and use of horizontal directional drilling. Due to the small volume of earth moved and standard construction mitigation measures to be implemented, minimal dust will be generated.

Stage 2 of construction involves dredging, excavation and disposal of material as required to lay the berth foundation and construct the berth. All material dredged and excavated from the ocean floor will have a high moisture content. Due to the high moisture content, minimal dust will be released during the handling and transfer of the material and no significant dust impacts are expected during stage 2 of construction works.

4.2.1 Emissions inventory

The potential impacts of construction were assessed based on a 20 metre wide easement undergoing earthworks with earth movements related to activities typical of pipeline construction. Dust emissions for each construction area have been calculated using generic emission factors based on a range of typical construction activities. The derived emission rates were characterised using generic emission factors published in the *Western Regional Air Partnership Fugitive Dust Handbook* (WRAP) (Countess Environmental, 2006).

Fine particle emissions associated with exhausts from vehicles and plant used during construction activities are accounted for in the emission factors for earthmoving and handling used in the assessment. Exhaust emissions during construction are expected to be discontinuous, transient, and mobile.

Total suspended particles and dust deposition is usually assessed against annual criteria however, these criteria are less relevant to the Project as construction works would be transient. The primary emission of concern during the construction phase was found to be dust as PM_{10}. As a result, for this Project, air quality was assessed in terms of distances at which the relevant criteria are achieved at any time.

The dust emission factors used in the construction assessment are provided in Table 4-2. The emission factors have been sourced directly from literature where applicable, however where TSP and $PM_{2.5}$ emission factors were not provided, the following assumptions were made:

- TSP/PM_{10} ratio assumed to be a factor of 2
- $PM_{2.5}$/PM_{10} ratio assumed to be 0.1.

Table 4-2 Dust emission factors for construction activities

Construction activity	Particle size emission factors (g/m^2/s)			Source
	PM_{10}	Total suspended particles (TSP)	$PM_{2.5}$	
General and fixed construction activities	3.63238E-05	7.26477E-05	3.63238E-06	WRAP – Recommended PM10 emission factors for construction operations Level 1 (Worst-case conditions).

The following assumption have been applied to the construction air quality assessment:

- General construction activities have been conservatively modelled as 20 (width) by 100 metre (length) areas along the length of the pipeline easement. The 100 metre length is considered an appropriate discretisation interval to calculate the worst case air quality buffer distances from the easement.
- Emission factor used assume - WRAP – Recommended PM_{10} emission factors for construction operations Level 1 (Worst-case conditions).
- Earthworks will be undertaken during stage 1 construction activities.
- Dredged material will contain a large moisture content and not be a significant source of particulates and dust
- Adequate water supplies will be available to undertake dust suppression watering

4.3 Project operational activities

The primary emission source associated with the operation of the project are the engines on board the FSRU and LNG carrier. These emissions are released via a stack on each vessel. Engine details from the FSRU and LNG carrier have been supplied by AIE. It is understood that the FSRU and the LNG carrier can be operated using gas (LNG) or liquid fuel (MGO). It is AIE's intention to primarily operate both the FSRU and LNG carrier using boil off gas (LNG) as a energy source.

The emergency generator and auxiliary boiler on board the FSRU have the potential to produce emissions. AIE have stated that the auxiliary boilers are not expected to operate as recovered heat from the main engines will be used. Additionally it was mentioned that the emergency generator will be operated for 30 minutes every week for test purposes only. It is assumed the generator will not be tested while the LNG carrier is docked. The emissions from these sources are not considered significant as they are not intended to be used during everyday operations and are not expected to exceed emissions from the assessed scenarios in this assessment.

The following sections outline the air quality emissions from the FSRU and LNG carrier while operating on gas and liquid to account for any operational scenario. The number of engines operating has been assessed over a range of scenarios and is discussed in Section 6.

4.4 FSRU emissions

The FSRU is to be powered using four WARTSILA 8L50DF engines. A summary of engine specifications are provided in Table 4-3. The engines, when in use, have been assumed to operate continuously at 100 % capacity.

Table 4-3 FSRU engine specifications

Engine no.	1		2		3		4	
Engine make and model	Wartsila W8L50DF		Wartsila W8L50DF		Wartsila W8L50DF		Wartsila W8L50DF	
Power rating (kW)	7800		7800		7800		7800	
Rotational speed (RPM)	514		514		514		514	
Fuel type	MGO	Gas	MGO	Gas	MGO	Gas	MGO	Gas
Outlet diameter (m)	1		1		1		1	
Exhaust flowrate (m^3/s)	26.8	22.9	26.8	22.9	26.8	22.9	26.8	22.9
Exhaust temp (˜ C)	343	373	343	373	343	373	343	373

4.4.1 FSRU emissions (gas fuelled)

The emission to air for the gas fuelled FSRU scenario are presented in Table 4-4. The emission rates have been calculated using exhaust gas emission data supplied by AIE provided in Appendix A. Sulfur dioxide (SO_2 emissions were calculated assuming a fuel sulfur content of 3.5 parts per million which is typical for LNG. Benzene and polycyclic aromatic hydrocarbons (PAH) emission rates were scaled off the provided formaldehyde emission rate using the ratio between emission factors from the *National Pollutant Inventory emission estimation technique manual for combustion engines version 3.0 (2008)* table 54.

Table 4-4 FSRU emissions (gas fuelled)

Pollutant	Engine number and emission rate (g/s)			
	1	2	3	4
Particles (PM_{10})	0.14	0.14	0.14	0.14
NO_x	2.60	2.60	2.60	2.60
CO	1.95	1.95	1.95	1.95
SO_2	0.0023	0.0023	0.0023	0.0023
Benzene	0.0042	0.0042	0.0042	0.0042
Formaldehyde	0.5	0.5	0.5	0.5
PAH	0.0000016	0.0000016	0.0000016	0.0000016

4.4.1 FSRU emissions (liquid fuelled)

The emissions to air for the liquid fuelled scenario are presented in Table 4-5.

Particulate (PM_{10} and $PM_{2.5}$) emissions factors were sourced from the *National Pollutants Inventory Emission estimation technique manual for Maritime operations version 2.1, table 9*. Sulfur dioxide (SO_2) emissions were calculated assuming a fuel sulfur content of 0.5 % (by mass [m/m]) as per the International Maritime Organisations fuel sulfur limit that is applicable on or after 1 January 2020.

Nitrogen oxides (NO_x), carbon monoxide (CO) and Volatile organic compound (VOCs) emission rates were calculated based on the US EPA (2017) Tier 2 emission limits.

Benzene, formaldehyde and PAH emission rates were scaled off the VOC emission rate using the ratio of emission factors from the *National Pollutant Inventory emission estimation technique manual for combustion engines version 3.0 (2008)* table 43.

Table 4-5 FSRU emissions (liquid fuelled)

Pollutant	Engine no. and emission rate (g/s)			
	1	2	3	4
PM_{10}	0.91	0.91	0.91	0.91
$PM_{2.5}$	0.50	0.50	0.50	0.50
NO_x	22.68	22.7	22.7	22.7
CO	10.83	10.8	10.8	10.8
SO_2	3.74	3.7	3.7	3.7
VOCs	4.33	4.33	4.33	4.33
Benzene	0.043	0.043	0.043	0.043
Formaldehyde	0.0043	0.0043	0.0043	0.0043
PAH	0.00000063	0.00000063	0.00000063	0.00000063

4.5 LNG carrier emissions

The LNG carrier will tether alongside the FSRU temporarily while the LNG carrier is unloading LNG to the FSRU. An LNG carrier, for the purposes of this assessment has been modelled as being powered by three WARTSILA 8L50DF engines and one WARTSILA 6L50DF.A maximum of two engines are required to be operational to power the LNG carrier during this process. This assessment assumed engines 1 and 2 of the LNG carrier will operate at 100 % capacity.. Engine specifications are provided in Table 4-6.

Table 4-6 LNG carrier engine specifications

Engine no.	1		2		3		4	
Engine make and model	Wartsila W8L50DF		Wartsila W8L50DF		Wartsila W8L50DF		Wartsila W6L50DF-B	
Power rating (kW)	7300		7300		7300		5850	
Rotational speed (RPM)	514		514		514		514	
Fuel type	MGO		MGO		MGO		MGO	
Outlet diameter (m)	1		1		1		1	
Exhaust flowrate (m^3/s)	26.8	22.9	26.8	22.9	26.8	22.9	26.8	22.9
Exhaust temp (˜ C)	343	373	343	373	343	373	343	373

4.5.1 LNG carrier emissions (gas fuelled)

The emission to air for the gas fuelled LNG carrier scenario are presented in Table 4-7.

The emission rates have been calculated using exhaust gas emission data supplied by AIE. Sulfur dioxide (SO_2) emissions were calculated assuming a fuel sulfur content of 3.5 ppm which is typical for LNG. Benzene and PAH emission rates were scaled off the provided formaldehyde emission rate using the ratio between constituent emission factors from the *National Pollutant Inventory emission estimation technique manual for combustion engines version 3.0 (2008)* table 54.

Table 4-7 LNG carrier emissions (gas fuelled)

Pollutant	Engine number and emission rate (g/s)			
	1	2	3	4
Particles (PM_{10})	0.14	0.14	0.14	0.10
NO_x	2.60	2.60	2.60	1.95
CO	1.95	1.95	1.95	1.46
SO_2	0.0023	0.0023	0.0023	0.0017
Benzene	0.0042	0.0042	0.0042	0.0031
Formaldehyde	0.50	0.50	0.50	0.37
PAH	0.0000016	0.0000016	0.0000016	0.0000012

4.5.2 LNG carrier emissions (liquid fuelled)

The emissions to air for the liquid fuelled scenario are presented in Table 4-8.

Particulate (PM_{10} and $PM_{2.5}$) emissions factors were sourced from the *National Pollutants Inventory Emission estimation technique manual for Maritime operations version 2.1, table 9*. Sulfur dioxide (SO_2) emissions were calculated assuming a fuel sulfur content of 0.5 % (m/m) as per the International Maritime Organisations fuel sulfur limit that is applicable on or after 1 January 2020.

Nitrogen oxides (NO_x), carbon monoxide (CO) and Volatile organic compound (VOCs) emission rates were calculated based on the US EPA (2017) Tier 2 emission limits.

Benzene, formaldehyde and PAH emission rates were scaled off the total VOC emission rate using the ratio of constituent emission factors from the *National Pollutant Inventory emission estimation technique manual for combustion engines version 3.0 (2008)* table 43.

Table 4-8 LNG carrier emissions (liquid fuelled)

Pollutant	Engine number and emission rate (g/s)			
	1	2	3	4
PM_{10}	0.91	0.91	0.91	0.68
$PM_{2.5}$	0.50	0.50	0.50	0.37
NO_x	22.68	22.68	22.68	17.01
CO	10.83	10.83	10.83	8.13
SO_2	3.74	3.74	3.74	2.80
VOCs	4.33	4.33	4.33	3.25
Benzene	0.043	0.043	0.043	0.033
Formaldehyde	0.0043	0.0043	0.0043	0.0033
PAH	0.00000063	0.00000063	0.00000063	0.00000048

4.5.3 Assumptions

The following assumptions were applied to the operational modelling:

- Engine exhaust outlets were modelled as stacks. Stack properties have been provided by AIE.
- Emission factors for the gas fuelled scenarios were supplied by AIE. Emissions factors for the liquid scenarios were taken from the US EPA Tier 2 emissions limits, the *National Pollutant Inventory emissions estimation technique manual for Combustion engines Version 3 (2008)* and the *National Pollutant Inventory emissions estimation technique manual for Maritime operations version 2.1 (2012).*
- Two engines on board the FSRU are assumed to operate at 100 % capacity 24 hours a day. Two of the four engines on board the LNG carrier have been assumed to be operational during docking activities and while the carrier is unloading its cargo to supply power.

5. Meteorology

5.1 Overview

Site specific meteorology for the project was produced using CALMET. The CALMET simulation produced a 3D wind field for the modelled year. Prognostic TAPM data was used alongside observations taken at two NSW Bureau of Meteorology (BoM) sites as inputs into the CALMET model. Details of the procedure undertaken to produce the site specific meteorology is outlined in the following sections.

5.2 Methodology

The characterisation of local wind patterns generally requires accurate site-representative hourly recordings of wind direction and speed over a period of at least a year.

Existing observational data is available from the following locations:

- Port Kembla (BoM)
- Albion park (BoM)

In order to produce a representative site-specific meteorological data set encompassing the meteorological data from all the observational sites, the following methodology was carried out:

- Production of a 3D gridded dataset with the prognostic model TAPM.
- Utilising the TAPM 3D gridded dataset as an initial guess field for the CALMET meteorological model.
- Utilising data from all observation sites (Port Kembla and Albion park BoM sites) for surface level observations.

An analysis of meteorology from the years from 2013 to 2017 was conducted to select a period considered to be most representative of ‘normal’ conditions. The analysis shows that the year 2014 is the most representative year based on a review of temperature, wind speed and wind direction. Meteorological characteristics of the 2014 year closely followed the average of all years from 2013 to 2017 suggesting 2014 represents a typical year.

Summary charts of the representative year analysis are provided in Appendix B.

5.3 TAPM modelling

The TAPM prognostic model was run to obtain a coarse meteorological 3D gridded dataset for the site for the selected model period. This dataset is based on synoptic observations, local terrain and land use information with a resolution of 1,000m. The TAPM model parameters are summarised in Table 5-1 and are selected in accordance with the NSW Approved Methods for the Modelling of Air Pollutants in NSW (Approved Methods)[1].

Table 5-1 TAPM model parameters

Parameter	Value
Modelled period	1 December 2013 to 1 January 2015
Domain centre	UTM: 56H 300,727 mE, 6,178,414 mS Latitude = -34° 31' Longitude = 150° 49.5'
Number of vertical levels	25
Number of easting grid points	25
Number of northing grid points	25
Outer grid spacing	30,000 m x 30,000 m
Number of grid levels	4
Grid level horizontal resolution	Level 2 – 10,000 m Level 3 – 3,000 m Level 4 – 1,000 m

5.4 CALMET modelling

The US EPA Approved version of CALMET (Version 5) was used to resolve the wind field around the subject site to a 200m spatial resolution. The application of CALMET for this purpose is an approved modelling approach in NSW as per the Approved Methods with model guidance documentation provided[2] .

Upon completion of the broad scale TAPM modelling runs, a CALMET simulation was set up to run for the model period, combining the three dimensional gridded data output from the TAPM model with the site specific surface data from the Port Kembla and Albion park south BoM stations. This approach is consistent with guidance documentation.

All model settings were selected based on the recommendations provided in the model guidance documentation (with the exception that O'Brien vertical velocity adjustments was enabled) CALMET was run using the "Hybrid" mode with the TAPM data provided as an initial guess field.

The southwest corner of the CALMET domain, or the origin, was located at UTM Zone 56 coordinates 288.227 kilometre east and 6165.914 kilometre north. The CALMET domain extended 23 kilometre to the east and north.

The CALMET domain consisted of 115 grids in both the east and north directions, with a grid resolution of 0.2 kilometre.

CALMET settings were selected as per the model guidance document for "Hybrid" mode

[1] Environment Protection Authority 2017, Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, January 2017.

[2] Barclay, J & Scire, J, 2011, Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia', prepared for NSW Office of Environment and Heritage, Sydney, March 2011

The TERRAD, RMAX and R variables were set to the values presented in Table 5-2 based on an inspection of the terrain elevations in the immediate vicinity of the subject site, based on model guidance. The CALMET model parameters are summarised in Table 5-2.

Terrain and land use data used for the CALMET modelling are presented in Figure 5-1 and Figure 5-2.

Table 5-2 Summary of CALMET model parameters

Parameter	Value
Modelled period	1 January 2014 to 31 December 2014
Mode	Hybrid (NOOBS = 1)
UTM zone	56
Domain origin (south-west corner)	Easting: 288.227 km Northing: 6165.914 km
Domain size	115 x 115 at 0.2 km resolution (23.0 km x 23.0 km)
Number of vertical levels	11
Vertical levels (m)	20, 40, 60, 90, 120, 180, 250, 500, 1000, 2000, 3000
CALMET settings for hybrid mode Settings selected in accordance with (OEH, 2011)	TERRAD = 10.0 km RMAX1 = 15.0 km RMAX2 = 15.0 km RMAX3 = 15 km RMIN = 0.1 km R1 = 10.0 km R2 = 10.0 km
Initial guess field	TAPM .m3d file used as an initial guess field for CALMET.
Surface data	Port Kembla E: 308.220 km N: 6183.373 km Albion Park E: 297.251 km N: 6173.109 km
Upper air data	No site specific upper air data is utilised. Upper air data is included within the TAPM .m3d initial guess field.
Land use and terrain data	Land use data was manually developed through assessment of aerial imagery to accurately reflect the land use in the area. High-resolution terrain data was sourced from the STRM 1-second (~30 m) database.

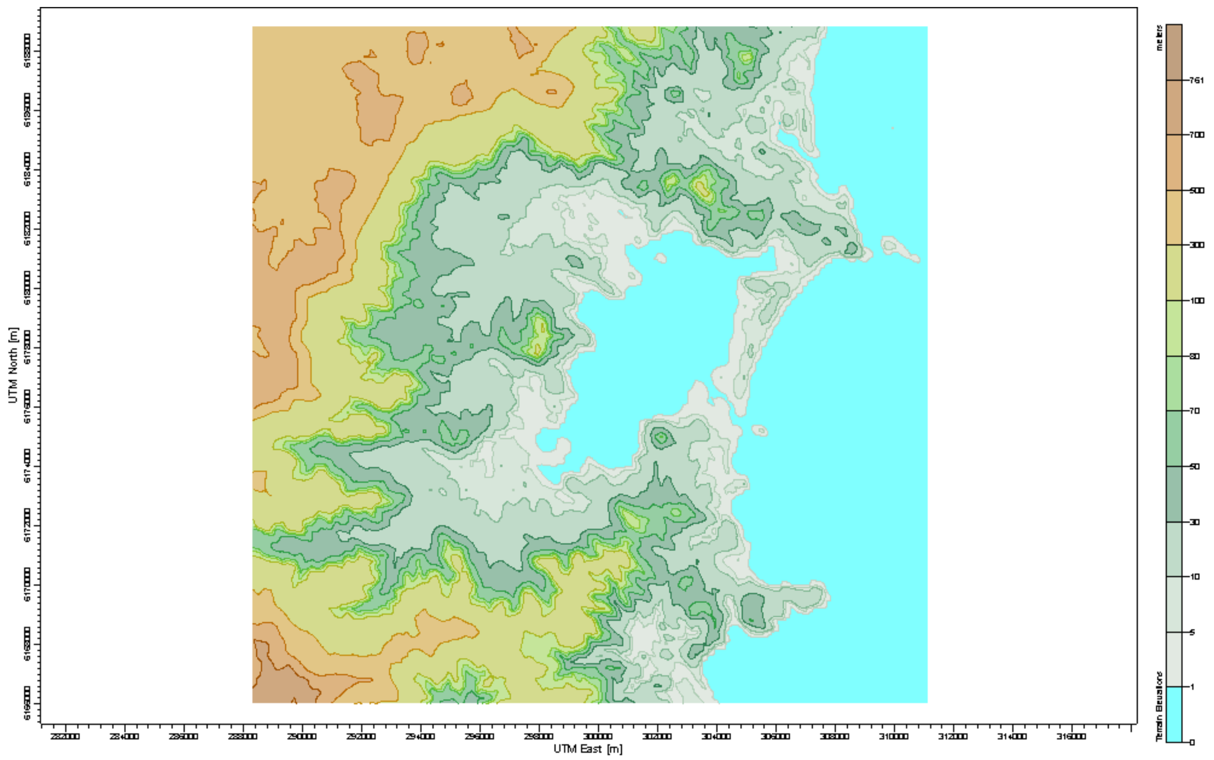


Figure 5-1 Terrain data used for CALMET modelling

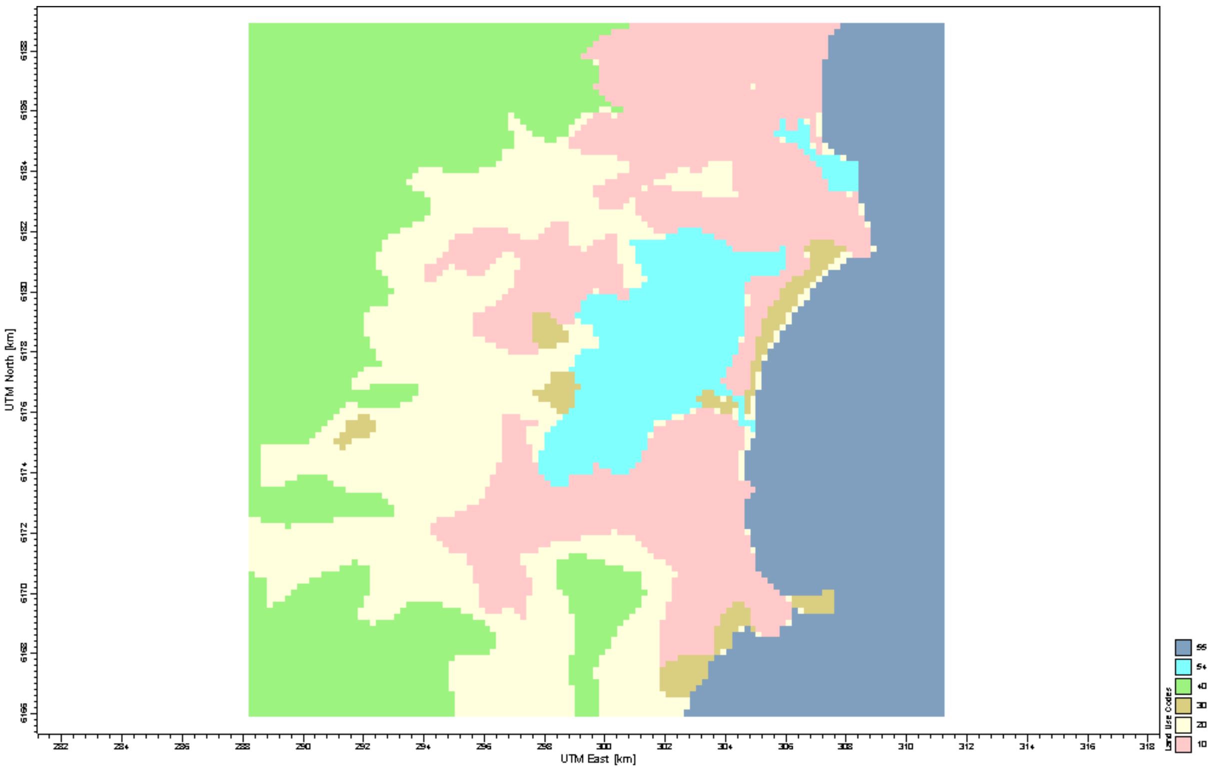


Figure 5-2 Land use data used for CALMET modelling

The local meteorology largely determines the pattern of off-site air quality impact on receptors (houses, businesses and industry). The effect of wind on dispersion patterns can be examined using the wind and stability class distributions at the site from the dataset that is produced by CALMET. The winds at the site are most readily displayed by means of wind rose plots, giving the distribution of winds and the wind speeds from these directions.

The features of particular interest in this assessment are: (i) the dominant wind directions and (ii) the relative incidence of stable light wind conditions that yield minimal mixing (defines peak impacts from ground-based sources).

5.4.1 Annual pattern in wind

The average wind rose for the entire data period taken at the project site is shown in Figure 5-3 and shows the following features:

- The predominant annual average wind directions are from the west and northeast
- The average wind speed measured was 3.94m per second
- Calms (winds speeds less than 0.5m per second) occurred 0.82 % of the time

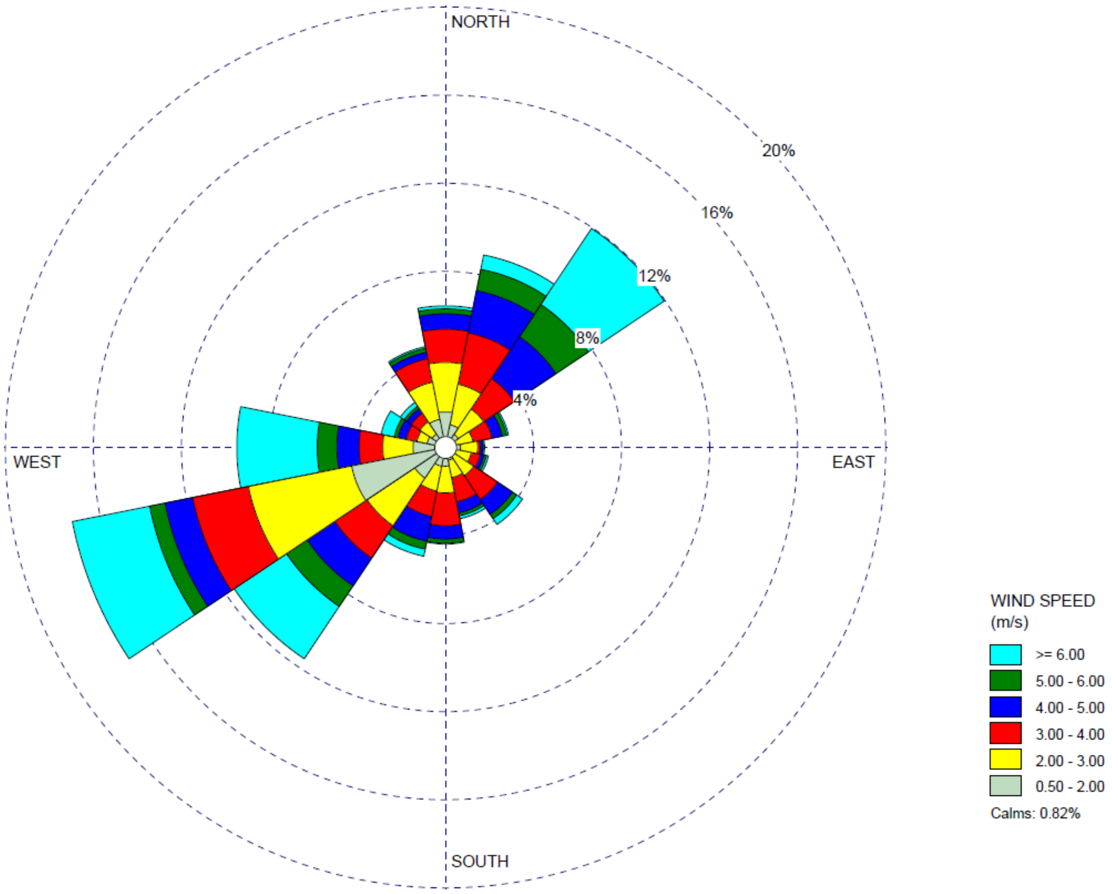


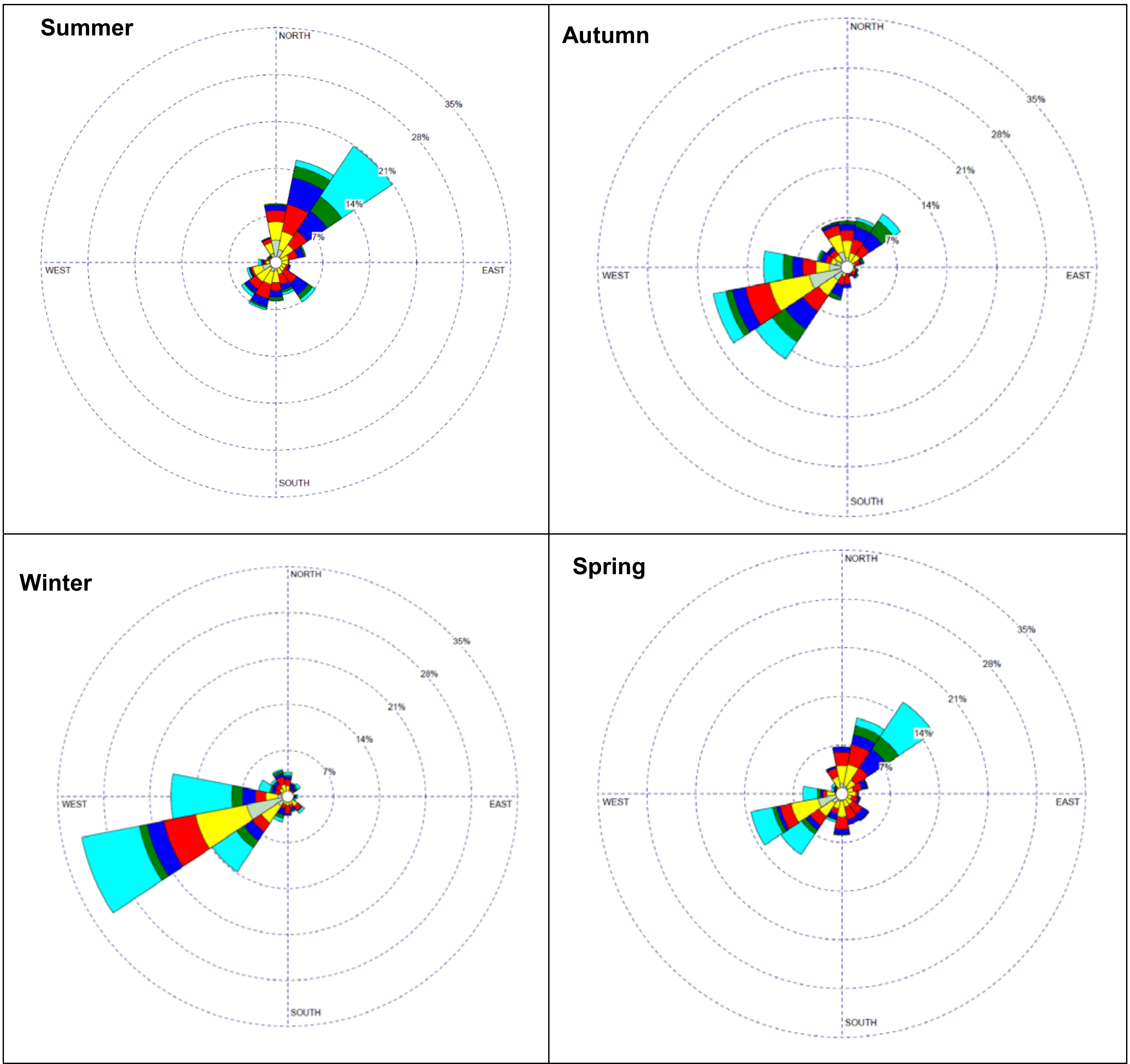
Figure 5-3 Wind rose for CALMET for 2014

5.4.2 Seasonal variation in wind pattern

The seasonal wind roses for 2014 are presented in Figure 5-4 and show that:

- During summer the predominant wind direction is from the northeast.
- During winter, westerly and south westerly winds are the most dominant.
- Autumn and spring are transitional periods. During these seasons both summer and winter patterns are observed. Autumn wind patterns are characteristically similar to

winter, generally consisting of westerly winds. Spring displays a higher percentile of northeast winds.



Season	%Complete Record	Average WS (m/s)	Calms Frequency (%)
Summer	100%	3.62	1.34
Autumn	100%	3.58	0.68
Winter	100%	4.66	0.27
Spring	100%	3.91	1.01

Figure 5-4 Seasonal wind roses for 2014

5.5 Pattern of atmospheric stability

Atmospheric stability substantially affects the capacity of a pollutant such as gas, particulate matter or odour to disperse into the surrounding atmosphere upon discharge and is a measure of the amount of turbulent energy in the atmosphere.

There are six Pasquill–Gifford classes (A-F) used to describe atmospheric stability, and these classes are grouped into three stability categories; stable (classes E-F), neutral (class D), and unstable (classes A-C). The climate parameters of wind speed, cloud cover and solar insolation are used to define the stability category as shown in Table 5-3, and as these parameters vary diurnally, there is a corresponding variation in the occurrence of each stability category.

Stability is most readily displayed by means of stability rose plots, giving the frequency of winds from different directions for various stability classes A to F.

Table 5-3 Stability category relationship to wind speed, and stability characteristics

Stability category	Wind speed range (m/s) [a]	Stability characteristics
A	0 – 2.8	Extremely unstable atmospheric conditions, occurring near the middle of day, with very light winds, no significant cloud
B	2.9 – 4.8	Moderately unstable atmospheric conditions occurring during mid-morning/mid-afternoon with light winds or very light winds with significant cloud
C	4.9 – 5.9	Slightly unstable atmospheric conditions occurring during early morning/late afternoon with moderate winds or lighter winds with significant cloud;
D	≥6	Neutral atmospheric conditions. Occur during the day or night with stronger winds. Or during periods of total cloud cover, or during the twilight period
E	3.4 – 5.4 [b]	Slightly stable atmospheric conditions occurring during the night-time with significant cloud and/or moderate winds
F	0 – 3.3 [b]	Moderately stable atmospheric conditions occurring during the night-time with no significant cloud and light winds

a Data sourced from the Turner's Key to the P-G stability Categories, assuming a Net Radiation Index of +4 for daytime conditions (between 10:00 am and 6:00 pm) and –2 for night-time conditions (between 6:00 pm and 10:00 am)

b Assumed to only occur at night, during Net Radiation Index categories of –2.

Figure 5-5 shows the frequency of stability class for all hours of the model generated dataset. The following observation were made:

- Stable atmosphere conditions (classes E and F) are the dominant stability state of the atmosphere occurring 40 % of the time.
- Neutral stability (class D) occurs 29 % of the time.
- Unstable atmospheres (classes A, B and C) occur about 31 % of the time.

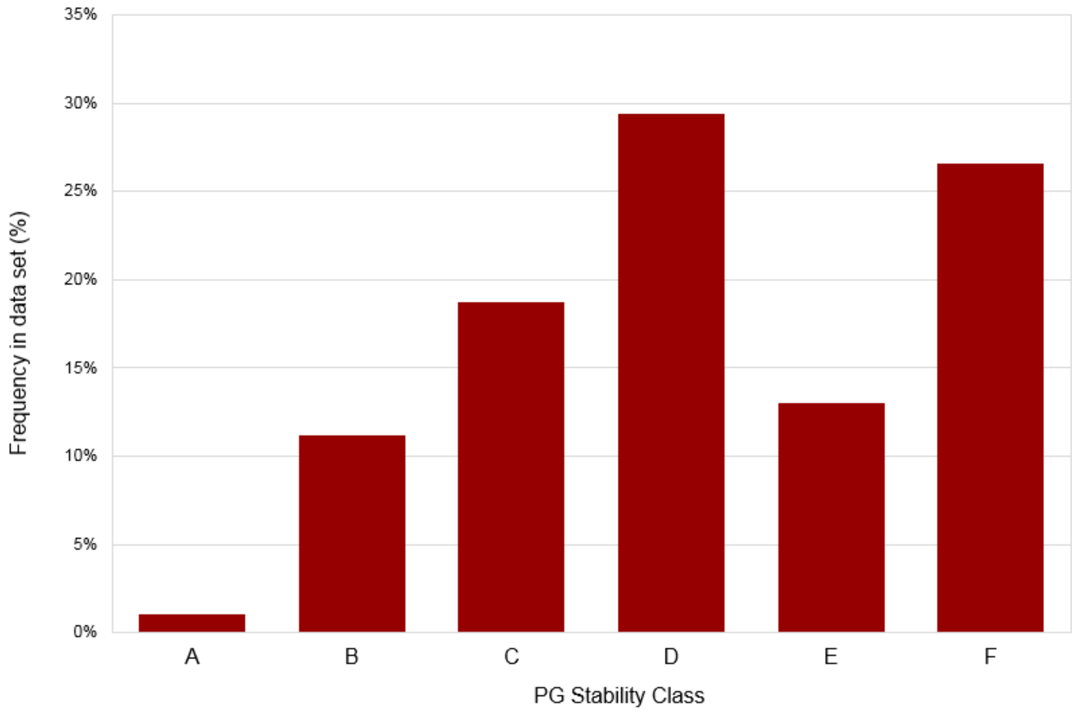


Figure 5-5 Distribution of stability class for the model period

6. Impact Assessment

This Section presents the predicted worst case air quality impacts for the construction and operation of the project.

6.1 Model settings

Atmospheric dispersion modelling was carried out using the CALPUFF version 6 dispersion model. CALPUFF is a non-steady-state, Lagrangian puff dispersion model. It is accepted for use by the Office of Environment and Heritage and NSW Environment Protection Authority for application in environments where wind patterns and plume dispersion is strongly influenced by complex terrain, the land-sea interface or where there is a high frequency of stable calm night-time conditions.

All model settings were selected based on the recommendations provided in the *Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia (2011)*.

For this assessment, the CALPUFF dispersion model was used to predict ground-level concentrations of pollutants from the proposal. The grid size used in the CALPUFF model was equivalent to the CALMET domain. The same grid resolution of 200 metre used for the CALMET model run was used in CALPUFF.

Chemical transformations were not modelled within CALPUFF, however as discussed in more detail below, the formation of NO_2 from NO from combustion has been assessed using Method 2 in the Approved Methods (NSW EPA, 2016). Method 1 (Section 8.1.1) in the Approved Methods assumes 100 % of NO will be converted to NO_2. This is considered extremely conservative as in reality, only a fraction of NO will be converted to NO_2. Therefore, a more detailed assessment has been undertaken for all receptors using Method 2 (Section 8.2.2) of the Approved Methods. Method 2 is based on NO reacting with ozone in the atmosphere to form NO_2. Background ozone data was sourced from Kembla Grange for the year 2014.

6.2 Construction

Given the primary air quality concern during construction is dust, a screening level dust assessment was undertaken for proposed construction activities with consideration of the Approved Methods (EPA, 2016). The modelled scenario assumes construction works occurring along the pipeline easement and the predicted worst-case PM_{10}, $PM_{2.5}$ and TSP concentrations are presented below as concentration versus distance graphs.

6.2.1 Scenario 1: General construction activities

The results for scenario 1 are shown in Figure 6-1 (daily) and Figure 6-2 (annual) respectively. The results indicate the following:

- The daily PM_{10} criteria and $PM_{2.5}$ criteria are met at 80 metre and 10 metre from the construction area
- The annual TSP, PM_{10} and $PM_{2.5}$ criteria are met at 20 metre, 70 metre and 60 metre from the construction area.

The nearest sensitive receptor from the easement has been identified as over 100 metre from the easement. Hence, the dust criteria will not be exceeded at any sensitive receptor in the study area during general construction operations within the easement.

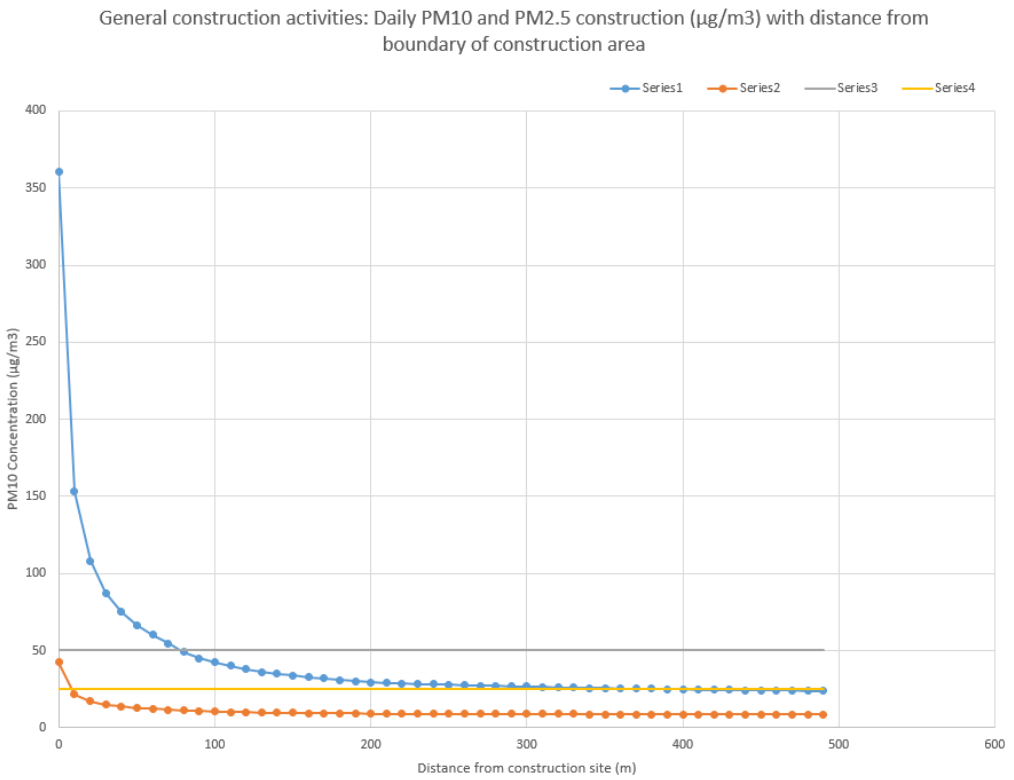


Figure 6-1 Scenario 1: Daily PM_{10} and $PM_{2.5}$ concentrations with distance from boundary of construction area (including background)

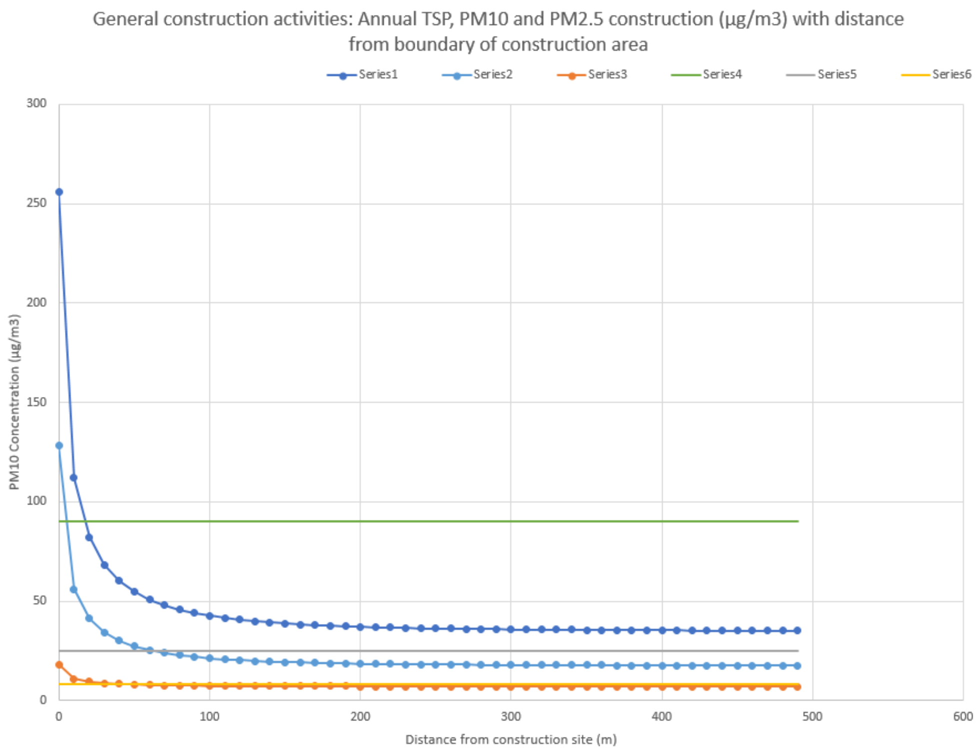


Figure 6-2 Scenario 1: Annual PM_{10}, $PM_{2.5}$ and TSP concentrations with distance from boundary of construction area (including background)

6.3 Operation

An LNG carrier entering Port Kembla to offload its LNG cargo will be present in the environment for a limited time. In most instances the carrier will enter and leave the port within 2 – 3 days. It takes between 24 – 36 hours to offload and LNG carrier and it will seek to immediately travel to another location for further deliveries. At present, a LNG carrier is expected to arrive every two – three weeks.

To conservatively assess the cumulative impact from the project, the FSRU and LNG carrier have been modelled together to account for worst case emissions. During both the tethering and the unloading processes, only two engines on board the LNG carrier will be operational. Likewise, only two engines on board the FSRU are required to be operating continuously during the regasification process.

The FSRU and LNG carrier can be operated using gas (LNG) or Liquid (MGO). AIE has advised that the FSRU and LNG carrier will likely consume gas as their primary energy source. However it is possible that gas or liquid fuel may be used on either vessel.

To account for all possible air borne emissions, the following scenarios have been modelled (all scenarios assumed two engines are active on board the FSRU and two engines are active on board the LNG carrier):

- Scenario 1 – gas fuelled FSRU and liquid fuelled LNG carrier (possible operating scenario)
- Scenario 2 – liquid fuelled FSRU and liquid fuelled LNG carrier (possible operating scenario)
- Scenario 3 – gas fuelled FSRU and gas fuelled LNG carrier (likely operating scenario)

Additional modelling was undertaken to ensure compliance in the unlikely event that all four engines are required to be operational onboard the FSRU. The following scenarios have been modelled (all scenarios assumed four engines are active on board the FSRU and two engines are active onboard the LNG carrier:

- Scenario 4 – gas fuelled FSRU and liquid fuelled LNG carrier (unlikely operating scenario)
- Scenario 5 – liquid fuelled FSRU and liquid fuelled LNG carrier (unlikely operating scenario)
- Scenario 6 – gas fuelled FSRU and gas fuelled LNG carrier (possible operating scenario)

6.3.1 Scenario 1 – gas fuelled FSRU and liquid fuelled LNG carrier

Scenario 1 is composed of a gas fuelled FSRU (two engines are active) and a liquid fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 1 are presented on Table 6-1. No criteria exceedances are predicted at the sensitive receptor locations.

The calculated NO_2 levels using Method 2 are provided in Table 6-1. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentiles, which is consistent with their assessment criterions. All other pollutants are presented as the maximum 100th percentiles predicted concentrations.

Table 6-1 Scenario 1 predicted pollutant concentrations (µg/m^3)

Receptor	Predicted pollutant concentrations (µg/m^3)									
	PM_{10}		$PM_{2.5}$		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	25	8	246	30000	570	29	20	0.4
R01	1.3	0.08	0.60	0.04	85	123	36	0.3	3	0.00002
R02	1.7	0.09	0.83	0.04	105	226	59	0.4	4	0.00004
R03	1.1	0.10	0.50	0.05	101	98	29	0.3	3	0.00002
R04	2.1	0.14	0.98	0.07	129	192	50	0.3	4	0.00004
R05	1.3	0.10	0.62	0.05	102	216	57	0.3	3	0.00004
R06	1.0	0.06	0.50	0.03	82	167	44	0.2	3	0.00002
R07	0.9	0.17	0.43	0.08	86	80	23	0.2	3	0.00002
R08	1.0	0.17	0.50	0.08	105	141	44	0.2	3	0.00003
R09	0.9	0.07	0.46	0.03	153	176	57	0.3	4	0.00004
R10	1.4	0.15	0.65	0.07	102	139	40	0.3	4	0.00003
R11	1.5	0.12	0.72	0.06	103	195	58	0.4	4	0.00004

6.3.2 Scenario 2 – liquid fuelled FSRU and liquid fuelled LNG carrier

Scenario 2 is composed of a liquid fuelled FSRU (two engines are active) and a liquid fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 2 are presented in Table 6-2. No criteria exceedances are predicted at the sensitive receptor locations.

The calculated NO_2 levels using Method 2 from the Approved Methods are provided. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors.

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentiles, which is consistent with their assessment criterions. All other pollutants are presented as the maximum 100th percentiles predicted concentrations.

Table 6-2 Scenario 2 predicted pollutant concentrations (μg/m^3)

Receptor	Predicted pollutant concentrations (μg/m^3)									
	PM_{10}		$PM_{2.5}$		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	25	8	246	30000	570	29	20	0.4
R01	2	0.1	1.2	0.07	91	192	66	0.5	0.05	0.00001
R02	3	0.2	1.5	0.08	127	400	125	0.7	0.07	0.00001
R03	2	0.2	1.0	0.09	117	172	59	0.5	0.05	0.00001
R04	4	0.2	2.0	0.13	140	296	88	0.5	0.05	0.00001
R05	2	0.2	1.1	0.09	109	341	107	0.6	0.06	0.00001
R06	1	0.1	0.7	0.06	103	197	59	0.4	0.04	0.00001
R07	2	0.3	0.9	0.16	103	135	46	0.4	0.04	0.00001
R08	2	0.3	1.0	0.16	154	218	75	0.4	0.04	0.00001
R09	2	0.1	1.0	0.07	161	346	119	0.5	0.05	0.00001
R10	2	0.3	1.3	0.14	116	236	82	0.6	0.06	0.00001
R11	3	0.2	1.4	0.11	112	341	117	0.7	0.07	0.00001

6.3.3 Scenario 3 – gas fuelled FSRU and gas fuelled LNG carrier

Scenario 3 is composed of a gas fuelled FSRU (two engines are active) and a gas fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 3 are presented in Table 6-3. No criteria exceedances are predicted at the sensitive receptor locations.

The calculated NO_2 levels using Method 2 from the Approved Methods are provided. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors.

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentiles, which is consistent with their assessment criterions. All other pollutants are presented as the maximum 100th percentiles predicted concentrations.

Table 6-3 Scenario 3 predicted pollutant concentrations (µg/m³)

Receptor	Predicted pollutant concentrations (µg/m³)							
	PM_{10}		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	246	30000	570	29	20	0.4
R01	0.35	0.02	58	38	0.04	0.05	6	0.00002
R02	0.42	0.02	59	74	0.08	0.06	8	0.00002
R03	0.30	0.03	58	39	0.04	0.05	5	0.00002
R04	0.65	0.04	70	65	0.07	0.06	7	0.00002
R05	0.31	0.03	58	65	0.07	0.05	7	0.00002
R06	0.22	0.02	58	42	0.04	0.04	5	0.00002
R07	0.28	0.05	63	28	0.03	0.04	5	0.00001
R08	0.29	0.05	63	56	0.07	0.04	5	0.00002
R09	0.36	0.02	80	98	0.12	0.05	6	0.00002
R10	0.44	0.04	58	47	0.05	0.06	7	0.00002
R11	0.46	0.03	58	88	0.10	0.07	8	0.00003

6.3.4 Scenario 4 – gas fuelled FSRU and liquid fuelled LNG carrier

Scenario 4 is composed of a gas fuelled FSRU (all four engines are active) and a liquid fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 4 are presented in Table 6-4. No exceedances of the criteria are predicted.

The calculated NO_2 levels using Method 2 from the Approved Methods are provided. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors.

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentile, which is consistent with their assessment criteria. All other pollutants are presented as the maximum 100th percentile predicted concentrations.

Table 6-4 Scenario 4 predicted pollutant concentrations (µg/m^3)

Receptor	Predicted pollutant concentrations (µg/m^3)									
	PM_{10}		$PM_{2.5}$		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	25	8	246	30000	570	29	20	0.4
R01	1.4	0.1	0.60	0.04	86	140	36	0.3	6.0	0.00002
R02	1.9	0.1	0.83	0.04	108	264	59	0.4	7.3	0.00003
R03	1.2	0.1	0.50	0.05	103	110	29	0.3	5.9	0.00002
R04	2.5	0.2	0.98	0.07	131	227	50	0.3	7.6	0.00003
R05	1.4	0.1	0.62	0.05	105	248	57	0.3	6.6	0.00003
R06	1.1	0.1	0.50	0.03	89	183	44	0.2	5.0	0.00002
R07	1.1	0.2	0.43	0.08	87	94	23	0.2	5.0	0.00002
R08	1.2	0.2	0.50	0.08	113	152	44	0.2	5.5	0.00002
R09	1.1	0.1	0.46	0.03	154	185	57	0.3	7.0	0.00003
R10	1.6	0.2	0.65	0.07	104	162	40	0.4	7.5	0.00003
R11	1.7	0.1	0.72	0.06	104	225	58	0.4	7.6	0.00003

6.3.5 Scenario 5 – liquid fuelled FSRU and Liquid fuelled LNG carrier

Scenario 5 is composed of a liquid fuelled FSRU (all four engines are active) and a liquid fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 5 are presented in Table 6-5. No criteria exceedances are predicted.

The calculated NO_2 levels using Method 2 from the Approved Methods are provided. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors.

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentile, which is consistent with their assessment criterions. All other pollutants are presented as the maximum 100th percentile predicted concentrations.

Table 6-5 Scenario 5 predicted pollutant concentrations (µg/m^3)

Receptor	Predicted pollutant concentrations (µg/m^3)									
	PM_{10}		$PM_{2.5}$		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	25	8	246	30000	570	29	20	0.4
R01	3.3	0.2	1.8	0.1	102	295	101	0.7	0.1	0.00001
R02	4.0	0.2	2.2	0.1	166	607	191	1.0	0.1	0.00001
R03	2.9	0.3	1.6	0.1	133	242	84	0.7	0.1	0.00001
R04	6.4	0.4	3.5	0.2	161	543	174	0.9	0.1	0.00001
R05	2.8	0.2	1.6	0.1	152	547	171	0.9	0.1	0.00001
R06	1.9	0.2	1.1	0.1	129	323	101	0.6	0.1	0.00001
R07	2.6	0.5	1.4	0.2	143	228	77	0.6	0.1	0.00001
R08	2.8	0.5	1.6	0.3	162	379	131	0.6	0.1	0.00001
R09	3.1	0.2	1.7	0.1	174	619	214	0.8	0.1	0.00001
R10	4.1	0.4	2.2	0.2	131	373	129	0.9	0.1	0.00001
R11	3.9	0.3	2.1	0.2	127	542	178	1.0	0.1	0.00001

6.3.6 Scenario 6 – gas fuelled FSRU and gas fuelled LNG carrier

Scenario 6 is composed of a gas fuelled FSRU (all four engines are active) and a gas fuelled LNG carrier (two engines are active). The predicted pollutant concentration for Scenario 6 are presented in Table 6-6. No criteria exceedances are predicted at the sensitive receptor locations.

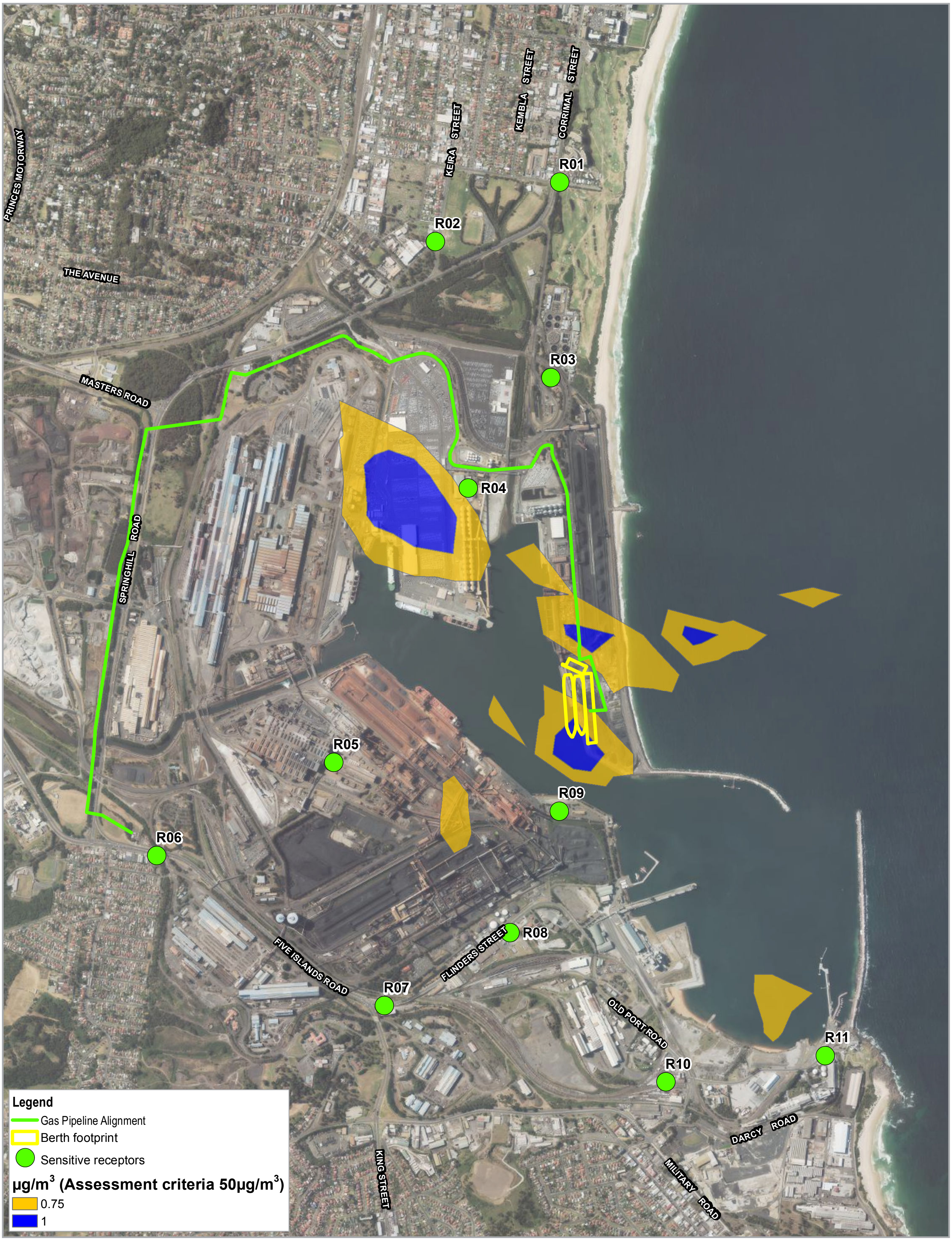
The calculated NO_2 levels using Method 2 from the Approved Methods are provided. The NO_2 levels are predicted to comply with the criteria at all sensitive receptors.

Benzene, formaldehyde and PAH concentrations are presented as 99.9th percentiles, which is consistent with their assessment criterions. All other pollutants are presented as the maximum 100th percentiles predicted concentrations.

Table 6-6 Scenario 6 predicted pollutant concentrations (μg/m^3)

Receptor	Predicted pollutant concentrations (μg/m^3)							
	PM_{10}		NO_2	CO	SO_2	Benzene	Formaldehyde	PAH
	24 hour	Annual	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
Criteria	50	25	246	30000	570	29	20	0.4
R01	0.51	0.03	58	53	0.1	0.07	8	0.00003
R02	0.62	0.04	85	109	0.1	0.10	11	0.00004
R03	0.44	0.04	62	44	0.1	0.07	9	0.00003
R04	0.99	0.06	73	98	0.1	0.09	10	0.00003
R05	0.43	0.04	65	99	0.1	0.08	10	0.00003
R06	0.29	0.02	58	58	0.1	0.06	7	0.00002
R07	0.40	0.07	68	41	0.0	0.06	7	0.00002
R08	0.44	0.07	73	68	0.1	0.06	7	0.00002
R09	0.48	0.03	85	112	0.1	0.08	10	0.00003
R10	0.63	0.06	72	67	0.1	0.09	11	0.00003
R11	0.60	0.05	64	98	0.1	0.09	11	0.00004

Contour plots of each assessed pollutant for the most likely operational scenario (Scenario 3) are presented in Figure 6-3 to Figure 6-9.



Paper Size ISO A4

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

Australian Industrial Energy
Port Kembla Gas Terminal

Predicted 24 hour incremental PM10 concentrations (Scenario 3, 100th percentile, µg/m3)

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Figure 6-3

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Print date: 31 Oct 2018 - 15:49 (SMA record: 2) (SMA record: 39)

Data source: ; (c) Department of Finance, Services and Innovation 2015; (c) Department of Finance, Services and Innovation 2012; (c) Forest Corporation of NSW 2017; (c) State of New South Wales and Office of Environment and Heritage; NSW Crown Copyright - Department of Planning and Environment; (c) Commonwealth of Australia (Department of the Environment) 2013; (c) Commonwealth of Australia (Department of the Environment) 2014. Created by: afoddy

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Australian Industrial Energy
Port Kembla Gas Terminal

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Predicted 1 hour incremental NOX concentrations (Scenario 3, 100th percentile, µg/m3)

Figure 6-4

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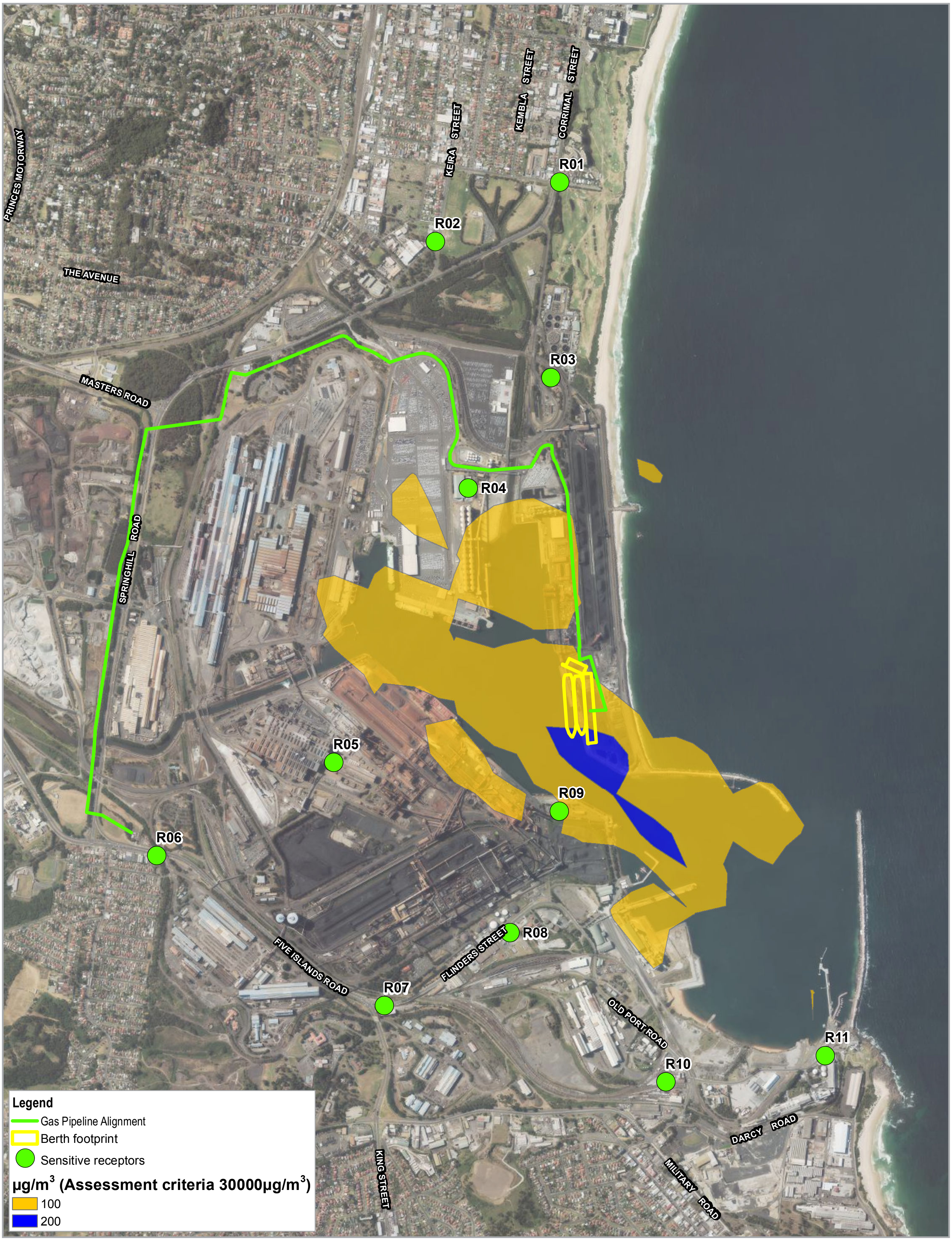
Data source: ; (c) Department of Finance, Services and Innovation 2015; (c) Department of Finance, Services and Innovation 2012; (c) Forest Corporation of NSW 2017; (c) State of New South Wales and Office of Environment and Heritage; NSW Crown Copyright - Department of Planning and Environment; (c) Commonwealth of Australia (Department of the Environment) 2013; (c) Commonwealth of Australia (Department of the Environment) 2014. Created by: afoddy



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Australian Industrial Energy
Port Kembla Gas Terminal

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Predicted 1 hour incremental CO concentrations (Scenario 3, 100th percentile, µg/m3)

Figure 6-5

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Metres

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

Australian Industrial Energy
Port Kembla Gas Terminal

Project No.	21-27477
Revision No.	A
Date	31 Oct 2018

Predicted 1 hour incremental SO2 concentrations (Scenario 3, 100th percentile, µg/m3)

Figure 6-6

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Print date: 31 Oct 2018 - 15:49 (SMA record: 2) (SMA record: 43)

Data source: ; (c) Department of Finance, Services and Innovation 2015; (c) Department of Finance, Services and Innovation 2012; (c) Forest Corporation of NSW 2017; (c) State of New South Wales and Office of Environment and Heritage; NSW Crown Copyright - Department of Planning and Environment; (c) Commonwealth of Australia (Department of the Environment) 2013; (c) Commonwealth of Australia (Department of the Environment) 2014. Created by: afoddy

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Australian Industrial Energy
Port Kembla Gas Terminal

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Predicted 1 hour incremental Benzene concentrations (Scenario 3, 99.9th percentile, µg/m3)

Figure 6-7

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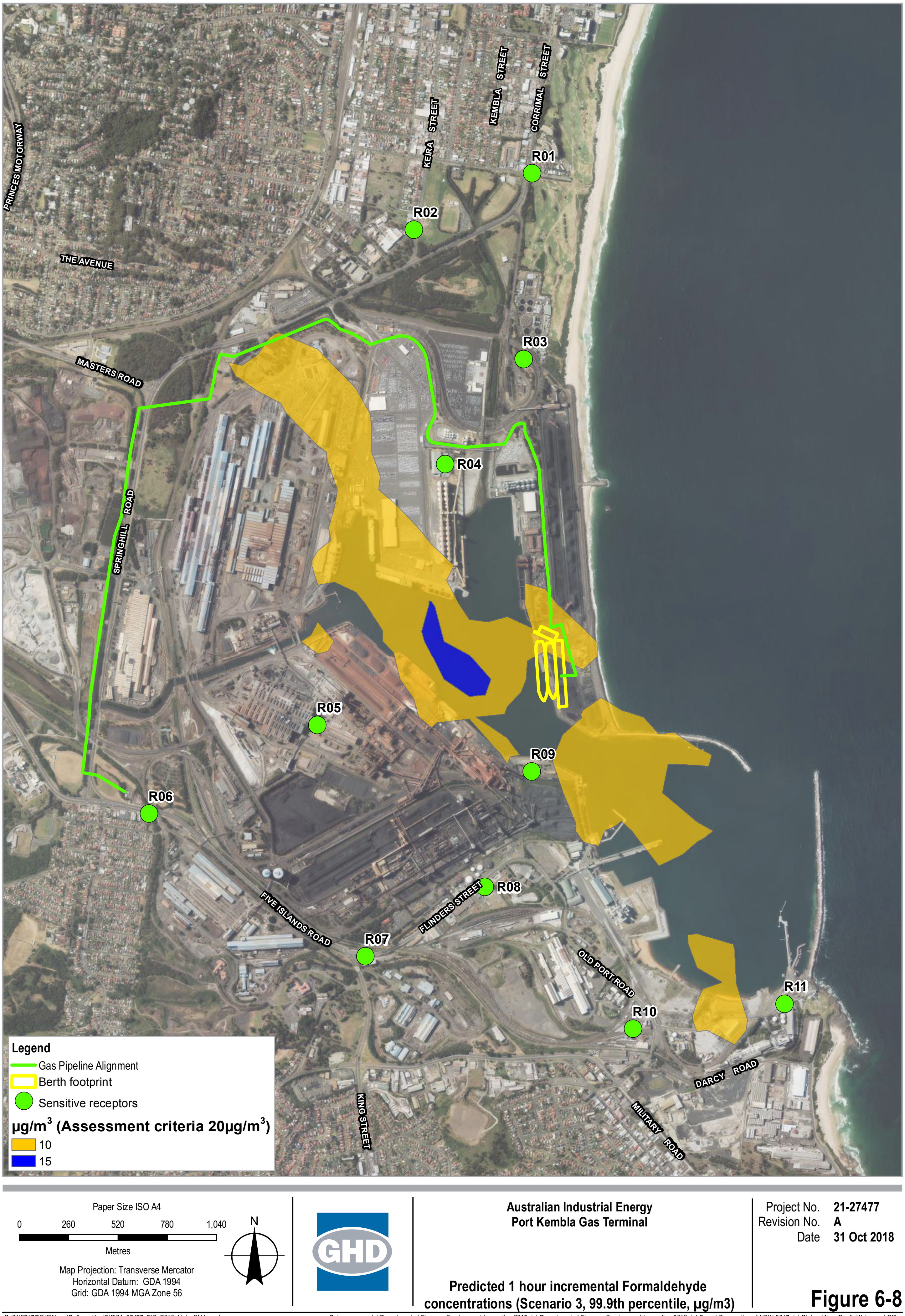
Data source: ; (c) Department of Finance, Services and Innovation 2015; (c) Department of Finance, Services and Innovation 2012; (c) Forest Corporation of NSW 2017; (c) State of New South Wales and Office of Environment and Heritage; NSW Crown Copyright - Department of Planning and Environment; (c) Commonwealth of Australia (Department of the Environment) 2013; (c) Commonwealth of Australia (Department of the Environment) 2014. Created by: afoddy



Australian Industrial Energy
Port Kembla Gas Terminal

Predicted 1 hour incremental Formaldehyde concentrations (Scenario 3, 99.9th percentile, µg/m3)

Project No. 21-27477
Revision No. A
Date 31 Oct 2018

Figure 6-8

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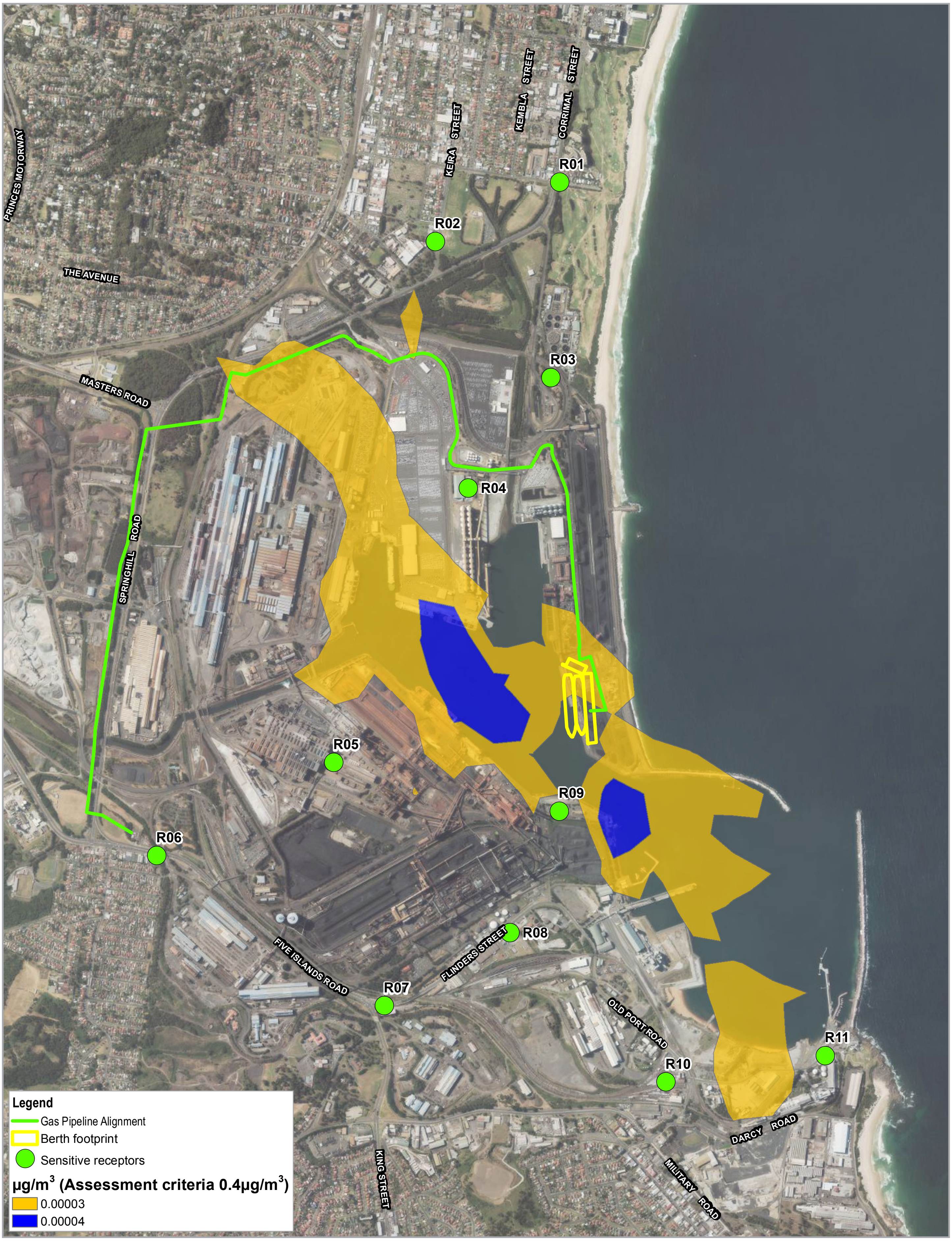

Paper Size ISO A4

0 260 520 780 1,040

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

Australian Industrial Energy
Port Kembla Gas Terminal

Project No. **21-27477**
Revision No. **A**
Date **31 Oct 2018**

Predicted 1 hour incremental PAH concentrations (Scenario 3, 99.9th percentile, µg/m3)

Figure 6-9

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Print date: 31 Oct 2018 - 15:50 (SMA record: 2) (SMA record: 46)

The assessment identified the potential for elevated formaldehyde concentrations during Scenario 6. Scenario 6 assumed four gas fuelled engines are active on the FSRU and two gas fuelled engines are active on the LNG carrier. This scenario is unlikely to occur as only two engines are required on the FSRU during regasification operations. Four engines are only required when travelling at maximum speed on the open seas.

Formaldehyde emissions for Scenario 6 meet the criteria at all assessed sensitive receptors, however the contour plot in Figure 6-10, shows that there are areas where the 99.9th percentile ground level concentrations exceed the criteria (orange areas). These locations are located principally over the Inner Harbour and near The Cut and will occur only during worse case dispersion conditions. These exceedances are predicted to occur for 3 one hour periods over the entire modelled year (exceedances occur 0.03% of the time). These potential formaldehyde exceedances are not considered significant and will not impact sensitive receptors in the Port Kembla region.

Figure 6-10 Formaldehyde assessment criteria exceedance locations (Scenario 6)

7. Mitigation

While general construction activities are not expected to exceed air quality standards at nearby receptors, the following mitigation measures are recommended.

- Water material prior to it being loaded for on-site haulage, where appropriate
- Aim to minimise the size of storage piles where possible
- Limit cleared areas of land and clear only when necessary to reduce fugitive dust emissions
- Control on-site traffic by designating specific routes for haulage and access and limiting vehicle speeds to below 25km per hour
- All trucks hauling material should be covered on the way to the site and should maintain a reasonable amount of vertical space between the top of the load and top of the trailer
- Operations conducted in areas of low moisture content material should be suspended during high wind speed events or water sprays should be used

These measures will assist in reducing impact on all areas off-site during construction activities.

Operational air quality impacts are not anticipated and no specific mitigation is provided. It is recommended that the project remains compliant with IMO legislation and domestic air quality guidelines to ensure future operations comply with air quality standards.

8. Conclusion

GHD has undertaken an air quality assessment for the construction and operation of the proposed liquefied natural gas import terminal at Port Kembla. A screening level construction air quality assessment was undertaken and predicted no exceedances of the 24 hour and annual particulate criteria.

The operational assessment considered six potential operating scenarios. There are no predicted exceedances of the impact assessment criteria during normal operations which consists of two gas engines operating on the FSRU and two gas engines on the LNG carrier.

The assessment identified that formaldehyde had the potential to exceed the criteria during operation of the unlikely worst case operating scenario (Scenario 6 - which consists of four gas engines operating on the FSRU and two gas engines operating on the docked LNG carrier). This scenario is unlikely to occur and the areas which exceed the criteria are over water. No other exceedances of the impact assessment criteria are predicted.

Based on assumptions as outlined in the assessment, the predicted pollutant emissions from the construction and operation of the project are expected to comply with the relevant criteria when assessed in accordance with the Approved Methods. The application of standard dust mitigation measures will assist to minimise potential impacts from construction of the project. Compliance with International Maritime Organization (IMO) legislation and domestic air quality guidelines will minimise the impacts from the operations of the project.

9. References

National Pollutant Inventory, Emission estimation technique manual for Combustion engines Version 3 (2008), Australian government, Department of Environment, Water, Heritage and the Arts.

National Pollutant Inventory, Emission estimation technique manual for Maritime operations Version 2.1 (2012), Australian government, Department of Sustainability, Environment, Water, Population and Communities.

NSW EPA. (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. *NSW Government Gazette of 26 August 2005, minor revisions Novemeber 2016*. Sydney, NSW: Department of Environment and Conservation NSW (DEC).

OEH NSW. (2011). *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia'.* Sydney: NSW Office of Environment and Heritage.

Appendices

Appendix A – Exhaust gas emission data

EXHAUST GAS EMISSION DATA

Gas operation with LFO as pilot fuel

Constant speed: 500 rpm and 514 rpm

Emissions *(Note 1)*	Unit	Load [%]				
		100	90	75	50	30
Concentration at 15% O2						
NOx	vol-ppm, dry	90	90	90	90	90
CO	vol-ppm, dry	113	120	127	314	721
THC (as CH4)	vol-ppm, dry	779	759	746	1213	2888
NMHC (as CH4) *(Note 2)*	vol-ppm, dry	108	105	103	-	-
Formaldehyde	vol-ppm, dry	27	27	26	42	101
Particles *(Note 3)*	mg/Nm3, dry	10	10	10	15	19
Typical measured O2 concentration	vol-%, dry	11,8	11,7	11,5	11,9	12,6
Specific emissions						
NOx (as NO2) *(Note 4)*	g/kWh	1,2	1,2	1,2	1,3	1,5
CO	g/kWh	0,9	1,0	1,1	2,8	7,3
THC (as CH4)	g/kWh	3,6	3,5	3,6	6,3	16,8
NMHC (as CH4) *(Note 2)*	g/kWh	0,49	0,48	0,49	-	-
Formaldehyde	g/kWh	0,23	0,23	0,23	0,41	1,10
Particles *(Note 3)*	g/kWh	0,064	0,065	0,067	0,11	0,16
SO2 *(Note 5)*	g/kWh	-	-	-	-	-
Typical CO2 *(Note 6)*	g/kWh	430	-	-	-	-
Mass concentration at 5% O2 *(Note 7)*						
NOx (as NO2)	mg/Nm3, dry	500	500	500	500	500
CO	mg/Nm3, dry	380	407	428	1061	2437
THC (as CH4)	mg/Nm3, dry	1508	1468	1444	2348	5589
NMHC (as CH4) *(Note 2)*	mg/Nm3, dry	203	203	200	-	-
Formaldehyde	mg/Nm3, dry	98	98	94	152	366
Particles *(Note 3)*	mg/Nm3, dry	27	27	27	41	52

FPP curve for 500 and 514 rpm

		Load [%]				
Specific emissions		100	90	75	50	30
NOx (as NO2) (Note 4)	g/kWh	1,1	1,1	1,0	5,0	6,0
CO	g/kWh	0,9	1,0	1,1	2,8	7,3
THC (as CH4)	g/kWh	3,6	3,5	3,6	4,0	4,5
NMHC (as CH4) (Note 2)	g/kWh	0,49	0,48	0,49	-	-
Formaldehyde	g/kWh	0,23	0,23	0,23	0,41	1,10
Particles (Note 3)	g/kWh	0,064	0,065	0,067	0,11	0,16
SO2 (Note 5)	g/kWh	-	-	-	-	-
Typical CO2 (Note 6)	g/kWh	430	-	-	-	-

Tolerances:

LOAD %	100-75	50	30
NOx	+/- 0%	+/- 25%	+/- 50%
CO	+/- 15%	+/- 25%	+/- 50%
THC	+/- 15%	+/- 25%	+/- 50%
NMHC	+/- 32%	+/- 32%	+/- 60%
formaldehyde	+/- 20%	+/- 30%	+/- 60%
particles	+0% or less then the tabled values		

Note 1 At ISO 3046 - 1:1995(E) standard reference conditions. Except for LT-water temperature, which is 35 °C for the Wärtsilä 50DF engine in gas operation.

Note 2 NMHC (non-methane hydrocarbon) emissions are highly dependent on used gas composition and are calculated case by case if needed. The values are valid for the following gas composition: methane: 93 vol-%, ethane: 5 vol-%, propane: 1.5 vol-%, butane: 0.5 vol-%

Note 3 Particles measured as "dry dust" according to ISO 9096-03 or alternatively EPA method 17 measurement standards under steady state conditions.

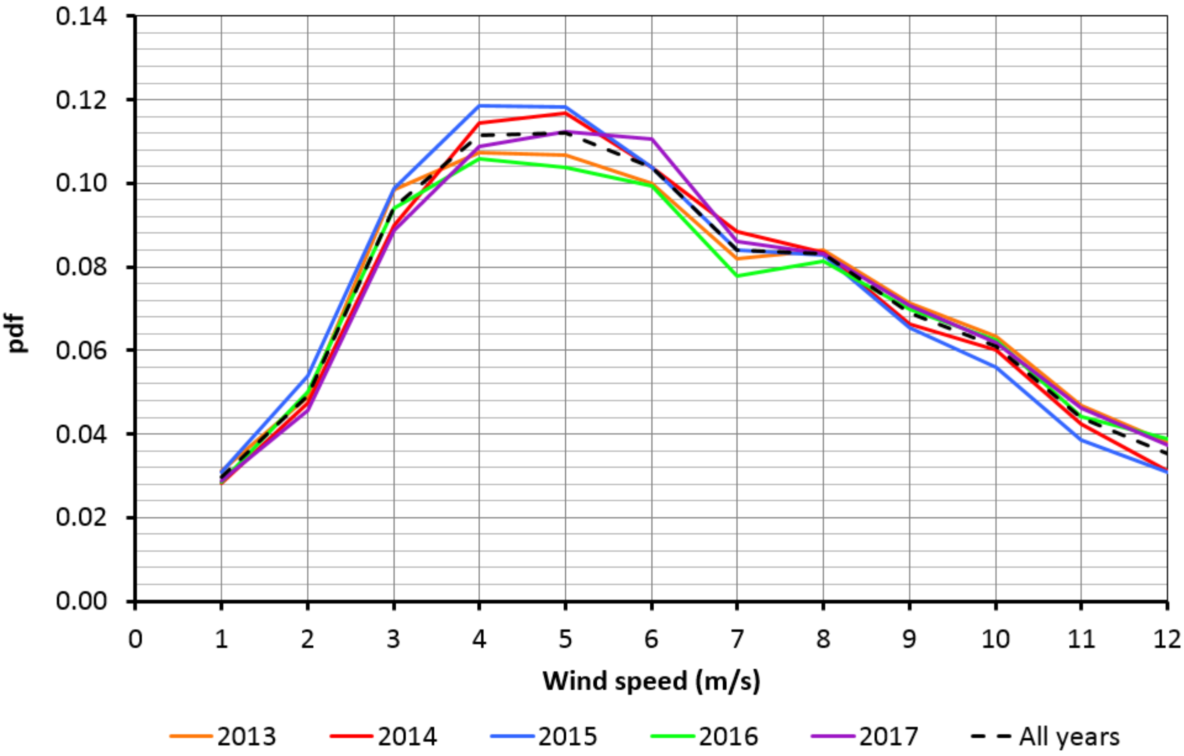
Note 4 Recommended guarantee value for marine engines is 3 g/kWh weighted Nox

Note 5 SO2 emissions depend on the sulphur content of the fuel gas, pilot fuel and lube oil and can be calculated as follows:
SO2 [g/kWh] = ((fuel consumption [kJ/kWh])/(LHV,real [MJ/kg])(fuel sulphur content [w-%])+(1.2g/kWh)*(pilot fuel sulphur content [w-%])+(0.3g/kWh)*(lube oil sulphur content [w-%]))/100*64/32*

Note 6 CO2 emissions depend on engine efficiency and fuel carbon content and can be calculated as follows:
CO2 [g/kWh] = (fuel consumption [kJ/kWh])/(LHV,real [MJ/kg])(fuel carbon content [w-%])/100*44/12*

Note 7 Values given in Nm3 is at 0 °C and 101.3 kPa.

Appendix B – Selection of representative year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Wind speed (m/s)
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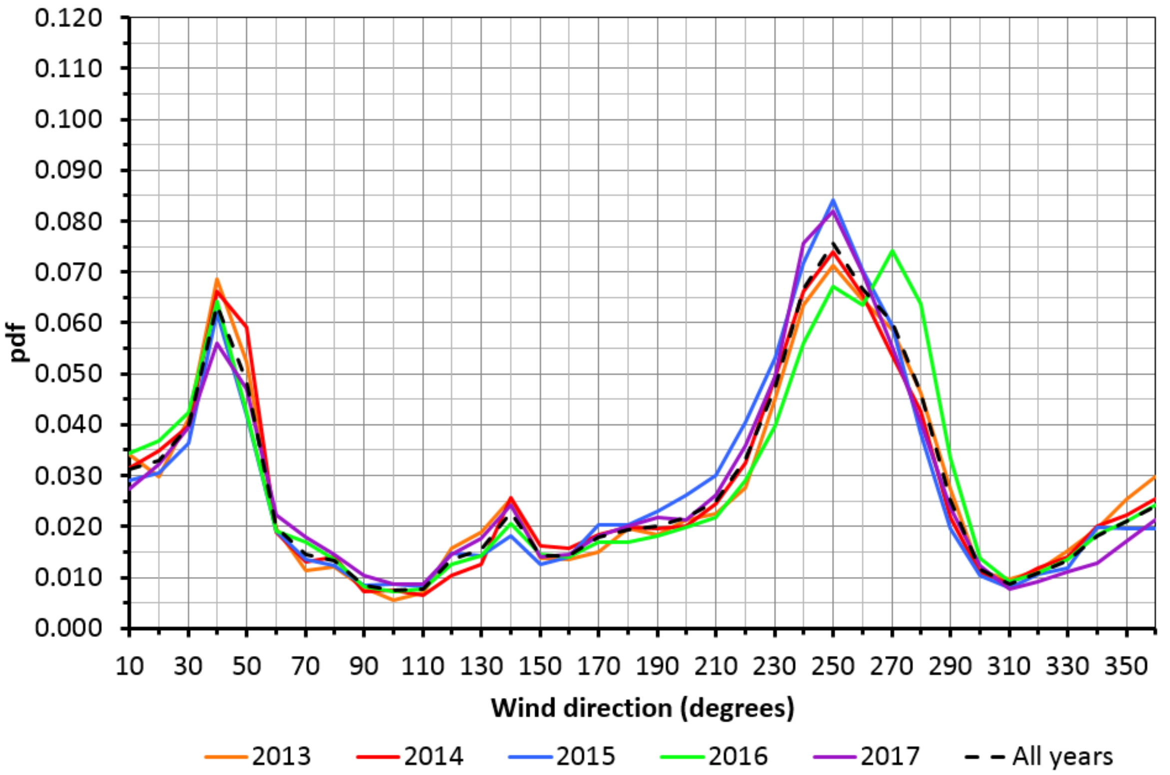
All years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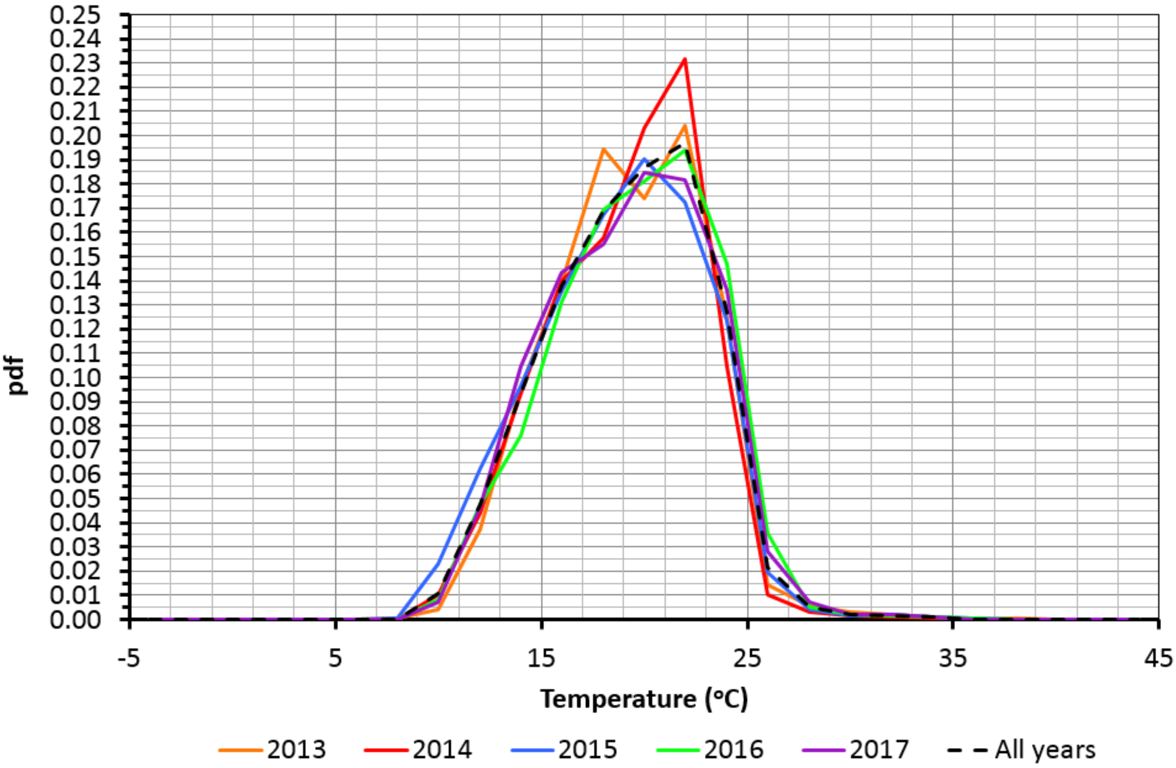
All years



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Temperature (°C)
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